ANIMAL RESOURCES OF INDIA

Protozoa to Mammalia

State of the Art

ZOOLOGICAL SURVEY OF INDIA

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Edited by
Director, Zoological Survey of India

सत्यमेव जयते

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FOREWORD

The Zoological Survey of India, one of the premier scientific institutions of the country has completed 75 years of dedicated service to the nation. On this happy and momentous occasion the Director, Professor Mohammad Shamim Jairajpuri and his team of devoted scientists have brought out a number of highly valuable publications culminating in the present one on **Animal Resources of India**: State of the Art.

This book was essential and has been brought out at a very appropriate time to make us all aware of the richness of our fauna. Our future developmental programmes must not be at the cost of faunal wealth of the country, but should be planned as an integral component of such natural resources. The vast information given in this book would provide not only the benchmark data useful to a number of organisations and individuals deeply interested and committed to the conservation of our natural resources like zoologists, students, non-government and government organisations, Universities, Research Institutes etc. This could be a beginning for serious exercise on environmental impact assessment, ecosystem maintenance and sustainable utilisation of our animal resources. The book covers the entire range of animals that occur in India right from the unicellular protozoans to the highly evolved mammals. The expertise available in India and abroad, and some selected references have been given for each group.

Congratulations are due to the Director for bringing out such an excellent book and for continuing the good work for which the Zoological Survey of India has been well known. Perhaps the time has come now to consider whether in addition to the task of inventorisation and description of hitherto unknown species, the Zoological Survey of India with the strong base that it has, should now venture into the study of the inter-relationships of animals and the fragile ecosystems that they live in.

In providing valuable information on biological diversity the Zoological Survey of India, has fulfilled the high expectations we have in it and I am sure such work will continue. I wish the scientists of this great institution all success in this endeavour.

R. Rajamani
Secretary to the Govt. of India
Ministry of Environment & Forests

Paryavaran Bhawan
New Delhi
1st July, 1991

PREFACE

The importance of fauna and flora in the survival and continuance of Man in this world is now better understood and appreciated. The realization has come rather too late as a large number of species of animals and plants have already been wiped out from the face of the earth, mainly due to the onslaught of human civilisation leading to loss of habitat, environmental degradation, pollution, etc. India, with its very large number of varied ecosystems, is one of the richest countries of the world in its biological resources, but these have suffered a severe blow due to human population explosion. A large number of animal species are threatened with extinction and some have already become extinct. It is, therefore, extremely important that the various species be collected and identified and their biology and behaviour studied as the information would lead to the adoption of strategies for their conservation. Further, the availability of every species and each gene shall be vital in developing bio-technology and for use in genetic engineering, both of which are crucial in shaping our biological future on this planet during the 21st century and onwards.

With only two percent of the world's land-mass, India possesses, as per estimates, about five percent of known fauna and flora. This number is likely to go up steeply as more and more people study biological diversity. The Ministry of Environment & Forests, Govt. of India which is the nodal agency in supporting such studies has a very positive and encouraging attitude in this matter. The Zoological Survey of India, a premier institute of the country, has been playing a pivotal role in this endeavour, in the past as well as at present. Further, it has well drawn out, ambitious and highly significant plans for future study of the distribution, inventorisation, description, ecology, etc. of animal species.

In 1980, the Zoological Survey of India published under the editorship of the then Director, Dr. T. N. Ananthakrishnan, the **State of Art Report : Zoology** which gave an account of animal groups found in India. The present book, though with a different title **Animal Resources of India : State of the Art** is a considerably enlarged and up-dated version of that publication. It *provides* under one cover information on Indian animal species from **Protozoa to Mammalia**, *identifies* expertise on each group and *lists* some relevant papers for further reference.

We had planned to bring out this book during the **Platinum Jubilee Year** (July, 1990 - June, 1991) of the Zoological Survey of India and release it on 1st July, 1991. I am delighted that this has been accomplished. I would like to congratulate Dr. J. R. B. Alfred, Joint Director-in-charge publications and Mr. G. Sivagurunathan, Publication Production Officer for the job well-done as also the three co-ordinators, Drs. R. K. Varshney (Insecta), V. C. Agrawal (Chordata) and N. V. Subba Rao (Invertebrata excluding Insecta), for their extremely pains-taking efforts and editorial assistance without which this book would not have seen the light of the day. I would also like to thank all those, from ZSI or outside, who have helped in the preparation of this document by providing write-up on different groups and/or for editorial assistance.

I hope that the book will not only serve as a valuable source of information for those interested in the taxonomic study of the animal resources of India but also for those involved in their sustainable exploitation and conservation.

On the completion of 75 years of ZSI I consider it a great privilege and honour to dedicate this book to the nation.

MShamimJairajpuri

1st July 1991

Professor MOHAMMAD SHAMIM JAIRAJPURI
Director
Zoological Survey of India

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An Overview

The planet Earth is unique in many ways, its most important feature being the presence of the biosphere with life support system. Life originated here, multiplied and diversified through the ages and now exists on it in myriads of forms and shapes. Animals and plants, comprising fauna and flora or biota of the world, consisting of the simplest species to the most complex, are distributed in the various ecosystems. Though environment has brought about origin and evolution of life, the organisms themselves have also induced significant environmental changes, the formation of the ozone layer being one such change which enabled evolution of terrestrial organisms. Environment and life are thus inseparable. Since the formation of the Earth some 4.5 billion years ago, its environment has never remained constant. It has been changing ever since, slowly and imperceptibly but surely, exerting pressure on organisms to gradually change in order to remain matched with their ecosystems. Though several factors have been responsible for the tremendous biological diversity that came into existence, environmental changes and the ability of organisms to respond through natural selection appear to have been the most critical of factors.

Life abounds on land, in the air and in sea. The sea which is nearly 70% of Earth's surface served as a cradle for primitive organisms before these could inhabit the land. The land-mass which now consists of seven continents together with clusters of small to big islands, as located today, are not stationary. Their positions and configuration have been changing (Continental Drift and Platetectonics) ever since the supercontinent, Pangea which was a single land-mass broke up. While drifting, the continents passed through varying climates and this had a profound impact on biological evolution in general and organismal diversity in particular. The present-day Indian subcontinent which was originally a part of Gondwana land further split-up into east and west Gondwana. India together with Australia and Antarctica formed part of east Gondwana. However, it soon got detached from these two continents and pushed northwards up the sea of Tethys causing gradual shrinkage and ultimate disappearance of the latter. The subcontinent finally bumped into the southern face of Eurasia leading to the formation of the highest, and most magnificent but youngest chain of mountains, the Himalaya. The geological history of India, its geomorphology and physiography is outstanding in several ways as also its fauna and flora.

Biological diversity

Zoogeographically, India belongs to the Oriental realm, but the Ethiopian, Palaearctic species and some belonging to other realms are also found here. Part of it is because of the invasion of fauna and flora from other areas but man has also contributed to this diversity. The geographical area of India is about 329 million hectares and its coastline stretches to nearly 7,000 km. The climate ranges from temperate to arctic in the Himalaya, to tropical and sub-tropical in its Indo-Gangetic plains and the peninsular region. The vegetative cover is rich and of a varied type, consisting of all kinds of forests and a vast expanse of grasslands, each with its teeming millions of fauna characteristic of these habitats. The Thar desert in western Rajasthan is the hottest and most hostile. The annual rainfall also varies from about 100 mm in the deserts to as high as 5,000 mm in Cherrapunji hills of Meghalaya. There are three well-defined seasons - the summer, rainy and winter, and two rather less defined ones - the autumn and spring. The ecology of major regions of India is, however, largely

Mohammad Shamim Jairajpuri, Director, Zoological Survey of India

dependent on rainfall. Though the area of the country is only about 2% of world's total land-mass, India harbours as much as 5% of all known species of animals and plants. Based on information available, the Indian fauna comprises a little over 65,000 species. Of these, the insects constitute about 40,000, molluscs a little over 5000, mammals 372, birds 1228, reptiles 428, amphibians 204, and fishes 2546. Eighty one species of mammals, 47 of birds, 15 of reptiles, 3 of amphibians and a large number of butterflies, moths and beetles are listed as endangered.

TABLE I

India's major biogeographic habitats

	Biogeographic Zone	Biotic Province
1	Trans-Himalayan	Upper Regions
2	Himalayan	North West Himalaya West Himalaya Central Himalaya East Himalaya
3	Desert	Kutch Thar Ladakh
4	Semi-Arid	Central India Gujarat-Rajwara
5	Western Ghats	Malabar Coast Western Ghat Mountains
6	Deccan Peninsula	Deccan Plateau South Central Plateau Eastern Plateau Chhota-Nagpur Central Highlands
7	Gangetic Plain	Upper Gangetic Plain Lower Gangetic Plain
8	North-East India	Brahmaputra Valley North-Eastern Hills
9	Islands	Andaman Islands Nicobar Islands Lakshadweep Islands
10	Coasts	West Coast East Coast

Source : "Conserving our Biological Wealth", WWF for Nature-India

The richness of animal resources of India is largely due to its geographical position and the fact that it possesses all possible kinds of ecosystems within its territorial limits, e.g., mountain ranges, valleys, flat lands, arid and semi-arid zones, rivers, lakes, estuaries, oceans, islands, etc, (Table I). These estimates of its faunal wealth, are based on available data, but the real numbers are likely to be much higher. Many areas of the country are yet to be fully explored and also there are several animal groups, in particular those belonging to invertebrates, that have not been studied in depth, due to lack of either material or expertise. Further, fauna of aquatic habitats, (Table II) especially marine and also those inhabiting terrestrial ecosystems, have received only scanty attention. It is, therefore, expected that in years to come, with extensive collection of materials, and subsequent study, the knowledge of animal wealth of India will increase substantially. More and more

TABLE II
Wetland ecosystems in need of urgent attention

	Region	Places	Importance	Species of interest	Threats
A.	Himalayan or High Altitude Wetlands				
	High Altitude Arid Zone Wetlands	Salt Lakes	Summer breeding habitat, waders and waterbirds	Black-necked crane	Mineral exploitation, Urbanisation
	Wetlands of Kashmir Valley	Nowgaon, Mirgund Haigam, Hokarsar, Malgam	Migratory waterfowl in winter, breeding grounds		
	Himalayan Wetlands	Sapa Marshes, Apatani Marshes			
B.	Wetlands of Arid Zone	Bharatpur, Rann of Kutch, Nal Sarvor	Breeding areas, winter migrants	Siberian crane and breeding flamingos	
C.	Gangetic Plain Wetlands				
	Permanent and semi-permanent Wetlands	Chaurs (N. Bihar), Kabar Lake (Bihar), Harike (Punjab), Sultanpur (Haryana), Nawabganj (U.P.)	Rich avifauna, winter migrants	Rhino, wild buffalo, swamp deer	Bird shooting Chokingofwater outlets
D.	Wetlands of Eastern India	Duars (N. Bengal), Jaldapara, Manas, Kaziranga, Loktak Lake	Large mammals	Rhino, buffalo	
E.	Wetlands of Peninsula	Kolleru Lake			Development of drainage
F.	Coastal Wetlands	Rann of Kutch, Khijida area, Ghed swamps, Kerala backwaters, Point Calimere, Pulicat Lake, Bhitarkanika, Sundarbans	Bird habitats, marine and estuarine fauna, migratory waders and mangroves	Crocodile tiger	

Source : "Conserving our Biological Wealth", WWF for Nature-India.

species will be described as animal taxonomy progresses further. This will possibly pave the way for their proper and sustainable utilization for humanity, pertaining to agriculture, medicine, etc. Proper knowledge of biological or genetic diversity of animals is also essential in understanding animal-animal-plant relationships on one hand and those with their ecosystems on the other, and both these types of information are necessary for their effective conservation.

Human population explosion

Human population of India which is 17% or 1/6th of the total humanity of the world is highly disproportionate keeping in view the land area of the country and the available resources. Moreover, the population is rising at an alarming rate as can be judged from the following data. It jumped from 238 million in 1901 to 361 million in 1951, a rise of 52% in 50 years. In 1981, it touched the 685 million mark, a leap of 90% in 30 years. The census conducted this year (1991) puts the population figure at around 840 million, which shows an increase of nearly 25% in 10 years. If it goes at this pace, perhaps the billion mark will be crossed by the turn of century or even earlier. This would mean an approximate rise of nearly 300% during the 20th century alone. The human population explosion, as is already well known, has its own problems which are of a very serious magnitude and particularly for a developing country like India. Every individual competes, in fact struggles, for basic necessities of life, like food and shelter and this directly or indirectly puts pressure on natural resources and the ecosystems. The population level, due to breeding and/or cultivation, of those species of animals and plants which are directly consumed, utilized or associated with man like buffaloes, cows, goats, mosquitoes, houseflies, as also wheat, rice, pulses, sugarcane, potatoes, etc., just to mention a few, would also tend to rise. This could be inferred from the fact that over half of the world's population of buffaloes and approximately 1/7th of the cattle and goats live in India. It would not be difficult to imagine the extent of pressure that these are putting on our natural ecosystems to meet their needs for fodder. Further, in order to cater to the requirements of human populations, more and more virgin land will be used for housing, buildings industries, dams, roads, schools, hospitals, as also for raising cattle and growing crops, vegetables, fruit trees etc.

Faunal loss and conservation strategies

The main brunt of the inevitable expansion, aggression and exploitation by one species, the Homo sapiens, *is borne by the natural ecosystems and their biota. As a consequence, these are either converted into artificial ecosystems or exploited and degraded, gradually but consistently, to such an extent that they fail to replenish and are lost forever along with their valuable fauna and flora. According to an assessment made in 1986, about 80% of the original wildlife habitat has been lost in tropical Asia. The depletion of fauna and flora of the world, especially in the developing countries, has been taking place for a long time but now that it has crossed all conceivable limits, its extent and impact are being felt globally. Unfortunately, as is also pointed out above, much of this loss is due to human activity particularly those meant for widening our economic, agricultural and industrial bases. Environmental pollution is increasing at an alarming rate and threatening to bring about severe climatic changes in the world, which may have far reaching consequences for man and other forms of life. Increase in the concentration of greenhouse gases is leading to global warming which would result into parched crops and flooded coastlines in many countries. The ozone layer depletion which is progressively increasing, would cause ultraviolet-B radiation and may threaten the very existence of fauna and flora on the Earth. Human beings, particularly those in the developed countries with the advances already made in the fields of science and technology may still be able to somehow escape these imminent dangers, but the future of man and the vast biological diversity looks very bleak indeed. It is true, though it may sound rather ironical, the countries which are poor in biological diversity are rich in biological technology and vice versa. This underlines the need for global co-operation in matters pertaining to utilisation of biological resources, as only this can ensure harnessing genetic variability for economic growth and prosperity*

TABLE III

Forest Area by Forest Types

Sl. No.	Forest Types	Area (million ha)	Percentage of total forest area
1	Tropical wet evergreen	4.5	6.02
2	Tropical semi-evergreen	1.9	2.55
3	Tropical moist deciduous	22.6	30.25
4	Littoral and swamp	0.7	0.94
5	Tropical dry deciduous	29.2	39.10
6	Tropical thorn	5.2	6.96
7	Tropical dry evergreen	0.1	0.13
8	Sub-tropical broadleaved hill	0.3	0.40
9	Sub-tropical pine	3.7	4.95
10	Sub-tropical dry evergreen	0.2	0.27
11	Montane wet temperate	1.6	2.14
12	Himalayan moist temperate	2.7	3.61
13	Himalayan dry temperate	0.2	0.27
14	Sub-alpine		
15	Moist alpine scrub	1.8	2.41
16	Dry alpine scrub		
	Total	74.7	

Source : *Government of India, Ministry of Agriculture, Department of Agriculture & Cooperation, Forestry Division, July 1981 (Singh, 1986).*

of all mankind. The break-through in the biotechnology in general and genetic engineering in particular has created tremendous potential and opened up new avenues for humanity. The technology is now available for transferring genes from wild relatives to domesticated plants and animals. The loss of any species or gene puts a limitation on options that are likely to be available to us for shaping our biofuture. The evolutionary processes of nature which had shaped new species of organisms in geological history appear, most likely, to have been thrown out of gear because of large scale environmental degradation and the resultant climatic changes. By and large only extinction of species is now taking place and that too is increasing day by day. Extinction much like evolution is a natural phenomenon that progressed at an extremely slow pace, with approximately one species becoming extinct in a thousand years. But during 1600 A.D. to 1950 this number has increased to 10 species, and now it has jumped to one species or more per year. The plant species are perhaps disappearing at a rate much faster than those of animals.

India is losing at an alarming rate its vast genetic heritage, the animal wealth of the country, even before these are properly studied and understood. The value of these resources is immense for us and our future generations. Nature has gifted biological diversity to be ***enjoyed*** *and exploited gainfully for the progress of humanity and not to be* ***destroyed*** *and written off from the face of Earth altogether. We must understand that* ***our own survival depends on their existence and not on their extinction.*** *The Govt. of India, particularly the Ministry of Environment and Forests and many non-Government organisations like WWF-India are making commendable efforts in the conservation and*

TABLE IV

Statewise Forest Area

State/Union Territory	Geographical area ('000 ha)	Forest area ('000 ha)	Percentage of forest area to geographical area
States			
Andhra Pradesh	27,682	6,367.1	22.96
Assam	7,852	3,070.8	39.11
Bihar	17,388	2,923.2	13.36
Gujarat	19,598	1,964.8	10.02
Haryana	4,422	169.7	3.84
Himachal Pradesh	5,567	2,114.2	37.97
Jammu & Kashmir	22,224	2,188.6	9.85
Karnataka	19,177	3,838.6	20.01
Kerala	3,887	1,125.1	28.94
Madhya Pradesh	44,284	15,541.4	35.09
Maharashtra	30,776	6,416.7	20.85
Manipur	2,236	1,515.4	67.77
Meghalaya	2,249	851.0	37.84
Nagaland	1,653	289.9	17.53
Orissa	15,578	5,996.3	38.49
Punjab	5,036	259.2	12.73
Rajasthan	34,221	3,043.9	8.89
Sikkim	730	282.0	38.63
Tamil Nadu	13,007	2,201.4	16.92
Tripura	1,048	592.0	56.48
Uttar Pradesh	29,441	5,114.9	17.37
West Bengal	8,785	1,183.0	13.46
Union Territories			
Andaman & Nicobar Islands	829	714.4	86.17
Arunachal Pradesh	8,358	5,154.0	61.66
Dadra and Nagar Haveli	49	20.2	41.22
Delhi	149	Negligible	—
Goa, Daman & Diu	381	130.9	34.35
Mizoram	2,109	1,662.9	78.84
Other U. Ts.	63	—	—
All India	328,779	74,721.6	22.73

Source : *"India's Forests – 1980 and 1984". Central Forestry Commission. New Delhi, and "Development of Forestry and Forest Products – Country Profile – India". Government of India, Ministry of Agriculture, 1981 (Singh, 1986).*

preservation of our biological diversity. The first step in this direction should be the restoration of habitats that have been destroyed or lost due to human interference. Further deforestation must stop immediately and whatever has been lost should be regenerated, if possible. The Government has shown concern for wildlife habitat preservation by declaring 54 National Parks and 372 Sanctuaries totalling 1,09,652 sq. km. This number is likely to go up further to 148 National Parks and 503 Sanctuaries in the near future covering an area of 1,51,342 sq. km. Some habitats where the fauna and flora live undisturbed in its pristine beauty and glory and the evolutionary processes of Nature are perhaps still going on uninterrupted have been identified and declared as Biosphere Reserves by the Government mainly for the purposes of their protection and preservation for posterity. Commendable efforts have also been made to save some endangered species, particularly those of large mammals like lions, tigers and some birds. No doubt these efforts have borne fruit, particularly those pertaining to the Project Tiger. Based on the success of these projects efforts are now being made to protect elephants whose population is fast depleting. While such measures to save single species are laudable, conservation is essentially a holistic concept which starts from the protection of habitat and extends to the conservation of entire biological diversity. After all, every species of animal and plant, whether big, small or microscopic is important, as these are inter-linked with each other, have co-evolved and are tied together in a web of life. Man himself is very much a part of this web and shares the Earth with other forms of life. Hence the existence, continuance and conservation of biological diversity shall ensure Man's own survival on this planet. More so the biological diversity and its components have ecological, genetic, scientific, aesthetic, recreational, cultural, educational, social and economic value and it is entirely in the interest of Man to protect and preserve them for posterity.

Role of the Zoological Survey of India

The richness of the fauna of the country and the need for their exploration was recognised a long time ago. This is evident from the fact that the Zoological Survey of India was established some 75 years back mainly for taxonomic study of animal species. But taxonomy is not the exclusive domain of ZSI as many scientists working in the universities and other research institutes have also made highly significant contributions to this field and some are still continuing to do so, though the trend is on the decline because of general disenchantment with taxonomic research. Since its inception in 1916, ZSI scientists are busy in faunal explorations with particular emphasis on biogeography (i.e., animal distribution), taxonomy (identification and classification) and ecology (their relationship with the environment). These results are published, in scientific journals of the department and outside as well. The most significant publication worthy of special mention here are the fauna series entitled **Fauna of India***. These are a continuation of the earlier well-known* **Fauna of British India** *series. The fauna volumes provide authoritative and detailed accounts on the faunistics of different animal groups up to the level of species and are of immense value in identification work. So far, 115 volumes have been published and a few more are in the press, providing descriptions of about 25,000 animal species. Side by side, during the last few years, another series by the name* **Fauna of States** *has also been initiated which will provide details of animal species of various states of the Indian Union.*

For the economic and technological development of the country, it is necessary that we should have an adequate knowledge of our natural resources including animal wealth, which forms an important and an integral component of such resources. This knowledge is considered necessary so that our future developmental programmes should not be at the cost of our faunal wealth. It has, therefore, become absolutely essential to obtain information on the identity, distribution, interactions and population levels of animal species for these purposes as also for their conservation. In this volume an attempt has been made to provide information on the state of our knowledge of the various animal groups that occur in India. This is also with the purpose of focussing our attention on those areas where some lacuna exists and there is need and scope for further work or expertise development. This information should provide the much needed base-line data which can *be used by taxonomists, ecologists, parasitologists, entomologists, ichthyologists, in fact by all shades of zoologists in their research work. Further, the information would be useful to the Govt. of India for environmental impact assessment, ecosystem maintenance and proper and sustainable exploitation of these resources. This may lead to development of newer biological technologies which will help in enhanced bio-medical research potential and agricultural and horticultural productivity of the country. India which is already rich in biological diversity has the credentials to become rich biotechnologically as well.*

Over one million species of animals have been identified and described so far from all over the world. Of these, nearly 80% species are those of insects. But these numbers are only the tip of the iceberg as many zoologists believe that at least 20 to 25 million species, some even say 40-50 million, actually exist in this world. Majority of this huge number lives in tropics and sub-tropics. The hitherto unknown species mostly belong to invertebrates like insects, nematodes and protozoans. The task of collection, inventorisation and description of species, before these are virtually lost to science due to environmental degradation and habitat destruction, is indeed stupendous. Unfortunately, taxonomists are becoming fewer and along with that taxonomy is fast declining and there is an acute dearth of talent to tackle this problem in India as also in many other countries of the world. ZSI being the premier institute of taxonomy has great responsibilities in this regard. With its Headquarters at Calcutta and an extensive network of regional, ecological and field stations in other parts of the country, each with taxonomists having valuable and vast experience in the field and laboratory on taxa belonging to various animal groups and habitats, it has to play a major role and provide the much needed service to the nation. Every zoologist knows fully well that no work in experimental or applied zoology is possible without first determining the correct identity of the species. The ZSI is custodian of a very huge and highly valuable ***National Zoological Collection*** *comprising more than one million specimens belonging to 75,000 species including nearly 10,000 species from the neighbouring countries like Burma, Pakistan, Bangladesh, Thailand, Sri Lanka, etc. This proud possession has over 15,000 type specimens making it thereby one of the most valuable reference collections of the world. Some specimens in this collection are as old as 150 years or more.*

The present work, though under a different title ***Animal Resources of India : State of the Art*** *is an enlarged and up-dated version of the* ***State of Art Report : Zoology*** *published by ZSI in 1980. It provides information on the species of animals from Protozoa to Mammalia under one cover,* identifies *experts of each group in India and abroad and lists some selected references for those interested in further reading and research. A brief account on the groups is presented below.*

PROTOZOA TO MAMMALIA

Invertebrates *(other than insects)*

Living organisms according to the recent classification which is accepted by majority of biologists are distinguished into three Kingdoms, viz., Plantae, Protista and Animalia. The last mentioned two are concerned with animals and hence are dealt with in this book. The Kingdom Protista includes subkingdom Protozoa, which was hitherto considered only as a phylum. As per the currently accepted opinion the subkingdom Protozoa is divisible into seven phyla, of which one, namely Labyrinthomorpha is not represented in India. The Indian species of Protozoa constitute only about 8% of the total world fauna. However, as per the estimates much more species, 3 to 4 times the recorded number of 2577, are expected to occur in India. The Indian Protozoa are represented by 52% free-living and 48% parasitic species as against the world's 68% free-living and 32% parasitic. It reveals that in India there is much scope of further research on these organisms. In spite of their importance in medical and allied fields, and considering the gaps in our knowledge in India, there are only 12 experts engaged in research on protozoans. Of course, Foraminifera is the subject of interest also for geologists and oil technologists. Besides ZSI, work on Protozoa is being carried out only at seven Indian universities.

Thirty two phyla have been recognised under the Kingdom Animalia (Parker, 1982), *but all phyla have not appealed in equal measure to researchers. It may be due to their rare occurrence or lack of importance for man or both. There is either no data or no experts available in India at least on nine phyla viz., Mesozoa, Gnathostomulida, Nemertinea, Nematomorpha, Loricifera, Priapulida, Pogonophora, Tardigrada and Pentastomida. Though an extremely rare group, Onychophora has been recorded from India once. The remaining 22 phyla have not received a balanced attention from research workers, as some of the groups are very well studied while others rather poorly, as evidenced from the accounts given in the following pages. The phylum Mollusca has the largest number of known species from India (5042), followed by Nematoda (2350), Platyhelminthes (1622), Annelida excluding Archiannelida (1072) and Echinodermata (765). The phylum Phoronida is smallest with only three species known from India. Chaetognatha is another phylum which is represented here by 30% of the world's species.*

Among freshwater planktonic groups, Phylum Rotifera is the most dominant one with 310 species and having drawn 20 experts to its study in India. Crustacea is a major class of Arthropoda of which only a few subclasses have received proper attention. Decapoda due to their commercial value have attracted many workers. The planktonic groups, such as Cladocera, Copepoda have also been extensively studied because of their value to fisheries. Moreover, Copepoda due to their importance in biomass production have attracted a number of workers, about 84 in total. Our knowledge of freshwater Cladocera is reasonably good, but the marine species are known poorly. Except for a few well-known groups, the taxonomy of Crustacea remains far from satisfactory as there is lack of expertise on many of its subclasses.

Major constituents in the marine meiofauna are Nematoda, Gastrotricha, Kinorhyncha, Archiannelida and some other groups, such as calanoids, etc. Although recent, our knowledge on the meiofauna is fairly good and the studies so far have shown a high degree of endemicity. Among groups which are exclusively marine, the phyla Sipuncula and Echiura have been adequately studied and a fairly good amount of taxonomic data is available. Porifera which occur both in freshwater and sea have also been satisfactorily worked out. The studies on various marine groups have brought out the existence of a very rich biological diversity in Andaman and Nicobar group of islands. There are 359 species of echinoderms out of a total of 765; 25 and 14 species of Echiura and Sipuncula are found in these islands respectively as against the total species numbering 33 and 38 from the rest of India.

The taxonomy of groups like Coelenterata, Crustacea, etc., is poorly known, but for certain groups drastic changes have taken place. For example, in sponges a total of about 5000 known species have been reduced to only 47. In coelenterantes, much expertise is not available in the country. Only Siphonophora and hard corals are well-worked out but on other Classes either there are few experts or no experts at all. No expertise is available for the identification of soft corals and the related groups. There has been no work recently on Ctenophora. Among other minor phyla, the Bryozoa has received more attention than Phoronida, Entoprocta and Brachiopoda.

Some groups, especially those in the terrestrial and freshwater ecosystems, have been taxonomically well-worked out but there seems to be no analytical data as far as the status of the groups themselves is concerned. From the details presented it is not possible to indicate the areas possessing rich biological diversity. In spite of a few publications in the Fauna series, gaps still exists in our knowledge on the distribution of various groups in the sub-continent. As the status of many species is not exactly known it is not possible to name species threatened with extinction.

The available expertise is not evenly distributed to all phyla. Two groups, viz., Platyhelminthes and Nematoda have active schools of research and there are 30 and 25 researchers respectively working on various taxonomic aspects of these animals. Among Annelida, Oligochaeta has attracted a number of workers (12). Similarly, planktonic groups like Rotifera, Cladocera and Copepoda have a number of workers. In general it is seen that our knowledge of marine fauna is far from satisfactory. The importance of marine organisms in contributing to bio-active compounds has been realised only recently and it has *consequently exposed the existing gaps in our knowledge. The nematodes constitute about 90% of all metazoa in the world and are known to occur in every possible type of habitat, e.g., marine, freshwater, terrestrial. They live as free-living, predaceous or as parasites of almost all groups of invertebrate and vertebrate animals. When fully studied the number of nematode species may compare well with those of insects or may even surpass them, but in order to achieve this, the number of experts has to go up sharply. It is yet to be seen fully as to how many zoologists would be attracted towards this group, but the agricultural, medical and veterinary importance of nematodes has the potential of attracting talent and the process seems to have already began.*

In Arthropoda, the Diplopoda (millipedes) and Chilopoda (centipedes), both grouped together earlier under Myriapoda, have not been taxonomically studied to the desired extent, although 12 families of the former and 4 Orders of the latter are found in India. Some groups such as Opiliones though found in India have not been studied well. Xiphosura (king crabs, also called "living fossils") is the only living Order of Palaeostracha of which two species occur in India. All these groups need more study of their taxonomy, habits and habitats. Acari (the mites) have been studied well largely due to their economic value. There are about 2,000 species occurring in diverse habitats, like water, soil, store-house, nests, house dust, etc. They parasitize plants and different groups of invertebrate and vertebrate animals. Keeping in view the diversity of the group, the number of experts available is not satisfactory. ZSI scientists have contributed significantly to the study of plant mites in the recent past.

Insects

Insects comprise 75-80% of the total animal species that have been recorded on this planet. They appeared in the Devonian period and since then have continued to evolve in large numbers of species on one hand (quality-wise), and because of shorter life cycles, high fecundity and ability to survive in almost every type of niche, in huge populations on the other hand (quantity-wise). Insects can thrive in all ecosystems, but there are no totally marine species.

Ancient sanskrit literature refers to different kind of insects like Patanga, Bhramara, Pipilika, Makshika, *etc. The early naturalists from Aristotle onwards have known insects well and divided these into various groups. The earliest insect worker in India was perhaps Mandavya referred to in a story of* Mahabharata, *who had the habit of collecting and pinning insects but unfortunately had to pay with his life for this act by being himself impaled on the point of a sharp crowbar. Laksha, the product of lac insect, is the subject of another popular story of Mahabharata. However, entomology in modern India can be traced from the middle of 18th century, with the arrival of Christian missionaries and subsequent establishment of the East India Company. In present day animal classification, Insecta is a Class of the phylum Arthropoda, together with Crustacea, Arachnida etc. The insects are grouped into about 30 Orders, of which two, Grylloblattodea and Zoraptera, do not occur in India and hence are not included here.*

Based on number of taxa, Coleoptera is the largest Order, followed by Lepidoptera, Diptera, Hemiptera and Hymenoptera. In India, Coleoptera is represented by 103 families having about 15000 species; Lepidoptera 80 families and 13000 species; Diptera 87 families and 5500 species; Hemiptera 77 families and 6500 species and Hymenoptera 57 families and 5000 species. The various Orders of the wingless insects, the Apterygota as also a few winged ones have lesser number of taxa. In India, Strepsiptera is represented only by 8 species belonging to 3 families. The Mecoptera is represented by 2 families and 15 species, Protura 3 families and 20 species, Diplura 3 families and 16 species, and Thysanura 3 families and 23 species. In general, 4-5% of the world species of insects occur in India.

The topography of the country provides wide range of locational, altitudinal and temperature conditions. The altitude variations from sea level to the snowy mountains present a series of vertical zones between the coastal plains and high peaks. The insect fauna is largely influenced by vegetation, rainfall, temperature, etc. Right from the arid zones of Rajasthan to the moist forests and high rainfall areas such as in Meghalaya to the insular ecosystem of Andaman, Nicobar and Laccadive groups of islands, a great variety of insects are known to occur in this country. Insects have been collected from almost all parts of the country, and obviously some regions are richer than the others. The tropical evergreen forests of eastern Himalaya and north-eastern hills have provided maximum number of insect species. This could be due to the type of vegetation, hot and humid climate, and the geographical location of the area which is the meeting place of Indian peninsular, Malaysian, Chinese and Palaearctic regions. Other regions rich in insect diversity are the rain forests and the hilly areas of south India, viz., the Nilgiris, Anaimalai, Palni, and Western Ghats. They harbour many endemic taxa, some of which also occur in Sri Lanka. The third such richer habitat of insects is the western Himalaya, covering the states of Jammu and Kashmir, Himachal Pradesh, and Kumaon and Garhwal regions of Uttar Pradesh. Many species occurring in these areas are also found in Tibet, Afghanistan, Pakistan and Iran. With the temperate climate and forests of oak, pine, cedar, etc., these areas provide niches for many rare species. Thus, it is evident that in the elevated and colder areas of the country the insect diversity is much more. Some of them like Khasi Hills, Sikkim, Darjeeling, Yercaud, Simla (and also Mergui archipelago of Burma, formerly part of British India) are famous type localities of a very large number of species including some unique ones. There are still many such areas, like Pangi Valley (H.P.), Valley of Flowers (U.P.), Neora Valley (W. Bengal) and Tirap (Arunachal Pradesh), which remain largely underexplored. The islands of Bay of Bengal and Arabian sea also deserve further exploration for their insect wealth.

Great Indian Desert is poor in insect fauna compared with moist deciduous forests in other parts of the country. Nevertheless the desert dwelling species present interesting adaptations. About 20 Orders are represented here, the prominent ones being Coleoptera (including aquatic species), Hymenoptera (89 species), Lepidoptera (e.g., 77 species of butterflies), Isoptera (27 species) and Neuroptera (13 species).

Since population studies have not been carried out on majority of invertebrates including insects, it is not possible to identify species threatened with extinction. However, some groups may be considered endangered and a few are named here. Anisozygoptera, an intermediate suborder between Anisoptera (dragonflies) and Zygoptera (damselflies) is represented in the region by a single relict species, Epiophelebia laidlawi. It was collected from Darjeeling district (Eastern Himalaya) where it inhabits pools of hill streams.

In Indian Coleoptera, several species belonging to 9 genera of Carabidae, 10 of Chrysomelidae, and 5 genera of Cucujidae are considered rare. Indian species of Lepidoptera comprise some rare and some very rare species, most of which are butterflies. These are given in Table V (Varshney, 1986).

Stick and leaf insects (Phasmida) present astonishing examples of mimicry in nature. Although 60 species have been recorded from this region, mostly from north-eastern India, this group is exceedingly rare. It is feared that with further environmental degradation such as deforestation, pollution, etc. several taxa of insects and other micro-arthropods shall vanish altogether.

Insects became important with the realization of the immense amount of loss caused by them as pests of economic plants and as carriers of diseases in men and animals. Desert locust is the foremost example of how much havoc a single species of insect can cause. Mosquitoes as carriers of malaria, are another example of their potential in the spread of diseases. Tribolium and Trogoderma are cosmopolitan pests of the stored grains. Termites, cockroaches, lice, borers, flies, etc., among insects and mites, ticks and scorpions among allied arthropods, are dreaded all over the world. Insect pests cause at least 10% loss annually to our agricultural and horticultural crops and forest resources. A rough estimate may indicate that the country is losing about ten hundred crores of rupees per year due to injurious insects. On the other side, there are beneficial insects, viz., the honey bees, the silk moths (there are basically 4 kind of silks produced in the country from different species) and the lac insects. India produces the largest quantity of lac in the world. Some insect species are either parasitic or predaceous on other insects and mites. They are thus agents *of biological control of the pests. Some species are likewise useful in control of weeds. The value of insects as pollinators also can not be ignored.*

TABLE V

Rare species of some families of Indian butterflies

Family	Total No. of spp./ssp	Rare species	Very rare species
Amathusiidae	55	14	3
Danaidae	77	7	3
Lycaenidae	670	130	50
Nymphalidae	440	92	45
Papilionidae	217	23	18
Pieridae	182	26	7
Satyridae	336	71	18
Total	1977	363	144

It is apparent that the number of workers available in the country who are engaged in insect identification is far less than required to deal with the number of species of insects occurring in India. In Coleoptera there are 20 workers, while in Lepidoptera 19 workers, who are presently engaged in taxonomic studies. This number is insignificant when we take note of the fact that there are 103 families of Coleoptera and 80 families of Lepidoptera found in India. Only a few groups like Isoptera, Odonata and Rhopalocera (Lepidoptera) have some experts available in different places. Certain groups like Diptera, Microlepidoptera, Siphonaptera etc., do not have any worker on several families in India. Groups like sucking lice (Anoplura), parasitic Hymenoptera, Blattaria, etc., also need more workers. Undoubtedly, insect groups of economic importance require attention on priority basis and suitable arrangements have to be made, for proper training in the country and abroad, to develop expertise as soon as possible.

The hemichordates which are exclusively marine represent one of the smallest phyla comprising 15 genera and 118 species so far known from the world. Indian hemichordate fauna is represented by only 12 species belonging to four genera. Proper attention has not been given to this group because of their rare occurrence and lack of economic importance. No work has been done on Classes, the Protobalanidae, Cephalodiscidae and Planctospaeridae. The expertise available is very meagre and presently there are only two workers in India, one of whom is in ZSI.

Chordates

The protochordates are a most primitive group of chordates which do not have a cranium and vertebral column. Out of some 2173 species known from the world, only 116 species belonging to 50 genera occur in India and all of these are marine. Their taxonomy and biology are also poorly studied. While practically no work has been carried out on cephalochordates, a number of families of sessile tunicates viz., Polycitridae, Dideminidae, Diazinidae, Cionidae, Corellidae, Octonimidae, Sortillidae and Molgulidae need to be worked out. Only three workers are currently engaged on protochordate study in the country of which one is in ZSI.

Because of their immense economic value as food and abundance in almost all aquatic habitats, fishes have gained tremendous attention throughout the world since time immemorial. Considerable literature is now available on their morphology, taxonomy, biology, ecology, economic importance, etc. Fishes also comprise the largest group of vertebrate animals in the world, consisting of 21723 species., which comes to nearly 50%

of the total vertebrate fauna. From Indian waters 2546 species belonging to 969 genera have so far been reported, of which 59% are marine and the remaining are freshwater. The Indian freshwater fish fauna has Indo-Chinese and Indo-Malayan elements. Interestingly, Ethiopian elements are almost absent excepting chichlids occurring in south India. The lung fishes, mud sirens and sturgeons are totally absent. The marine fishes have wide geographical distribution and some genera are common to Indo-Pacific and Atlantic oceans.

During recent years, over-exploitation of fishery resources followed by habitat destruction resulted in considerable decline of freshwater fishes in general and food and game fishes in particular. The important causes of habitat destruction are dynamiting of rivers, over utilization of water resources, construction of dams, pollution and silting of rivers, lakes and man-made reservoirs, and large scale collection of gravel. The most affected species in recent years are Mahasheers. Four species are considered as endangered and 17 as threatened. A good number of workers are currently engaged in fish taxonomic research. This includes 10 experts in ZSI and 16 in other institutions and many in the universities.

Amphibian fauna of India which includes frogs, toads, newts is also comparatively rich. It is represented by nine families, 32 genera and 204 species as against the world fauna of 330 genera and 5145 species. About 40% species of Indian amphibians are endemic. The amphibians are found throughout the country. Three genera of the family Pelobatidae occur in the Himalaya while the only species of the family Hylidae is restricted to north-eastern India. Among Bufonidae, 50% of the species are confined to southern India. The only species belonging to the family Salamandridae, the Himalayan newt is restricted also to north-eastern India. It is regarded an endangered species and is included in Schedule I of Indian Wildlife (Protection) Act of 1972 as emended up-to-date.

A number of frog species are edible and are considered a delicacy in many countries of the world but not in India. Till recently frog legs were being exported in large quantities to China, Japan, France, USA, etc., where these fetched high prices. This over-exploitation resulted in drastic decline in their population levels and consequently the export has now been banned by the Govt. of India. At present, there are four scientists in ZSI and eight in other institutions who are engaged in research on amphibian taxonomy.

The crocodiles, turtles, tortoises, snakes and lizards belonging to Class Reptilia occur widely in India. Four hundred twentyeight species representing 137 genera and 26 families are so far known from here which is about 8% of the world's fauna (5375 species). These include freshwater forms like gharial, mugger and fresh-water turtles, brackish-water species like salt-water crocodile and wart snakes, marine forms like sea turtle and sea snakes and terrestrial forms like tortoises, lizards and snakes. While sufficient information is available on reptilian fauna of other regions, there is lacuna in our knowledge of the fauna of north-eastern India, Telengana, Marathwada, Eastern Ghats, estuaries and mangroves of peninsular region. Naturally, these require proper attention of research workers.

A number of reptilian species are highly endangered and are listed in Schedule I of the Indian Wildlife Act. These include four species of monitor lizards, estuarine and marsh crocodiles, gharial, nine species of turtles and two species of snakes. The reptiles play a highly beneficial role in the human economy. For instance, the lizards feed on insect pests, snakes eat rats and their venom is used in medicine. Some species of reptiles have also been used as food. At present five scientists in ZSI and about two dozen in other institutes/universities are working on this group.

The Indian avifauna is quite rich. From the pheasants of the Himalaya to birds of the oceans, from the Blyth's Tragopan of dense evergreen forests of north-eastern India to the Great Indian Bustard of semi-arid tracts, they exhibit a great variety of forms, shapes and sizes. There are 1228 species of birds belonging to 405 genera and 78 families, out of which 42 are endemic. This constitutes more than 13% of total world's avifauna (9026 species). A number of bird species have been exploited vigorously for their flesh, feathers, etc. This along with large scale habitat destruction has resulted in drastic decline of their populations, 47 species are threatened with extinction and are included in Schedule I.

While birds are beautiful and are of considerable aesthetic value, they may not always be useful for mankind. Many species cause extensive damage to our agricultural crops and some species living in the vicinity of airports are hazardous for the flying aircraft. Currently six scientists in ZSI and 12 in other institutes and universities are engaged in avian research.

The mammalian fauna of India is represented by 372 species belonging to 169 genera and 45 families which constitute about 9% of the total world's mammalian fauna (4232 species). Out of these, 10 genera are endemic. Mammals are distributed quite widely in this country. Though generally terrestrial, they are also aquatic and volant. The aquatic mammals belonging to the Orders Cetacea and Sirenia are mostly marine. The bats are true fliers while the flying squirrels are gliders. While sufficient information is available on terrestrial mammals, our knowledge of aquatic species is rather meagre and this requires more attention. Further, many genera of the Orders Insectivora, Carnivora, Artiodactylea, etc., need revision.

A large number of wild mammalian species of India are threatened to extinction. Eighty one species have been included in Schedule I of which 25 are highly endangered. The recent status surveys of about 30 species carried out by scientists of the ZSI and some other institutes have revealed a general decline in their population. Urgent conservation measures are, therefore, required for their protection.

The mammals play an important role in human economy. While some species like those of monkeys are used for biomedical research, large scale crop destruction is caused mostly by rodents and also by monkeys, elephants, deer, antelopes, wild boar, etc., Fruit bats cause damage to some of our orchards. Active research on the mammalian taxonomy and ecology is being carried out in ZSI where as many as 21 scientists are involved. In other institutions there are eight workers and an unspecified number are working in the universities.

A summary of approximate number of species occurring in India and their share in the world fauna are given below :

TABLE VI

Estimated Number of Species (based on available data)

Group	India	World	% in India
Protozoa	2577	31250	8.24
Porifera	519	5100	10.18
Siphonophora	118	180	65.56
Sclerectinia	119	7000	1.70
Ctenophora	10	100	10.00
Platyhelminthes	1622	17500	9.27
Turbellaria	47	4000	1.17
Monogenea	295	2500	11.80
Trematoda	750	6500	11.54
Cestoda	530	4500	11.78
Rotifera	310	2500	12.40
Gastrotricha	88	2500	3.52
Kinorhyncha	10	100	10.00
Nematoda	2350	25000	9.40
Acanthocephala	110	800	13.75
Sipuncula	38	202	18.81
Mollusca	5042	80000	6.30

Group	India	World	% in India
Echiura	33	127	25.98
Annelida	**1093**	**12620**	**8.66**
Oligochaeta	585	4000	14.27
Polychaeta	428	8000	5.35
Hirudinea	59	500	11.80
Archiannelida	21	120	17.50
Onychophora	1	100	1.00
Arthropoda	**57525**	**952116**	**6.04**
Crustacea	**2970**	**24375**	**12.88**
Anostraca	72	175	41 14
Notostraca	11	15	73.33
Conchostraca	27	180	15.00
Cladocera	90	400	22.50
Ostracoda	120	2000	6.00
Copepoda	540	4500	12.00
Branchiura	4	75	5.33
Cirripedia	104	750	13.87
Isopoda	200	4000	5.00
Amphipoda	143	3600	3.97
Decapoda	1535	8500	18.06
Stomatopoda	124	180	68.89
Insecta	**50717**	**839052**	**6.04**
Thysanura	23	1250	1.84
Diplura	16	355	4.50
Protura	20	260	7.69
Collembola	200	5000	4.00
Ephemeroptera	94	2146	4.38
Odonata	491	5500	8.92
Plecoptera	113	2100	5.38
Orthoptera	759	14491	5.24
Phasmida	60	2500	2.40
Dermaptera	320	1800	17.77
Embioptera	33	200	16.50
Blattaria	156	4200	3.71
Mantodea	161	2000	8.05
Isoptera	300	2000	15.00
Psocoptera	85	2500	3.40
Phthiraptera	400	3000	13.33
Hemiptera	6500	80000	8.13
Thysanoptera	691	6000	11.51
Neuroptera	315	5000	6.30
Coleoptera	15000	350000	4.28
Strepsiptera	8	300	2.66

Group	India	World	% in India
Mecoptera	15	350	4.28
Siphonaptera	52	2000	2.60
Diptera	6093	96600	6.31
Lepidoptera	13000	142500	9.12
Trichoptera	812	7000	11.60
Hymenoptera	5000	100000	5.00
Diplopoda	162	7500	2.16
Chilopoda	100	3000	3.33
Xiphosura	2	4	50.00
Arachnida	**409**	**6385**	**6.40**
Scorpionida	102	1500	6.80
Pedipalpida	25	85	29.41
Solpugida	15	900	1.67
Opiliones	167	1600	10.43
Pseudoscorpionida	100	2300	4.35
Acari	1915	36800	5.20
Araneae	1250	35000	3.57
Phoronida	3	11	27.27
Bryozoa	170	20000	0.85
Entoprocta	10	60	16.67
Brachiopoda	3	300	1.00
Chaetognatha	30	100	30.00
Echinodermata	765	6226	12.28
Hemichordata	12	118	10.16
Chordata	**4894**	**47674**	**10.27**
Protochordata	116	2173	5.34
Pisces	2546	21723	11.72
Amphibia	204	5145	3.96
Reptilia	428	5375	7.96
Aves	1228	9026	13.61
Mammalia	372	4232	8.79
Grand Total	77452	1211584	6.40

From the foregoing account it is quite evident that India is rich in its biological diversity, because with its 2% geographical area it has about 6 % known animal species of the world and the same will also hold true for the plant species. The number of species recorded will rise further as and when more species are discovered. From the information available with us it appears that there are certain groups (e.g., Mesozoa, Nemertinea, etc.) which either do not occur in India at all or may be so rare that they have not yet been recorded. There are other invertebrate groups (e.g., Scyphozoa, Anthozoa, Pycnogonida, etc.) which are known from India but do not find a place in this volume, either due to non-availability of the relevant articles or lack of expertise. Then there are those groups (e.g., Dermaptera, Hemichordata, etc.) which are found either occasionally or abundantly but have not attracted the attention of zoologists since they do not have any economic importance. On *the other hand there are several groups (e.g., Platyhelminthes, Decapoda, etc.) which are economically important and hence have received the due attention of zoologists. Some groups like those of insects and Crustacea have been studied extensively but the enormity of number of species demands much more attention. The vertebrate species are by and large well known as they have a direct appeal to man and have formed a part of natural history studies by amateurs as well as professional scientists. Similarly, the protozoans and the nematodes, particularly the latter have possibly an exceptionally large number of hitherto unkonwn species but these have not been studied properly and extensively, in spite of their value to man, mainly due to their small to microscopic sizes and difficulties encountered in their collection and identification. The high percentage (50 - 73%) of occurrence of groups like Siphonophora, Stomatopoda, Xiphosura and Notostraca in India may be due to the small number of total known species in the world. In general, marine fauna have been studied rather inadequately as compared to those of freshwater or terrestrial species.*

It therefore points out to the need for a planned development of expertise in India so that groups which have a large number of species as well as those which are rare must be studied not only for their academic interest but also for their ecological role to understand the biological diversity in its proper perspective.

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PROTOZOA

Introduction

The protozoa are unicellular eukaryotic organisms, mostly microscopic. They are found in every possible niche of all habitats, from deepest ocean bed to the highest mountain tops and from tropical soils to antarctic snows. Though they are single celled, they are capable of carrying out all bodily functions necessary for survival. They include innumerably diversified tax with very simple to most complicated life cycle.

Although Gesner first described a foraminiferan protozoa,*Vaqinulina* in 1565, even before the invention of microscope, (Cole, 1926) and Linnaeus (1758) included 2 species of free living Protozoa in the 10th edition of his *Systema Nature*, still it is Goldfuss (1817) who coined the term 'Protozoa'

In the classical taxonomic scheme which was developed about the turn of the century, Protozoa was considered as phylum which was divided into 2 subphyla, viz., Plasmodroma and Ciliophora. The subphylum Plasmodroma was further divided into 3 classes - Mastigophora, Sarcodina and Sporozoa. This classificatory scheme was primarily based on locomotary organelles. With the advent of electron microscope and with flow of new data of taxonomic significance the aforesaid classification appeared obsolete. Consequently, a new revised classification was developed in 1980 by the Society of Protozoologists. According to this the Protozoa constitutes a subkingdom of the Kingdom Protista. This subkingdom is divided into 7 phyla, viz., Sarcomsatigophora, Labyrinthomorpha, Apicomplexa, Microspora, Ascetospora, Myxozoa and Ciliophora.

At present there are about 65,000 species of protozoa of which a little over half are fossils and more than 10,000 are parasitic. Sarcomastigophora is the largest phylum followed by Ciliphora and Apicomplexa. Phyla Microspora and Myxozoa comprise about 550 species and 500 species, respectively while both Labyrinthomorpha and Ascetospora are represented by a few species only. Among the living species of Protozoa, Sarcomastigophora account for about 60 percent, Ciliophora 23 percent, Apicomplexa 13.75 per cent, Microspora 1.75 per cent and Myxozoa 1.5 per cent of the total number of species.

An estimate of living protozoan species of the world is presented in Table 1.

TABLE 1

Living Protozoan species of the world

*Phylum**	*Freeliving*	*Parasitic***	Total
Sarcomastigophora	16,400	2,050	18,450
Ciliophora	4,700	2,500	7,200
Apicomplexa		4,550	4,500
Microspora		550	550
Myxozoa		500	500
Total	21,100	10,150	31,250

*Phyla Labryrinthomorpha and Ascetospora are known by few species only.
**Parasitic includes symbiotic and commensal protozoa also.

The protozoa are the most primitive animals according to the classical classification. But they are now treated more primitive than animals (hence, they are placed under kingdom Protista).

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The protozoa are best known as the causative agents of some dreadful diseases of man and his livestock, like malaria, sleeping sickness, dysentery, giardiasis, coccidiosis, etc. But they are also very much beneficial as they form important component of plankton and, their skelton (test, lorica, etc.) form cliffs and even chalk deposits. Many foraminiferans act as indicator for characterisation of natural oil. Some ciliates are considered as indicators of water pollution. Recent works reveal that the gregarines (Apicomplexa), the parasites of invertebrates, may turn out to be valuable in biological control of mosquitoes and other invertebrate vectors.

Historical Resumé

i) Pre-1900

Freeliving Protozoa

The first report of free-living protozoa from India dates back to 1842 when G.W. Grant reported the occurrence of 6 species of freshwater protozoa from Calcutta including 2 species of ciliates viz., *Coleps hirtus* and *Vorticella patellina*. Subsequently, Wallich (1864) recorded 4 species of testacid rhizopods from Gangetic Sundarbans of Lower Bengal. Carter (1864,1865) dealt with salt water rhizopods after obtaining the material from the vicinity of Bombay. Simmons (1889, 1891) reported on the occurrence of 12 genera of free-living ciliates from Calcutta and 1 species of reticulated amoeba, *Biomyxa vagans*. Mitchell (1862) contributed a short note on a ciliate from Bangalore.

The pioneering works on Indian Ocean foraminiferan fauna commenced at the end of the 18th Century when Fichtel and Moll (1878) described some new species from the Arabian sea. The Challenger Expedition (1873-1876) initiated the investigation of the world's oceans and was the first to cruise for the systematic collection of bottom samples. Brady's monograph of the Challenger foraminifera (1884) although not restricted to the Indian ocean alone, is one of the most important taxonomic papers on material from this region. Chapman (1895) also published some papers dealing with the shallow water forminifera from this sub-continent. Besides the oceanographic expeditions undertaken by Investigator, Siboga and John Murray, which passed through Indian seas, enlightened our knowledge on this group.

Parasitic Protozoa

So far as the parasitic protozoa are concerned, Carter (1898), Evans (1888), Hehir (1893), Crombie (1894), Sir Ronald Ross (1895-1899) and Daniells (1899) worked on the malarial parasites from India. It was Ross who, while working a Secunderabad and Calcutta elucidated the complete life cycle of malarial parasites of birds and their transmission by *Culex* mosquitoes. Further, he (1895) was the first to describe a gregarine parasite from a mosquito. Besides these, Anderson (1889) described a commensal ciliate *Anoplophrya aelosomata* from an earthworm.

Symbiotic Protozoa

The only published work on symbiotic protozoa during the Nineteenth Century was by Simons (1890) who gave a brief account of two flagellates from the gut of termites of Calcutta, without mentioning generic and specific names of those flagellates.

ii) 1901-1947

Freeliving Protozoa

As early as 1907 Penard reported 15 species of testacid rhizopods from the Sikkim Himalayas. Annandale (1907) recorded 2 species of ciliates from the freshwater and brackishwater ponds of West Bengal. Ghosh (1918-1929) published a series of papers recording 29 species of free living ciliates and 1 species of testacid rhizopod from pond and sewer water of West Bengal. Bhatia and Mallick (1930) studied some freshwater ciliates of Kashmir. Sandan (1927) and Mohan Rao (1928) reported large number of soil Protozoa from various parts of India.

Bhatia (1936, 1938) made two monumental publications, one on Ciliophora and the other on Sporozoa in the 'Fauna of British India' series. Seshachar and his collaborators (1940-70) contributed much on free living ciliates, while Singh (1941-1975) studied soil rhizopod in great detail.

Parasitic Protozoa

At the beginning of the 20th century, Chattterjee (1919-1935) contributed much on the parasitic flagellates, amoebae, etc. which cause dysentery in man. Mackie (1915), Swaminath (1923) and, Short and Swaminath (1927) reported on *Lankestria* species (Gregarinida) from sandflies in Assam and Bengal. Cornwall (1915) described some gregarinid parasite from silver fish. Bhatia and Setna (1924, 1926), Bhatia and Chatterjee (1925), Setna (1927, 1931), Gates (1926-1933), Ray (1933), Chakravarty (1933-1936) and Setna and Bhatia (1934) worked on gregarinid parasites of India.

During this period several species of coccidian parasites were reported. Ganapati (1941, 1952) reported two species of *Myriospora* from Waltair coast. The adeline coccidia, more precisely, the haemogregarinid parasites from Indian reptiles were investigated by Simond (1901), Laveran and Mesnil (1902), Laveran and Nathan - Larrier (1912), and De Mello and his co-workers (1915-1937). The sarcocystid parasites were studied by Chatterjee (1907) from the heart - muscle of a cow in Calcutta. Vasudevan (1927) reported sarcosporidian infection in man. De Mello (1935-1937) described 2 species of *Toxoplasma* from birds of Goa. The eimerid coccidian parasites from hosts belonging to all classes of vertebrates were reported by a large number of workers from different parts of the country. Cooper and Gulati (1926), Cooper (1926, 1927), Sen (1932) and Ware (1936) recorded cases of bovine coccidiosis from Mukteswar, Uttar Pradesh and Coorg District (South India). Knowles and Dasgupta (1934) recorded coccidial infection in man. Ray and his coworkers (1935-1937) described a number of species of coccidia from some mammals and reptiles from Calcutta, West Bengal. Setna and Bana (1935a,b) described two species of *Eimeria* from a fish and a lizard from Bombay. Halawani (1930 a,b) and Chakravarty and Kar (1944) also described 2 species of *Emeria* from Indian fishes. Ray and Raghvachari (1942), Ray, Raghavachari and Sapre (1942) and Chakravarty and Kar (1943, 1944, 1947) described a few species from Indian reptiles. Avian coccidia were reported by Mitra and Dasgupta (1937), Naik (1937), Chakravarty and Kar (1944), Ray (1945) and Chakravarty and Basu (1947), while Aiyar (1937) reported coccidiosis in the domestic dog and Kar (1943) in domestic goats.

The haemosporidian parasites were studied by a large number of workers during the pre-independence period of twentieth century. Daniells (1900), Cornwall (1901), Stephens and Christophers (1903), Christophers (1904), Donovan (1909), Gragg and Naidu (1918), Knowles and his co-workers (1923, 1931), Clark (1927) and Row (1928, 1930) made important contributions to our knowledge on the morphology of malarial parasites. Sinton (1929) published a complete bibliography of the literature dealing with malaria in India. Transmission and seasonal incidence of malaria in India were reported by Stephens and Christophers (1902), James (1903), Beutley (1911), James and Liston (1912), Adie (1913), Gill (1925), James, Nicol, and Shute (1927), Carter and Jacocks (1929), Carter (1930), Knowles and his associates (1919, 1935), King (1931) and Iyengar (1931-1934).

The malarial parasites of monkeys were studied by Knowles (1919), Donovan (1920), Knowles and Dasgupta (1932, 1934), Sinton and his associates (1937-35). Mackie (1914) described a malarial parasite in a bat and Sheather (1919) in the buffalo. De Mello and his co-workers (1923-1937) described several species of plasmodiid and haemoproteid parasites of Indian birds and mammals. The haemoproteid parasites from Indian birds were also reported by Acton and Knowles (1919), Alcock (1914), Adie (1915), Malkani (1936), and Chakravarty and Kar (1945a,b).

The piroplasmid parasites, *viz.*, *Theileria* and *Babesia* were recorded by Lingard (1903, 1907), Lingard and Jennings (1904), James (1905), Webb (1906), Christophers (1907), Gaiger (1910), Patton (1910), Nuttal (1908), Iyer (1933), Achar and Srikanth (1934), Mangrulkar (1937), Sintón (1921), Rau (1926), Symons (1926), Cooper (1926), Sarwar (1935), Shortt (1936) and Bhatia (1936) from wild and domestic mammals of India. Baldrey (1911) gave a useful summary on piroplasmosis in India.

The microsporan parasites belonging to the genus *Nosema* were reported by korke (1916) in the dog-flea, Adie (1922), Christophers and Short and Swaminath (1922) in *Cimex rotundatus*. Iyenger (1929) and Kudo (1929) studied the microsporidian parasites of anopheline larvae.

The myxozoan parasites of fishes were dealt with by several workers in India. Southwell (1915), Southwell and Prashad (1918) and Ray (1933) mysosporidian parasites from freshwater fishes. Chakravarty (1938, 1939, 1943) studied the myxosporidian parasites from the common food fishes of Bengal, while Setna (1942) and Ganapati (1941) reported on the myxosporidian parasites of marine fishes from Bombay and Madras respectively. Ray (1933) described a new species of Myxozoa, namely, *Zschokella prashadi* from the gall-bladder of two species of Amphibia (*Bufo melanosticus* and *Rana tigrina*) from Calcutta and also from the gall-bladder of a chelonian species, *Lissemys punctata granosa*.

Ghosh (1919-22), Bhatia and Gulati (1922), De Mello and his co-workers (1919-1934), Ray (1932) Niel (1935) studied opalinid and ciliate parasites of earthworms, cockroaches, termites and, toads and frogs from different parts of India. Chatterjee reported balantidial dysentery in man. Knowles and Das Gupta (1934) reported *Balantidium* and *Entamoeba hystolytica* in rhesus monkey in West Bengal.

Symbiotic Protozoa:

During the first half of the twentieth century Imms (1919), Cutler (1919-1921), De Mello and his co-workers (1919-1949) published several papers on termite flagellates reporting 49 species and 4 varieties. Kirby (1932) examined some alcohol preserved termite specimens of *Anacanthotermes macrocephalus* from India and recorded from it *Trichonympha turkestanica*.

Ghosh (1922) was the pioneer worker on rumen ciliates from India who reported 42 species of ciliates from the rumen of cow and goat from the slaughter house of Tangra, Calcutta. Unfortunately, this.work has never been referred by any subsequent workers on the subject in India or outside. Other workers on rumen ciliates from India are Jameson (1925), Kofoid and MacLennan (1930, 1932, 1933), Kofoid and Christensen (1934) and Dasgupta, (1935).

iii) 1948-1990

Freeliving Protozoa

During the post independence period Seshachar and his collaborators (1940-70) and Das, (1953-66) have contributed much on freeliving ciliates, Singh and his co-workers (1952-70) on soil protozoa, Mahadevan and Rao (1954), Ganapati and Satyavathy (1958) and Sethulakshmi and Amma (1958) on littoral formanifera of Indian mainland and islands scattered in Indian seas. Besides, Naidu (1963-66) have worked extensively on freeliving flagellates and rhizopods of South India, Nair and his collaborators (1960-74) and Das (1971 onwards) on freeliving protozoa of West Bengal, Mahajan (1969-1971, 1977) on freeliving protozoa of Rajasthan and, Das and Nair (1987) on freeliving protozoa of Orissa. Recently Choudhury and his co-workers (1987-89) have contributed on soil inhabiting rhizopods of West Bengal.

Maximum work on foraminifera has been done along the east coast of India. These are, by Ghosh, 1966, (one species of Spinosa rotalid from Digha beach), Bhatia and Bhalla, 1959 (14 benthic species from Puri beach), Satyavathy, 1954 (Waltair coast), Sarojini, 1958 (Waltair coast), Ganapati and Satyavathy, 1958 (103 species from continental shelf of Waltair coast), Ganapati and Sarojini, 1959 (distribution pattern of 103 species from the above material of 1958), Subba Rao and Vedantam, 1968 (distribution of 32 species on the continental shelf off Visakhapatanam at depth varying 11-104 fms.). Bhalla, 1968 (reported 16 species from beach sand of Visakhapatanam), Sastri and Pant, 1969 (Operculina rich sand from Madras coast), Bhalla, 1970 (15 species from Madras Marine beach), Ramanathan 1969 & 1970 (seasonal variation in forminiferal abundance in Veller Estuary, Madras), Gnanamuthu, 1943 (47 littoral benthic species from Krusadai Island, Gulf of Mannar), Daniel, 1949 (described some species from krusadai Island and adjacent area), Ameer Hamasa (1971) described four species as new records from the Palk Bay; Baliaeva, 1967 (distribution of the shells of planktonic foraminifera on the floor of the Bay of Bengal).

Comparatively less work has been done on the West Coast of India and Arabian Sea. Mention may be made of the work of Kurian, 1951 (*Operculina granulosa* from coastal waters of Travancore), Antony, 1968 (description and distribution of 164 species of the Kerala coast), Siebold (1971) reported that 12 species of benthic foraminifera were transported into the lagoon of Cochin by tidal currents from shallow open ocean off Cochin Harbour. Chatterjee and Gururaja, 1968 (some species/not identified from 8-10 fathoms depth off Mangalore coast); Chaudhuri & Biswas, 1954 (record of 12 species form Juhu Beach, Bombay); Rao, 1968-71, in series of papers described 84 species from shallow water of Gulf of Cambay while Sastri & Pant, 1969 (*Operculina* rich sand from Maharashtra coast) and Bhatia, 1956 recorded 45 species from Western India. Recently study has been made by Frerichs, 1970 on the distribution and ecology of benthic and planktonic forms in the sediments of the Andaman Sea.

Parasitic Protozoa

During this period a significant contribution on this group has been made by large number of researchers working in the Zoological Survey of India as well as different universities and instiutes of various parts of India.

Flagellate parasites, more particularly Trypanosomes have been studied comparatively in detail. Qadri (1962), Joshi (1973 onwards), Misra *et al.* (1973) and Roychowdhury and Misra (1973), Pandey and Pandey (1974), Mandal (1975), Narasimhamurti and Saratchandra (1980), Gupta and Jairajpuri (1981) and Das *et al.* (1986) dealt with fish trypanosmes. Mandal (1984) published a monograph on this group.

Ray and Choudhury (1983) also published a technical monograph on amphibian trypanosomes. Reptilian trypanosomes were studied by Sinha and Mandal (1976), Sinha (1978) and Ray (1987). Avian trypanosomes have been worked out by Singh and his co-workers (1951-1966), Subramanian and Singh (1962), Chatterjee and Ray (1971), Choudhury and Misra (1976), Nandi, *et al.* (1984) and Mandal (1988). Trypanosomes of mammalian hosts (both wild and captive) have been dealt with by Todd (1963), Mandal and his associates (1976), Das Gupta and his co-workers (1972 onwards), Sen Gupta (1974) and Choudhury and Misra (1973).

Non-trypanosome flagellate parasites (viz. *Retortomonas, Monocercomonas, Chilomastox,* etc.) of vertebrate hosts were studied by Tripathi (1954) Todd (1963), Krishnamurthy (1963, 1967, 1968), Janakidevi (1961, 1962) and Madre (1979) ; Narasimhamurti and Saratchandra (1979-82), Saratchandra (1981) those of invertebrate hosts (insects) by Sultana (1976) and Krishnamurthy and Sultana (1976).

Uttangi (1948, 1951, 1958, 1961) Tripathi (1954), Das and Mukherjee (1974), Mandal and Nair (1975), Shete (1982, 1984) and, Shete and Krishnamurthy (1984) contributed to our knowledge on opalinids and parasitic ciliates of vertebrate hosts, while Chakravarty and Chatterjee (1957), Karandikar and Rodji (1958), Bhaskar Rao (1969), Uttangi and Desai (1963), Mandal and Nair (1974), Biswas and Mukherjee (1974) and Mukherjee and Chakraborty (1975) reported different ciliate parasites from invertebrate hosts (earthworms, insects and millipedes).

Extensive researches on septate gregarines were made by Halder and his associates (1974 onwards). Uttangi and Desai (1961, 1962), Desai and Uttangi (1962), Rao (1962), Narasimhamurthy and Kalavati (1968 onwards), Devhar and Despande, (1971, 1977), Amoji and his associates (1973-1985), and Ramachandra (1974) have also done considerable work on the group. Mention is to be made here that Chakravarty (1959) proposed a new classification of the septate gregarines which has been internationally accepted.

Aseptate gregarines in India were studied by Misra and Roy Choudhury (1973), Pradhan and Das Gupta (1980, 1982), Sarkar (1983) and Roy Choudhury and Halder (1984).

Narasimhamurti and Kalavati (1960-1977) contributed much on a deline Coccidia from termites and centipedes. So far as haemogregarines are concerned Mandal *et al.* (1983) reported this group from fish hosts. Ray and Choudhury (1984) published a monograph on this group from amphibian hosts; Misra *et al* (1974), Misra (1976), Sinha (1978), Saratchandra (1981) and Ray and Bhattacharjee (1984) from reptilian hosts.

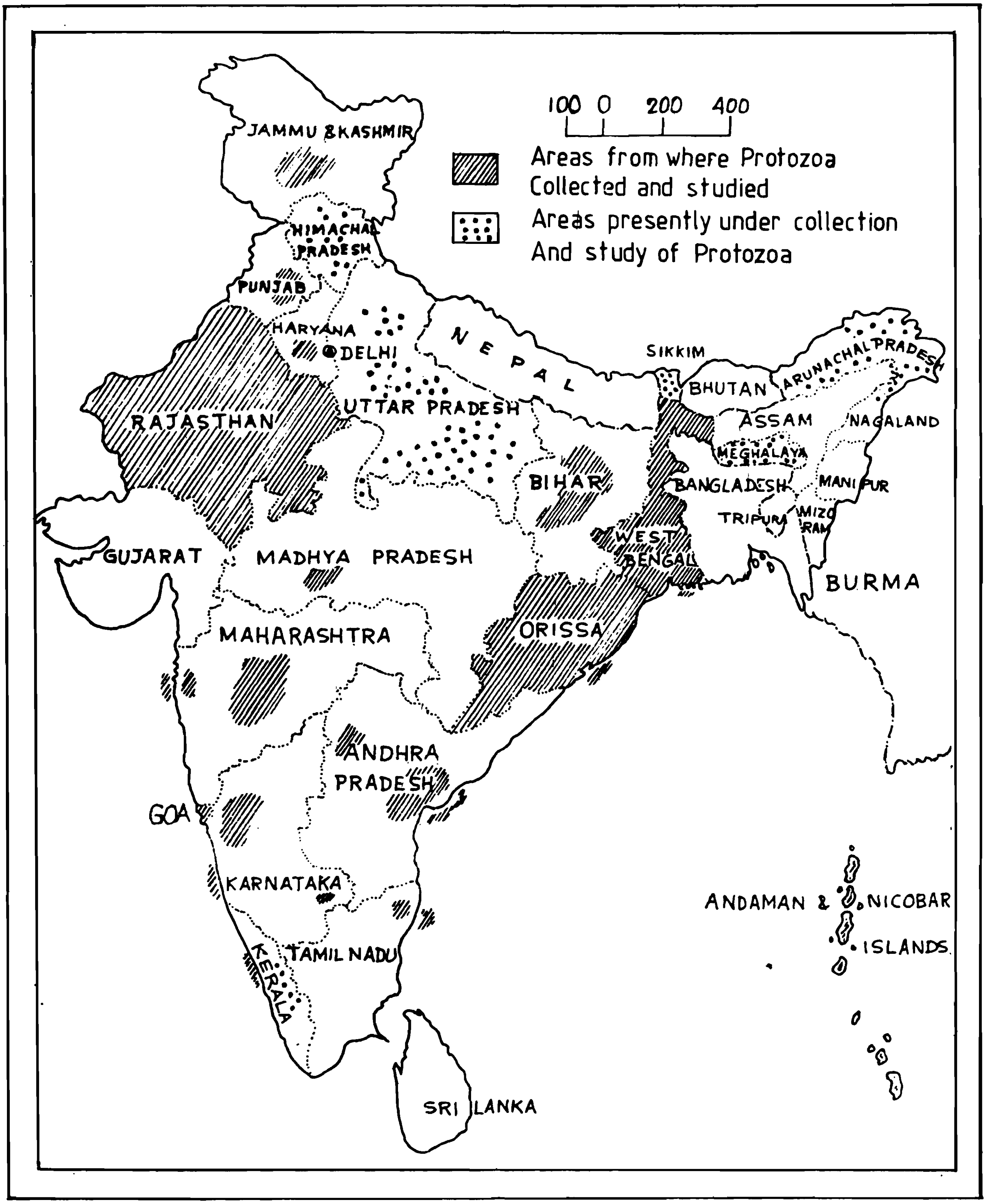
Only one species of aggregatine coccidia, *viz., Aggregata kudoi* has been reported so far from India by Narasimhamurthi (1979) from a molluscan host, *Sepia elliptica*. Many workers, however, contributed to the knowledge of Indian coccidia of the family Eimeriidae. Among them Chakravorty and Kar (1952), Gill (1955), Gill and Ray (1957), Ray and his associates (1952-1973), Bhatia and his co-workers (1963-71), Mandal and Chakravarty (1963-1965), Patnaik *et al.* (1963-66), Mandal and Nair (1973, 1974) Mandal (1976 onwards) and Bandyopadhayaya (1982-87) deserve mention. Recently Mandal (1987) made a significant contribution on Eimeriidae in the 'Fauna of India' series. In addition, Ray (1980) described *Lankesterella* from frogs, Sarkar and Haldar (1979) and Kundu and Halder (1984) reported *Dactylosama* from fishes and Ray and Sarkar (1969) recorded one species of *Gordonella* (which is now synonymised with *Schellackia*) from a lizard host, *Calotes versicolor*.

Haemosporidian parasites which include malaria and related parasites are dealt with by several workers from different vertebrate hosts. Misra, Halder and Chakravarty (1972) and Mandal *et al.* (1985) reported the occurrence of this group from Indian fishes and Ray and Choudhury (1981) from a frog, *Rana limnocharis*. Singh and his associates (1951-56), Ray and Bhatnagar (1953), Subramanian and Singh (1962), Grewal (1962-1964), Sarkar and Ray (1972), Nandi and Mandal (1977 onwards) and Pal and Das Gupta (1980) dealt with avian haemosporidia from different parts of India. Nandi and Mandal (1976) reported malarial parasites from bat and Sinha and Das Gupta (1989) from crab-eating monkey of Great Nicobar Island. Das Gupta and his co-workers (1965 onwards) have been mainly engaged in taxonomic study of malarial parasites of mammals.

Piroplasmid parasites of cattles and horse have been studied by Goutam and Banerjee (1977 onwards), Srivastava and co-workers (1977 onwards). Myxozoan parasites of freshwater fishes were reported by Chakravarty and his co-workers (1937-48), Tripathis (1952), Qadri 91962-70), Lalithakumari (1965-69), Bhatt and Siddiqui, (1964), Roy Choudhury and Chakravarty (1970), Karamchandani (1970), Mandal and Nair (1975), Halder and his co-workers (1978 onwards), Seenappa and Monohar (1980), Hagargi and Amoji (1981), Jayasri, (1982), Kundu (1985), Yatindra and Mathur (1988) and, Gupta and Khera (1987 onwards). Myxozoan parasites of estuarine and marine teleost fishes have been reported by Tripathi (1952), Narasimhamurthy, Kalavati and their co-workers, (1970 onwards), Choudhury and Nandi (1973), and Sarkar and his co-workers (1982-1989). In India a single species of myxozoan parasite *viz., Myxidium halddari* has been reported so far from the amphibian host, *Hyla arborea* by Sarkar (1982). Microsporan parasites were studied by Narasimhamurti and Kalavati (1972, 1979, 1985) and Ghosh (1989) and haplosporan parasites by Ganapati *et al.* (1964) and, Narasimhamurthi and Kalavati (1975).

Symbiotic Protozoa

During this period Karandikar and Vittal (1954), Banerjee (1956), Uttangi (1959, 1962) and Mukherjee and Maiti (1989, 1990) dealt with termite flagellates from Maharashtra, West Bengal, Karanataka and Arunachal Pradesh respectively, Das (1972 onwards) and Tiwari (1977 onwards) are engaged in studying taxonomy of the aforesaid group from West Bengal, Bihar and Uttar Pradesh.



Areas so far surveyed

On the other hand Banerjee (1955), Choudhury and Chatterjee (1962) and Mandal, Ray and Nair (1984) have worked on rumen ciliates.

Studies from Different Environs

Protozoa live under almost all natural conditions where moisture is found. They have been reported from freshwater, brackish water, marine water and even brine pools, from hot springs, snow drifts, mud, soil, leaf litter, moss and latex of various plants, (e.g., figs and allied forms, lettuce and Euphorbia plants). They are known to parasitise other unicellular organisms, even protozoa as well as almost all organs of multicellular animals. They are also found as parasites of several genera of aquatic plants. However, from India freeliving protozoa have so far been collected from freshwater, brackish and marine water, soil and moss. On the other hand, parasitic protozoa (which include symbiotes and commensals) occupy diversified host environs. These environs may, however, be broadly demarcated under 5 categories, *viz.*, epizoic, luminicolous, coelozoic, histozoic and coprozoic.

Freeliving Protozoa

i) *Freshwater environs*

From the perusal of literature it appears that first report of protozoa from India is made from freshwater environs by Grant (1842). Since then, considerable work on protozoa from this environs has been done by Ghosh (1818-1929), Nair and his co-workers (1960-1974) and Das (1971 onwards) from West Bengal, Bhatia and Mallick (1930) from Kashmir and Mahajan (1969, 1971, 1977) from Rajasthan. Earlier works on freshwater inhabiting ciliates are available in the Ciliophora volume in the Fauna of British India series, written by Bhatia (1936). A monographic account of freshwater protozoa of West Bengal is given by Das *et al.* (in press). In addition, Gopalkrishanan (1971) reported the occurrence of several genera of protozoa from the freshwater zone of Hugli Rupnarayan estuary in West Bengal.

ii) *Brackish water and marine environs* :

Majority of the marine protozoa reported from India belong to the order Foraminiferida. Maximum work on this group has been done along the east coast of India. Mention may be made here that Ghosh (1966) reported foraminifera from Digha coast, Bhatia and Bhalla (1959) from Puri coast, Ganapati and his co-workers (1958-59), Bhalla (1968) and Bhatt (1969) from Waltair coast, and, Sastri and Pant (1969) and Bhalla (1970) from Madras coast. Several investigators also studied this group along the West coast of India. Among them Antony (1968), Chatterjee and Gururaja (1968), Rao (1968-71), Freichs (1970) and Siebold (1981) deserve mention. Further Chapman (1985) reported 277 species of foraminifera from bottom samples near Laccadive islands.

Marine and brackishwater protozoa other than foraminifera are least studied. Carter (1864, 1865) reported salt water rhizopods from the vicinity of Bombay and Annandale (1907) recorded ciliates from some brackish water ponds of West Bengal. Shetty, Saha and Ghosh (1961) and Saha, Ghosh and Gopalkrishnan (1975) reported several genera and species of flagellates, rhizopods and ciliates from brackish water zones (Zones III and V) of the Hugli-Matla estuary. Among these, dinoflagellates belonging to the genera *Ceratium, Peridinium* and *Noctiluca* were found to be common throughout the year and the tintinnids (ciliates) were observed from June to November. Recently Das and Nair (1989) reported 41 species of freeliving ciliates from the Chilka lagoon, Orissa, based on their collections made during 1969-71.

iii) *Soil inhabiting protozoa*

Sandon (1927), Mohan Rao (1928) and Choudhury (1929) reported several species of soil protozoa from various part of India, Singh and his co-workers (1952-1981) did extensive work on soil inhabiting amoeba from Uttar Pradesh and Gujarat, and Choudhury and his associates

(1987-89) contributed much on the same group from West Bengal. All the soil protozoa reported so far from West Bengal are covered in the publication of Das *et al.* (in press).

iv) *Moss inhabiting protozoa*

This environ is least studied for protozoans. Penard (1907) initiated this work in Sikkim Himalayas and reported 15 species of rhizopods. After a long gap, Nair and Mukherjee (1968) recorded 12 species of testacid rhizopods from ground and tree mosses of West Bengal. Recently Das *et al.* (*in press*) have dealt with 13 species of rhizopods and 4 species of ciliates from West Bengal.

Parasitic Protozoa

i) *From Epizoic environs*

The epizoic or surface dwelling protozoans primarily belong to the phylum Ciliophora., They are usually sedentaric ectocommensals and are found on the body surface of the aquatic animals. Practically no work has been done on this group barring a single exception by Khajuria and Pillai (1951) who described one species, *viz.*, *Zoothamnium horai* from a grey mullet from West Bengal.

ii) *From Luminicolous environs*

The protozoa which inhabit the lumen of the gut of both invertebrate and vertebrate hosts embrace endocommensals, symbiotes and parasites. They are so termed based on their relationships with the hosts.

The first report of luminicolous protozoa from India was made by Anderson (1889) when he described a astemate ciliate, *Anoplophrya aelostomata* from earthworms. Subsequently, several workers made extensive studied on endocommensal ciliates (*viz.*, *Nyctotherus*, *Balantidium*, etc.,) and intestinal flagellates from the gut of both invertebrates and vertebrates. Among invertebrate hosts, termites, roaches and earthworms are paid maximum attention as has already been dealt with earlier. For details of works on termite flagellates Das (1983), for these of roaches Bhatia (1936) and, Mandal and Nair (1974) and those of earthworms Bhatia (1936), Biswas and Mukherjee (1974) and, Mukherjee and Chakraborty (1975) may be referred to. In addition, Karandikar and Rodgi (1958) reported the occurrence of some ciliate endocommensals (*viz.*, *Nyctotherus*) from millipede hosts, Chakraborty and Chatterjee (1957) from mole cricket and Uttangi and Desai (1963) from termites. Further Sultana and her coworker (1976) reported luminicolous flagallates of the genera *Retortamonas* and *Monocercomonas* from the lumen of insects.

Mention may be made here that Jamadar and Choudhury (1988) have recently dealt with 14 species of ciliates from the gills, labial palp, mantle cavity, buccal mass and buccal cavity of some estuarine and marine molluscs of India.

Extensive work on rumen ciliates has also been carried out from India, the taxonomic details of which are available in Ghosh (1922), Bhatia (1936), Banerjee (1955), Choudhury and Chatterjee (1962) and Mandal *et al.* (1984).

Endocommensals including opalinates and ciliates from vertebrate hosts, more specifically toads and frogs have been studied by several workers in India, for taxonomic details of which Bhatia (1938), Uttangi and his coworkers (1948-61), Tripathi (1954), Das and Mukherjee (1974), Mandal and Nair (1975), Shete and his associates (1982-1984) may be consulted.

Luminicolous flagellates of vertebrate hosts have been studied by Todd (1963), Krishnamurthy (1963-1968), Janakidevi (1961, 1962), Madre (1969) and Sarat Chandra and his coworkers (1979-82).

iii) *From Coelozoic environs*

The coelozoic forms are parasitic in their habit. The gregarines are chiefly coelozoic parasites in invertebrates, especially annelids. Ghosh (1923), Short and Swaminath (1927), Bhatia and his coworkers (1924-34), Chakravarty (1933-59), Kar (1948) Uttangi and his coworkers (1961-62), Amoji and his associates (1973-85), Haldar and his co-workers (1974 onwards), Narasimhamurti and Kalavati (1968 onwards) and Pradhan and Dasgupta (1980-82) made valuable contribution on gregarines of annelids and arthropods. The other important groups occurring in organs like gall bladder, urinary bladders, etc., of mainly lower vertebrates come under the group Myxozoa and Ascetospora. The works of Chakravarty (1939-48), Haldar and his associates (1974 onwards), Narasimhamurti and his associates (1979 onwards) and recently by Gupta and Khera (1988 onwards) on Myxosporida are worth-mentioning. Ganapati *et al.* (1964) reported a ascetosporan parasite from the body cavity of a copepod.

iv) *From Histozoic environs*

Maximum work has been done in India on histozoic forms mainly dealing with coccidian, haemosporidian and myxozoan parasites. Extensive work has also been carried out on haemoflagellates occurring in all the groups of vertebrates. Microsporidan and hoplosporidan parasites are relatively little studied in India.

Coccidian parasites have been studied by large number of workers indifferent parts of India as discussed earlier. For consolidated taxonomic account on Eimeriidae Mandal (1987), for those of harmosporidan parasites Bhatia (1938), Chakraborty and Kar (1945), Ray and his associates (1932-1961), Das Gupta and his co-workers (1961 onwards) and, Nandi and Mandal (1976 onwards) may be consulted. The important works on haemoflagellates are those of Joshi (1973 onwards), Roychoudhury and Misra (1973), Mandal (1975 onwards), Narasimhamurti and Saratchandra (1980) and, Ray and Choudhury (1983).

Myxozoan parasites are comparatively well studied. In this connection Chakraborty and his co-workers (1937-48), Qadri (1962-70), Haldar and his co-workers (1978 onwards), Narashimamurti, Kalavati and their associates (1970 onwards) and, Gupta and Khera (1987 onwards) deserve mention.

Microsporidan parasites have been reported from adipose tissues of insects by Narasimhamurti and Kalavati (1972-85) and Ghosh (1989).

v) *From Coprozoic environs*

Certain freeliving protozoa which are frequently found in the faecal matter of various animals are found to inhabit waters rich in decomposing organic matter. The cysts of those protozoa pass through the alimentary canal of the animal unharmed, and undergo development and multiplication in the faecal infusion. These are termed coprozoic protozoa which show a striking adaptability to survive in conditions quite different from those of the water in which they normally live. In India coprozoic protozoa are least studied. Das Gupta (1935) reported one such protozoa (flagellates), *viz. Oikomonas communis* from the rumen of the Indian goat, *Capra hircus.*

Estimation of Taxa

Total number of families, genera and species of protozoa reported so far from India is presented in the following table (Table-2) and compared with those known from the world.

From the table it is quite evident that barring one phylum Labyrinthomorpha altogether 6 phyla of Protozoa are represented from India. This is also to mention here that more than half of the Indian protozoan species are parasites (including symbiotes and commensals) as will be evident from the following table (Table 3).

TABLE 2

Group	Approximate number of:					
	Family		Genera		Species	
	W	I	W	I	W	I
Phylum Sarcomastigophora						
Subphylum Mastigophora	90	28	800	60	6,900	400
Subphylum Sarcodina	100	35	950	85	11,300	650
Subphylum Opalinata	1	1	5	4	250	30
Phylum Ciliophora	197	70	1135	150	7,200	600
Phylum Apicomplexa	71	20	330	42	4,550	750
Phylum Microspora	5	2	18	4	550	20
Phylum Myxozoa	15	4	40	12	500	125
Phylum Labyrinthomorpha	1		2		*	
Phylum Ascetospora	3	1	5	1	*	2
	383	161	3285	358	31,250	2577

W=World; I=India
* Few species

TABLE 3

Phylum	Approx. number of protozoan species from India. Parasitic	Freeliving	Total
Sarcomastigophora			
Mastigophora	198	202	400
Sarcodina	5	645	650
Opalinata	30	—	30
Ciliophora	200	400	600
Apicomplexa	750	—	750
Microspora	20	—	20
Myxozoa	125	—	125
Ascetospora	2	—	2
	1330	1247	2577

The aforesaid 1330 species of parasitic protozoa have been recovered from 585 host species as tabulated below (Table 4).

TABLE 4

Host group	Number of host species from which parasites reported	Number of parasite species
Mammals	70	150
Birds	120	260
Reptiles	25	110
Amphibians	25	110
Fishes	125	350
Invertebrates	220	350
	585	1330

Considering the fact that there are about 385 species of mammals, 1200 species of birds, 420 species of reptiles, 210 species of amphibians, 1700 species of fishes and 77,500 species of invertebrates (excluding protozoa) and assuming that there is only one species of parasitic protozoa for every host species (although Table-4 shows more than 2 protozoan parasites per host species) we can safely estimate the number of parasitic species from India. So far as freeliving protozoa are concerned varied habitats of many States of India are not thoroughly searched for. Moreover, many expected protozoan - rich habitats (like moss, lichen, etc.) are also not properly explored. When that is done we can expect to record the occurrence of 3 to 4 times the number of species of freeliving protozoa from India, of what has been known so far.

Classified Treatment

Phylum Sarcomastigophora

Subphylum Mastigophora

This subphylum whose representatives are popularly termed as flagellates comprises two classes, *Viz.*, Phytomastigophora and Zoomastigophorea. The former includes 10 orders out of which 5 orders, *viz.*, Cryptomonadida, Dinoflagellida, Euglenida, Chrysomonadida and Volvocida are reported from Indian waters. Taxonomy of Phytomastigophoran flagellates is least studied. Whatever published information is available on this group is intermingled with the algal or planktonic study. However, Naidu (1962) reported 8 species of the order Euglenida (belonging to 4 genera under 3 families) from the freshwater of ponds, tanks and wells of South India. Recently Das *et al.* (*in press*) have dealt with 24 species (belonging to 12 genera under 7 families and 4 orders) from West Bengal.

Zoomastigophorea comprise 8 orders out of which 7 orders, *viz.*, Kinetoplastida, Proteromonodida, Retortomonadida, Diplomonadida, Oxymonadida, Trichomonadida and Hypermastigida are known from India. Only parasitic or symbiotic zoomastigophoran flagellates have been studied in India while freeliving or coprozoic ones are almost completely neglected.

In India, flagellates belonging to the order Kinetoplastida are represented by the member of the genera *Trypanosoma*, *Trypanoplasma* and *Leishmania*. Among them *Trypanosoma* are comparatively well studied. Several species of trypanosomes were studied from all groups of vertebrate hosts as discussed earlier. The genus *Trypanoplasma* which is represented by a few species in India is worked out by Mandal (1984) and Wahul (1985). The genus *Leishmania* is the causative agent for visceral and dermal leishmaniasis and represented by two species, *L. donovani* and *L. tropica*. Many workers of different institutes have considerably contributed to our knowledge of leishmaniasis in India. Among them, K.K. Mallick and his coworkers in School of Tropical medicine, Calcutta, A.C. Ghosh in Cholera Research Institute, Calcutta, D.K. Ghosh in Indian Institute of Chemical Biology, Calcutta, Sen and his associates previously in CDRI, Lucknow and presently at PMRI, Patna, and A. Bhattacharya and his co-workers in the Calcutta University deserve mention.

Taxonomic studies of flagellates of the order Proteromonadida were undertaken by Das Gupta (1935), Todd (1963) and Krishnamurthy and his associates (1967 onwards) while those of the order Retortomonadida were made by Das Gupta (1935) and Krishnamurty and his co-workers (1967 onwards) from the rumen of Indian goat in West Bengal and from the gut of insects of Maharashtra respectively. Mention may be made here that two retortamondad species, *viz.*, *Retortamonas intestinalis* and *Chilomastix mesnili* are found in human intestine and reported by several medical institutes of India.

Giardia intestinalis is the only representative of the order Ciplomonadida. This flagellate is clinically important as it causes giardiasis in man.

Several genera of the oxymonadid flagellates *viz.*, *Oxymonas*, *Dinenympha*, *Pyrsonympha* and *Microrhopalodina* are reported from the gut of termites (Das, 1983 and Mukherjee and Maiti, 1989, 1990). Further, the genus *Monocercomonoides* is well represented in India and reported from the gut of inscets, amphibia, reptiles and mammals (Krishnamurthy and his coworkers, 1967 onwards).

Trichomonadid flagellates are comparatively well studied in India. Flagellates belonging to the families Descovinidae and Calonymphidae have been reported from termite guts (*see* Das, 1983). Representatives of the families Monocercomonadidae and Trichomonadidae have been found from both invertebrate and vertebrate hosts. Mention is to be made here that *Trichomonas vaginilis* causes vaginities in women and *T gallinae* causes *trichomonosis* in several avian host species. Both these parasites have been reported from India.

Except the genus *Lophomonas*, which occurs in the gut of cockroach, all other representatives of the order Hypermastigida inhabit termite gut. So far 52 species of hypermastigid flagellates have been reported from India (*see* Das, 1983) and one species *viz.*, *Lophomonas striata* is found to occur in the gut of Indian cockroach.

Subphylum Opalinata

As mentioned earlier, only 30 species belonging to 4 genera under 1 family have been reported so far from India.

Subphylum Sarcodina

This subphylum comprises 2 superclasses, *viz.*, Rhizopoda and Actinopoda with 8 and 4 classes respectively. Out of these, representatives of only 3 classes, Lobosea, Filosea and Granuloreticulosea of the Superclass Rhizopoda and all the 4 classes of the other superclass are reported so far from India.

In the class Lobosea gymnamoeba and testacid rhizopods are comparatively well studied. On the other hand, in the class Filosea a single family Eughyphidae with 5 genera and several species are reported from India. Both Lobosea and Filosea have been collected from soil (Singh and his coworkers, 1952-81), freshwater (Nair *et al.* 1971, Mahajan 1969, 1971), estuarine and marine waters (Gopalkrishnan, 1971 and Ghosh and his coworkers, 1986-1987) and moss (Nair 1968 and Das *et al.* in press) as freeliving. Some of these rhizopods are also parasites, of which few are the causative agents of human diseases. For example, *Entamoeba histolytica* is well known for causing human dysentery. *Naegleria fowleri*, *Acanthamoeba astronyxis* and *A. castellanii* which are primarily soil inhabiting forms can cause primary amoebic meningocephalitis and chronic granulomatus amoebic encephali in human being when they get chance to enter though the nasal cavity. Besides, some species of *Endamoeba* also parasitise man and his livestocks. So far as the class Granuloreticulosea is concerned foraminiferans, both living and fossil, are worked out in some detail as discussed earlier. Among other representatives of this class only two genera, *viz.*, *Biomyxa* and *Lieberkuhnia* with single species of each are known so far from India.

Among the 4 classes of the superclass Actinopoda representatives of the 3 classes, *viz.*, Acantharea, Polycystina and Phaeodarea are marine and included under the order Radiolarida according to the earlier classification. A vast area of the ocean floor is known to be covered with the ooze made up chiefly of radiolaridan skeleton. The other class Heliozoea include mostly freshwater species and few marine. From India few genera, e.g., *Clathrulina*, *Actinophrys*, *Actinosphaerium* and *Acanthocystis* with several species are reported.

Phylum Labyrinthulesa

It includes a single class Labyrinthulea and a single order Labyrinthulida with two genera, *viz.*, *Abyrenthula* and *Thraustochytrium*. This phylum is not yet represented from India.

Phylum Apicomplexa

It has only 2 classes, Perkinesea and Sporozoea of which the former is not yet reported from India. The class Sporozoea are well studied in India. It comprises subclasses, Gregarinia, Coccidie and Piroplasmia. The subclass Gregarinia has 3 orders, *viz.*, Archigregarinida, Eugregarinida and Neogregarinida. The former is not represented in India while eugregarines are well studied and well represented with nearly 250 species. For taxonomy of this group workers like Bhatia and Setna (1924-34), Chakraborty (1933-59), Uttangi and Desai (1960), Amoji and Rodgi (1970s), Narasihmamurti and Kalavati (1968 onwards), Haldar and his coworkers (1974 onwards) and Pradhan and Das Gupta (1980s) deserve mention. So far as neogregarines are concerned only one species belonging to the genus *Mattesia*, infecting the fat body and malpighian tubeles of squirrel flea (Siphonaptera) is known so far from India (Dasgupta, 1958).

The subclass Coccidia also includes three orders, *viz.*, Agamococcidiida, Protococcidiida and Eucoccidiida. The former is not yet reported from India while the second one is represented by 2 species belonging to the genus *Myriospora*, both from Indian polychaetes (Ganapati, 1941, 1952). Extensive researches on Eucoccidia have been made from India. Eucoccidia has 3 suborders Adeleina, Eimeriina and Haemosporina. About 20 species of adeline coccidia belonging to 6 genera under 2 family have been described so far from India (*see* Narasimhamurti 1960 onwards, Kalavati 1977 onwards, Mandal *et al.*, 1983 and, Ray and Choudhury, 1984).

The suborder Eimeriina is represented by about 250 species belonging to 14 genera under 6 families in India. For details of taxonomy of the family Eimeriidae Mandal (1987) and that of other families levine (1988) may be consulted. The suborder Haemosporiina includes malarial parasites of man and other vertebrates. About 125 species of haemosporids are reported from India. Both taxonomic and epizootiological studies have been made by several investigators in India. Major contributors to this field are Das Gupta (1967), Das Gupta *et al.* (1971), Greiner, Mandal and Nandi (1977), Misra and Choudhury (1977), Mahajan (1978), Dutta (1978), Choudhury *et al.* (1978), Ghosh *et al.* (1978) and Bennett and Nandi (1981).

The subclass Piroplasmia includes single order Piroplasmida. Six species of this group have been reported from wild and domestic animals of India (*see* Bhatia, 1938). The representatives of the genera *Babesia* and *Theileria* cause babesiosis and theileriosis in Cattles and other artiodactyles. Ray and Sarkar (1969), Haldar, Misra and Chakravarty (1971) and Sarkar and Haldar (1979) have contributed to the taxonomic studies of these genera. Gautam and Banerjee (1977) studied equine babesiosis, Subramanian and Berma (1977) and Gill (1978) worked on bovine theileriosis in India.

Phylum Microspora

This phylum includes 2 classes, *viz.*, Rudimicrosporea and Microsporea with 1 and 2 orders respectively. Out of these only one order Microsporida belonging to the latter class with about 20 species (*see* Bhatia, 1938, Narasimhamurti and his co-workers, 1965 onwards and Ghosh, 1989). Mention may be made here that *Nosema bombycis* causing Pebrine disease in silk moth was reported on several occasions in India.

Phylum Ascetospora

This phylum also comprises 2 classes, Stellatosporea and Paramyxea with 1 order each. Narashimhamurti and Kalavati (1975) and Ganapati *et al* (1975) reported 2 species of *Haplosporidium* from copepods. These protozoa belong to the order Balanospoirida of the class Stellatosporea.

Phylum Myxozoa

This Phylum includes 2 classes, Myxosporea and Actinosporea out of which the second one is not yet reported from India. On the other hand the class Myxosporea which includes coelozoic and histozoic parasitites of fishes, amphibians and chelonians are well studied in India. This class consist of 2 orders, Bivalvulida and Mullivalvulida both of which with about 125 species have been reported from India as mentioned earlier in details.

Phylum Ciliophora

This Phylum comprises 3 classes, 7 subclasses and 18 orders, out of which all classes and subclasses with 16 orders are represented in India. As mentioned earlier about 600 species of ciliates including 200 parasitic species belonging to 150 genera under 70 families have been reported so far from India.

Taxonomic account of Indian ciliates, both freeliving and parasitic, reported before 1935 are available in Bhatia's fauna on Ciliophora (1936). For subsequent works on freeliving ciliates Seshachar and his collaborators (1940-1970), Das, (1953-1966), Nair (1960 onwards), Mahajan (1969-1971, 1977) and Das (1971 onwards) may be referred.

All the ciliate endocommensals have been reported from the stomach, more particularly rumen of the cattle, sheep, goats and deer (*see* Ghosh, 1922, Bhatia, 1936, Banerjee, 1955, Choudhury and Chatterjee, 1962, Mandal, Ray and Nair, 1984). These endocommensals belong to the family Ophryoscalecidae under the order Entodiniomorphida and class Kinetofragminophorea., Mention may be made here that two non commensal species of the family Polydiniellidae under the aforesaid order, *Viz., Elephantophilus zeta* and *Polydinium* (now known as *Polydiniella*) *mysoreum* have been reported from the caecum and colon of Indian elephant from Nilgiri Mountains (Kofoid, 1935).

Parasitic ciliates on the vertebrate hosts mainly belong to the orders Triehostomatida and Heterotrichida under the classes Kinetofragminophorea and Polyhymenophorea respectively. There are, however, few species (e.g. *Trichodina* spp.) which come under the order Peritrichidaof the class Oligohymenophorea (Bhatia, 1936, Tripathi, 1952, Das and Mukherjee, 1974 and Shete and his collaborators, 1984). Parasitic ciliates of the invertebrate hosts embrace mainly the orders Scuticociliatida and Astomatida of the classes Oligohymenophorea and Kinetofragminophorea respectively. There are, of course, several species of parasitic ciliates of invertebrates belonging to the orders Heterotrichida and Peritrichida (Bhatia, 1936, Chakraborty and Chatterjee, 1957, Karandikar and Rodgi, 1958 and, Jamadar and Choudhury 1988).

Current Studies

In the Zoological Survey of India taxonomic studies of freeliving, parasitic and symbiotic protozoa of West Bengal and freeliving ciliates of the Chilka lagoon have been completed recently and those of Meghalaya, Arunachal Pradesh and Uttar Pradesh are currently under study.

Outside ZSI, different universities and institutes are also engaged in studying different aspects of Protozoological research. The works on immunology of Kala-azar parasites are being carried out in Calcutta University. In Kalyani University the taxonomical research particularly on Gregarines and Myxosporida is being continued. In Andhra University the works on both Taxonomy and Biology have been taken up on Microspora and Myxosporida. The study on coccidian parasites and parasitic flagellates are carried out in the Marathwada University. The life cycle and taxonomy of gregarines are being dealt with in the Karnataka University. Haemosporidan parasites are given special attention in the North Bengal University. Haryana Agricultural University (Dept. of Parasitology) is dealing with piroplasmid parasites along with their serroimmunology. Experimental works on malaria, *Leishmania* and amoeba are being carried out in the Central Drug Research Institute (CDRI); Lucknow. Several organisations like Indian Institute of Chemical Biology (IICB) Jadavpur, Calcutta, Cholera Research Centre (CRC), Calcutta and School of Tropical Medicine (STM), Calcutta are also dealing with experimental/immunological works on *Leishmania*. The Indian Veterinary Research Institute (IVRI), Izatnagar is carrying research on theileriosis in cattle. Malaria Research Centre (MRC), New Delhi is dealing with the malarial parasites of man in multi-dimensional way. The College of Veterinary and Animal Sciences, Parbhani, Maharashtra and Veterinary College, University of Agricultural Sciences, Bangalore are dealing with the problems of coccidia and coccidiosis of cattle. Osmania University, Hyderabad is engaged in studying the freeliving ciliates particularly on their taxonomy.

Expertise

INDIA

In ZSI

A.K. Mandal, [Coccidia, Kinetoplastida, parasitic ciliates and Myxosporida]. A.K. Das, [Symbiotic flagellates; freeliving Rhizopoda (amoebida and Testacida and freeliving ciliphora (freshwater and estuarine)]. N.C. Nandi, [Haemosporinaand Myxosporida]. D.N. Tiwari, [Symbiotic flagellates.] all of ZSI, New Alipore, M Block, Calcutta.

Elsewhere

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ABROAD

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J.O. Corliss, University of Maryland, U.S.A. [Freeliving Ciliates].

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MARINE PORIFERA*

Introduction

The period between 1765 and 1892 marked what could be termed the glorious era in the history of spongology and this was largely due to the pioneering work of scientists like Carl Linnaeus, George Cuvier, Jean Lamarch, J.E. Gray, R.E. Grant, G.D. Nardo, J.S. Bowerbank, H.J. Carter, N. Lieberkuhn, F.E. Schulze, E.O. Schmidt, G.C.J. Vosmaer, E.H.P.A. Haeckel, A. Hyatt, C. Keller, W. J. Sollas, S.O. Ridley, R. von Lendenfeld, N. Polejaeff, A. Dendy and E. Topsent in systematising the various groups of sponges, after studies on their physiology and the phylogeny. The sponges were till then considered to be plants and it was Ellis (1765) who first demonstrated the animal nature of sponges by observing the water currents produced by the oscula and the movements of the general body surface. As a result, scientists like Linnaeus, Lamarck and Cuvier grouped them together with the coelenterates, until Blainville (1816) placed them in a special group, Spongiaria. Grant (1836), who studied the morphology and physiology of this group, established the name Porifera. Later workers like Huxley (1875) and Sollas (1884) argued for the separation of the sponges from other multicellular forms (metazoa). According to modern zoologists, this group constitutes an isolated branch of metazoa called Parazoa, after Sollas.

Four different periods can be broadly demarcated in the history of spongology. A general interest which found expression in an overall study of the local fauna forms the central theme of the first period. This got amplified in the second on account of the facilities provided by many countries venturing for extensive voyages and expeditions. The material thus collected from far off places resulted in the monographic treatment of the families and the genera. The impact of the theory of evolution reached its zenith during this period. From the study of the major taxa and their evolution the attention then got diverted to the study of intraspecific variations, and this marks the third period. The fourth period, which includes the more recent work on sponges, belongs to the present century which has come to be characterised by a 'continuous refinement of the methods and concepts developed in the 19th century' (Mayr *et al.* 1953). The work of Levi (1956) and of Tuzet (1948) on the embryology and systematics, of Bergmann (1949) on sterols, of Hartman (1958) on systematics, ecology and life history of Porifera are examples, to cite a few.

Historical Resume

Spongology of the Indian Seas up to 1970

The history of the spongology of the Indian Ocean is rather a short one. The area which received some attention in the 19th century was Sri Lanka, and among the earlier major studies dealing with the Sri Lankan species were those of Esper (1798-1806). Ehlers (1870), Haeckel (1872), Bowerbank (1873), Carter (1880, 1881), Ridley (1884), Dendy (1887, 1889), Sollas (1888) and Lendenfeld (1889). Of the above, the work of Ridley (1884), Sollas (1888) and Lendenfeld (1889) make only occasional references to the fauna of Sri Lanka.

Towards the beginning of the present century there was an extensive survey of the pearl banks of Sri Lanka by the Fisheries Department of Sri Lanka. The large collections made by Prof. Herdman in 1902, were worked out by Dendy (1905). Of a total of 146 species that he described, 77 (52.7%) were new to science.Considering the richness, both in number and species Dendy regarded the Gulf of Mannar as 'an extremely rich centre of sponge distribution', and taking into account the affinity of Sri Lankan sponges with those of the Australian region he, (Dendy, 1905)

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* Adopted here from 'The history of spongology of Indian Ocean', *J. mar. biol. Ass. India*, 1976, 18 (3) : 610-625, with kind permission of the Director, CMFRI, Cochin-31 and the authorities of MBA,
P.A. Thomas, V.R.C. of CMFRI, Vizhinjam 695 521

included Sri Lanka in the Indo-Australian area, which, at the time of the *Challenger* report, included only Australia, East Indies and the Philippines. Burton (1930, 1937) added substantially to our knowledge of the sponge fauna of the Gulf of Mannar, and his latter work, 'The littoral fauna of Krusadai Island in the Gulf of Mannar' is of particular interest for its list of fauna and diagnosis of species. Rao (1941) in a paper 'Indian and Ceylon sponges of the Naturhistoriska Riksmuseet, Stolckholm, collected by K. Fristedt' dealt with 42 species and 3 varieties, of which 7 species and 3 varieties were new to science. An extensive survey of the marine sponges, with special reference to those of the Gulf of Mannar and the Palk Bay, was undertaken during the years 1964-67 by Thomas (1968 a), who recorded 125 species of Demospongiae belonging to 84 genera divided among 33 families. Of these 8 species were new to science and 20 were new records to the Indian region The interesting species collected during this survey have been dealt with in greater detail in the subsequent papers (Thomas, 1970a, b, c, d, e).

Comparatively very little work has been done on the shallow water marine sponge fauna of peninsular India. Along the east coast, Madras and Chilka Lake were investigated to some extent. Dendy (1887) and Ali (1954, 1956a) worked on the sponge fauna of Madras. The development of *Lissodendoryx similis* Thiele was worked out by Ali (1956 b) who in a later paper also discussed the ecology of the sponge fauna of Madras harbour (Ali, 1960). Sivaramkrishnan (1951) studied the development and regeneration of *Callyspongia diffusa* and *Tedania nigrescens* from the Madras Coast. The fauna of the Chilka Lake in Orissa was investigated by Annandale (1914, 1915a).

The major studies dealing with the deep sea sponge fauna of the Bay of Bengal are those of Dendy and Burton (1926) and Burton (1928), based on the deep sea sponges collected by R.I.M.S. 'Investigator' and deposited in the Indian Museum, Calcutta Kumar (1925) reported on the sponges dredged by the Bengal Fisheries steamer 'Golden Crown' Shallow water marine sponges collected from India including Andaman Islands, Burma and Sri Lanka were studied by Burton and Rao (1932). Of the 82 species reported in this work, 12 species and 3 genera were new. The main works dealing with the calcareous sponges of the Mergui Archipelago received considerable attention from Carter (1887).

The boring sponges of the Indian seas form a group that has been fairly well worked out in the past. The work of Annandale (1915 b) dealing with those of the family Clionidae is an outstanding contribution in this field not only for the significant additions to the fauna but also for the elaborate key and comprehensive diagnosis of 11 species of *Cliona* and 4 species of *Thoosa*. The specimens dealt with in this paper were from the Bay of Bengal, Arabian Sea, Persian Gulf and from several other places along the Indian coast. Studies on the same lines were continued in the subsequent work of Annandale (1915 c). Coral-boring sponges of the Gulf of Mannar and the Palk Bay were studied by Thomas (1969 a). About 20 species of boring sponges have so far been found to infest the coral reefs of the Gulf of Mannar and Palk Bay.

The fauna of the west coast of India is rather poorly worked out when compared to that of the east coast. The major contributions dealing with the fauna of the Gulf of Kutch are those of Dendy (1915, 1916) on Calcarea and non-Calcarea respectively collected by Mr. James Hornell at Okhamandal in Kathiawar, in 1905-1906. The sponge fauna of Karachi has also received some attention, (Kumar, 1924a, b, c; Kumar and Dyal, 1932). Species collected from the Gulf of Kutch, Bombay, Mangalore, Minicoy Island, Cochin, Quilon, Kovalam and Cape Comorin have been discussed by Thomas (1968 a).

Sponges are well known for their association with other animals and plants. Annandale (1911) discussed in detail the association of some sponges with molluscs of the family Vermetidae from the Bay of Bengal and in a later publication (Annandale, 1914) he dealt with similar association with oysters and mussels from the Madras harbour. Devanesan and Chacko (1941) reported the interesting association of the alga, *Ceratodictyon spongiosum* (Zanard) with the sponge, *Sigmadocia fibulata* (Schmidt), and also that of the cirripede, *Balanus longirostrum* Hoek with *Spirastrella inconstans* (Dendy) from the Krusadi Island. Rao (1914) recorded the association of the alga, *Phormedium spongeliae* (Schulze) with *Dysidea herbacea* (Keller). The association of the holothurian, *Chondrocloea striata* (Sluiter) with *Petrosia testudinaria* (Lamarck) has been recorded from the pearl banks of Tuticorin (Nayar and Mahadevan, 1965). The poltychaete *Polydora armata* Langerhans is also found in association with *Aulospongus tubulatus* (Bowerbank, 1873; Dendy. 1905, 1921).

Spongology of the Indian Ocean in General

The various expeditions conducted in the latter half of the 19th century and the first half of the present century have contributed substantially to our knowledge of the sponge fauna of the Indian Ocean.

The expeditions by H.M.S. Albert (1881-1882) Sealark (1905) and John Murray (1933-34) added substantially to our knowledge of the sponge fauna of the Indian Ocean in general and its various islands. Burton (1959) listed 315 species from the Indian Ocean area. The fauna of Seychelles bank received some attention and the latest data has been presented by Thomas (1969).

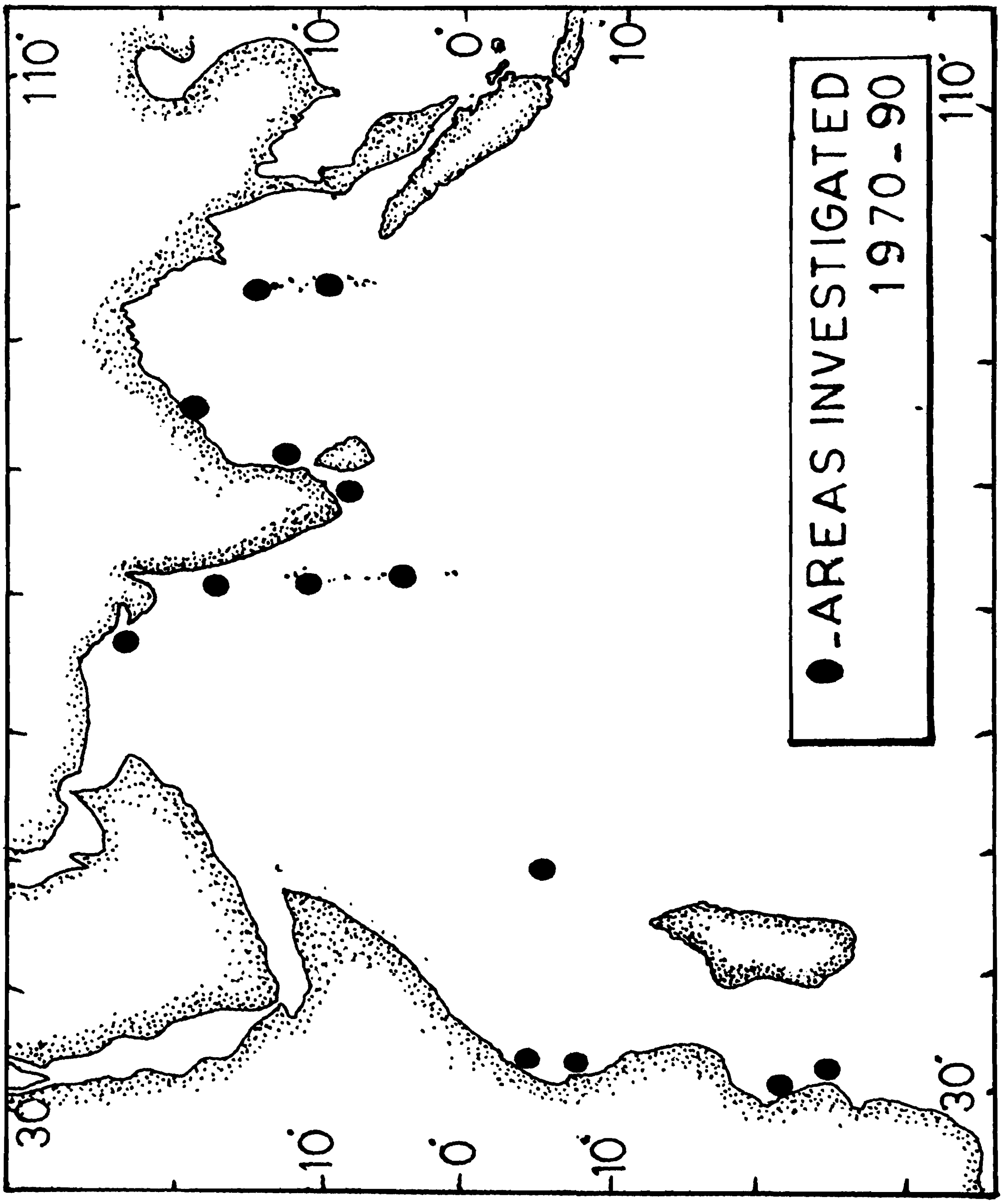
Papers dealing with the Indian Ocean species in general are those of Carter (1881, 1883), Hyatt (1887, 1888), Lendenfeld (1889, 1903), Levi (1964) and Vosmaer and Vernhout (1902). Unfortunately, the 'Challenger' collection added no direct information about the fauna of the Indian Ocean. But the elaborate monographs that appeared as an outcome of this expedition marked considerable advancement in the study of sponges, especially of the deep water forms. Of the 'Challenger' collections, Monaxonida was worked out by Ridley and Dendy (1886, 1887), Tetractinellida by Sollas (1888), Calcarea and Keratosa by Polejaeff (1883, 1884), and Hexactinellida by Schulze (1887).

Hexactinellida of the Indian Ocean is a group which has received considerable attention in the past. The work of Schulze (1887, 1895, 1900, 1902, 1904), Smith (1872), Dendy (1916), Levi (1964) and Burton (1959) from the major contributions in this field. Ijima (1926) published a list of recognisably known recent Hexactinellids after studying critically all the species collected by the previous authors from this region.

South African sponges have been the subject of intensive investigation in the past. Burton (1926, 1929) studied the Myxospongida, Astrotetraxonida and Lithistidae collected by South African Marine Survey. The order Lithistida, as defined by Sollas (1888), is a heterogenous group, their diversity suggesting a polyphyletic origin of this order; and Burton (1929) briefly pointed out the affinities of the various genera of this order. Burton studied the sponge fauna of South Africa from different areas like Natal (Burton, 1931, 1933 b), Still Bay (Burton, 1933 a), Oude Kraal, St. James, Seaforth and Muizenberg (Burton, 1936). Other accounts dealing with the South African spongs include those of Kirkpatrick (1901, 1902, 1903 a, 1903 b, 1913), Levi (1963) and Bosraug (1913). The fauna of Madagascar is known from the works of Bosraug (1913), Levi (1956, 1964), Vacelet (1967a, 1967b) and Vacelet and Vasseur (1965). The study of Vacelet (1967 a, 1967 b) brought to light several interesting genera and species of Pharetronid sponges. The fauna of Zanzibar is known from the work of Baer (1905), Jenkin (1908), Lendenfeld (1897) and more recently through the collection made by the 'John Murray' Expedition (Burton, 1959).

Accounts of the sponge fauna of Red Sea are available in a number of papers. The first paper by Keller (1889, 1891) who recorded 88 species. In recent years the Israel South Red Sea Expedition (1962), made collections from the area and these were worked out by Levi (1965), who earlier (1958) identified the samples collected by Calypso. He listed a total of 92 species of which 22 were new to science.

The fauna of the Australian coast has been well explored in the past. Lendenfeld's monographs and catalogues on Australian sponges, despite their errors and omissions, still remain the classic



Areas Investigated 1970-90

work on Australian sponges. Lendenfeld's 'species' were later reinvestigated and revised by many workers and the studies of Hallmann (1914, in three parts), Burton (1927), Whitelegge (1902 b), are worth mentioning in this context. An extensive study of the South Australian sponges, especially those from the neighbourhood of Port Phillip Heads, was undertaken by Carter in the years 1885-1886. Dendy's monograph of the Victoria sponges appeared in 1891 and his synopsis of the Austalian Calcarea Heterocoela in 1892. This was followed by the catalogue of non-calcareous sponges collected by Bracebridge Wilson from the neighbourhood of Port Philip Heads, in two parts (Dendy, 1895, 1896). F.I.S. 'Endeavour' conducted extensive fishing experiments in the years 1909-1910 along the coasts of New South Wales, Victoria, Queensland and Tasmania. Monaxonid sponges collected during this expedition were studied by Hallmann (1912) and th same author also revised the family Axinellidae provisionally, including forms having microscleres (Hallmann, 1916, 1917). The major accounts dealing with the Tasmanian sponges are those of Guiler (1950) and Shaw (1927). The sponge fauna of the Western and South-Western Australia also received some attention. Work of Dendy and of Frederick (1924) on the fauna of Abrolhos Island, of Rao and Hozawa (1931) on the Calcarea of South-West Australia, of Hentschel (1909, 1911) and Whitelegge (1905) on the fauna of South-West Australia, of Hentschel (1909, 1911) and Whitelegge (1905) on the fauna of South-West and West Australia, respectively, are the major contributions in this field. The sponges collected by the trawling expedition of H.M.C.S. 'Thetis' resulted in two volumes by Whitelegge (1906, 1907). The fauna of the Indonesian region also has been the subject of extensive study. Ternate sponges were investigated by Kieschnick (1896), Breitfuss (1898) and Thiele (1900, 1903); Amboina sponges by Kieschnick (1898), Schulz (1900), and Topsent (1897); and Aru and Kei Island sponges by Hentschel (1912). Sponges of the Christamos Island were worked out by Dendy (1887) and Kirkpatrick (1900, 1910, 1911).

Spongology of the Indian Seas - 1971 to 1990

After 1970, considerable progress has been made in the field of Porifera in India, particularly with regard to systematics. In this context mention may be made to the extensive studies on boring sponges, mainly clionids. Sponges destroying coral reefs (Thomas, 1969) and economically important gregarious molluscan shells of Indian seas were studied in detail, and these deal with a total of 13 genera and 32 species (Thomas, 1979). Estuaries like the Zuari and Mandovi (Goa) were investigated for boring sponges. Five species of boring sponges were present in the inshore realms of Goa, but their number in estuaries was only two. One species (*Cliona vastifica* Hancock) could migrate and colonise the rock oyster population common in these estuaries due to its low salinity tolerance. This sort of migration could also be noted in almost all the estuaries of India which were subsequently investigated. Hence this species (*C. vastifica*) may post a serious threat to any future molluscan farm along Indian estuaries (Thomas, 1975; Thomas and Thanapathy, 1980).

The economically important molluscan beds of the southwest coast of India and also the cultivated stocks at Vizhinjam were investigated in early 1980's for boring organisms with particular reference to sponges. It could be seen that 4 major taxa of marine organisms (sponge, polychaete, bivalve and sipunculid) infest the calcium carbonate secreting animals (such as molluscs, corals and calcareous algae) in the sea. Out of these 4 groups, sponges play an important role in destroying calcium carbonate matter by chipping off minute particles of similar shape and size (microerosion through microchips). Six species of sponges were found to infect the economically important molluscan beds (of mussel, sacred chank, rock oyster, pearl oysters and *Thais* spp.) in the southwest coast. It could also be seen that the cultivated stocks of mollusc were more vulnerable to sponge infection than the wild stocks. During these investigations it could also be noticed that two boring species have invaded the Indian molluscan beds around 1980. These have made their first appearance at Vizhinjam on cultivated pearl oysters. These to species (*Cliona margaritifera* Dendy and *C. lobata* Hancock) have since then migrated to the natural beds of gregarious molluscs so abundant along the southwest coast of India (Thomas *et al.*, 1983). The migration pattern of these two invaders, their incidence and competition with other boring sponge species already available in the various natural beds etc. were traced out for a period of eight years (1980-1987). There is a need for a continuous monitoring on the activities of these two species in the various commercially important molluscan beds of the southwest and southeast coasts of India.

Various islands of the Indian Ocean and adjacent seas were surveyed for a detailed documentation of the sponge fauna. The sponge fauna of Lakshadweep was subjected to a thorough study (Thomas, 1973; 1979a; 1980; 1980a; 1988 and 1989) and 91 species of sponges were collected. These 91 species may be classified under 32 genera and 23 families of Demospongiae. 18 species of boring sponges could be collected from various coral atolls and it could be noted that mortality of corals at Lakshadweep was mainly due to the infection of boring sponges. Bioerosion, which is so wide spread in the various coral Islands of Lakshadweep, could also be studied in depth (Thomas, 1988).

Sponge fauna of Seychelles bank was investigated at the request of Koninklijk Museum, Belgium, and sponges collected from Mahe Island were identified (Thomas, 1983a; 1981). The total number of species recorded was 104. Similar collections made from Islands like Mambone, Paradise and Inhaca by the above museum revealed the presence of 46 species referable to 21 families and 36 genera in Inhaca Island and 26 species, 15 families and 22 genera in Mambone and Paradise Islands (Thomas, 1979b; 1979c).

Species collected from Andaman and Nicobar group of Islands from time to time were analysed and found that there were 61 species referable to 44 genera and 25 families. Larger specimens were only picked up by various investigators who visited these Islands in the past and such specimens were used as 'source material for chemical studies. So the above number cannot be considered as conclusive. Exhaustive investigation, hence, is necessary to come to any plausible conclusion on the richness of the sponge fauna in these islands.

Maldive specimens were investigated in collaboration with the University of Southern California, U.S.A. The first collection from Maldives contained 17 species referable to 16 genera, of which 3 were new to science.

Areas investigated along the east African coasts were Zanzibar Island, Ras Iwatine and Manbone. Specimens were collected by the East African Marine Fisheries Research Organisation, Mombasa, and the study revealed the presence of 14 species, 13 genera and 10 families in Zanzibar Island (Thomas, 1976) and 10 species, 9 genera and 9 families in the other two localities (Thomas, 1976a).

The inshore realms of the Indian coasts were investigated in detail by the scientists of CMFRI. Besides the above samples the specimen collected and sent for identification by those interested in the study of bioactive substances from sponges were utilised for a qualitative appraisal of the sponge fauna of the respective areas. Sponges inhabiting the Gulf of Kutch were investigated and found that the fauna of this area was quite peculiar ecologically as the same was dominated by species that were highly tolerant to silt fall. 25 species falling under 22 genera and 5 families were represented in the Gulf of Kutch collections. Boring sponges were represented by 8 species which preferred dead and living coral skeleton so abundant there (Thomas *et al.* MS). The sponges of this area may be regarded as a population acclamatised to stressful conditions.

A qualitative appraisal of the sponge fauna of the Gulf of Mannar and Palk Bay was made and a checklist containing 275 species with brief descriptions was published (Thomas, 1986). The sponge fauna of Gulf of Mannar is somewhat well known through earlier work, but all the 94 species represented in the Palk Bay were new records for the area. Details pertaining to 275 species of Demospongiae referable to 136 genera and 38 families are provided with suitable illustrations in this paper (Thomas, 1986).

Fishing/Research Vessels like R. V. 'Klaus Sunnana', R. V. 'Skipjack', and FORV 'Sagar Sampada' have contributed considerably to our knowledge on the deep water sponge fauna of the Indian waters. 'Klaus Sunnana' collected 9 species (including 3 new species) of Demospongiae from depths varying between 180 and 325 m in the Gulf of Mannar (Thomas, 1970). 'Skipjack' owned by CMFRI, collected 8 species (including 3 new) from the southeast coast of India (48m) (Thomas, 1984). Sponges collected by FORV 'Sagar Sampada' are being investigated for their species composition.

Though sponges constitute a major group among fouling organisms in the marine environment nothing is known on the structure and composition of the fauna. Therefore the fouling sponges which migrate and establish the culture rafts at Vizhinjam were investigated and a detailed report was prepared. This report, together with details on boring sponges which infect the $CaCO_3$ secreting animals in the Indian seas, was presented at the Specialists' Meet on marine biodeterioration held at Kalpakkam (organised by IGCAR). This paper gives a pictorial key to the identification of various boring species (sponges) in the Indian seas (Thomas, 1990).

Sponges collected during the 3rd Indian Antarctic Expedition (Dec. '83 to March '84) from the sea off Queen Maud Land, Antarctica, were studied and reported. Of 6 species collected 3 were of the Class Hexactinellida and the rest of Demospongiae. One Demospongean species, viz. *Isodictya echinata* was new to science (Thomas and Mathew, 1986).

Estimation of Taxa

Phylum Porifera, the only phylum of the Subkingdom Parazoa, has an evolutionary history of about 570 million years. Sponges are represented in the extant oceans by about 5000 species in 790 genera and 80 families. This phylum is represented in the Indian seas by about 203 genera and 486 species. It is divided into 4 classes.

Class I. Calcispongiae (Calcareous sponges)

Typically marine, spicules made of $CaCO_3$ and are not differentiated into mega and microscleres. Total number of species so far recorded is about 500, but Burton (1963) extensively synonymised them to 47 species, and this has made a drastic cut in the Indian Ocean species to 14.

Class II. Demospongiae (Silicious sponges)

Largest group accounting to 95% of the recent sponges. Skeleton made of silica, spongin or with none; some may incorporate foreign objects into their body for rigidity. Species are dominantly marine though a family is widely distributed in fresh/brackish water environments. Total number of species falling under this class is about 4000; 428 in Indian seas.

Class III. Hyalospongiae (Hexactinellid sponges or glass sponges)

Common in deep water areas with about 600 species; 44 species are known from Indian seas. Spicules made of silica which are 6-rayed and divisible into mega and microscleres.

Class IV. Sclerospongiae (Coralline sponges)

A recently discovered class with about 15 species; not known from Indian seas yet. Skeleton of silica, spongin and calcium carbonate.

An examination of the sponge fauna of Indian seas reveals that it is dominated by Demospongean species (88.8%) followed by those of Hexactinellida (9.1%) and Calcarea (2.1%). This composition is in full agreement with that in the world oceans (Thomas, 1983a). The close relationship of the sponge fauna of the Indian seas with that of the Australian region, Red Sea and the Pacific Ocean is well known. This kind of an affinity is seen not only in the case of sponges but also with regard to every group of marine sedentary organisms (Thomas, 1983a).

Class Demospongiae is divided into 8 orders. The numerical abundance of various genera and species falling under each order is summarised.

Order	Genera	Species
Keratosida	15	27
Haplosclerida	19	64
Poecilosclerida	52	114
Halichondrida	20	53
Hadromerida	23	63
Epipolasida	12	23
Choristida	18	58
Carnosida	14	26
Total	173	428

It is evident from the above list that the Order Poecilosclerida is the largest and structurally the most diverse order of Demospongiae. Skeleton is composed of a combination of spicule and spongin fibre. Spicules, both mega and micro, may be of different sets with great differentiation in relation to regions of the sponge.

Hexactinellids are typically marine and are common in deeper areas. Skeleton is made of silica and both mega and microscleres have hexactine structure. The classification, here, is based on specific microsclere type coupled with the arrangement of large hexactinal megascleres, whether separate or fused.

Two orders are considered; Amphidiscophora possessing amphidiscs and Hexasterophora with hexasters, for microscleres. Numerical abundance of genera and species falling under the above two orders is as follows :

Order	Genera	Species
Amphidiscophora	5	24
Hexasterophora	14	20
Total	19	44

Calcareous sponges possess spicules of calcium carbonate and a differentiation into mega and microscleres is wanting. This class is divided into 2 families: Homocoelidae and Heterocoelidae. Family Homocoelidae is characterised by the presence of collared cells as a lining in the whole endosomal cavity and its outgrowths, while in Heterocoelidae no collared cells are found lining the endosomal cavity.

The number of genera and species falling under each family may be given as follows :

Family	Genera	Species
Homocoelidae	3	3
Heterocoelidae	8	11
Total	11	14

Burton (1963) in his iconoclastic work on the classification of calcareous sponges has extensively synonymised the then known species, attributing a remarkably wide degree of variability to each species. He reduced the number of existing genera from 54 to 22 and the number of species from more than 5000 to 47. This resulted in a drastic cut in the total number of Indian Ocean species to 14 wide-spread species; but this procedure is not accepted by several spongologists.

Current Studies

Our knowledge on the Calcareous and Hexactinellid sponges of the Indian waters is still confined to the classical monographs appeared in the pre-independence period. Larger vessels owned and operated by India can be more effectively used in surveying deeper waters for hexactenillid species which are specific to deeper areas.

Among Demospongiae the freshwater sponge is a group which has been investigated in detail by the scientists of ZSI and universities. Morphology and spicular characters in this family are highly variable and these have resulted in the description of several new species in the past Extensive study giving more importance to environmental factors may help in cutting down the present number which is so unwieldy for any qualitative assessment of the freshwater sponge fauna as a whole.

Marine Demospongiae, which constitutes the main bulk of the extant sponge fauna is poorly known and this is evident from the number of new species that are added from any locality which is explored for the first time. It is essential that our Demospongean fauna should be properly explored and documented.

Sponges which excavate hard calcareous substrata by chipping off minute particles of calcium carbonate from inside weaken the substrata making them more susceptible to vagaries of nature. This type of bioerosion often remains unnoticed in nature since the particles etched out (microchips) are of submicroscopic size. Only a few atolls in the Lakshadweep have been investigated in the past by CMFRI as a part of assessing the micro-erosion profile of Lakshadweep in general. Such multidisciplinary studies should be extended to all coral formations along the Indian coasts.

Boring sponges which cause wide spread mortality to the gregarious molluscs are now known from some selected areas only. When compared to other oceans the number noted in the Indian seas (totally 32) is probably a record number. Apart from the species already present in our seas, it is indicative that 2 species new to the area have invaded our molluscan beds in the recent past. Since these 2 species are capable of devastating any rich molluscan bed within a few days a continuous monitoring of these two species as well as others already present should be initiated on a long term basis in future.

It is heartening to know that many of these 'humble' animals have come to limelight in recent years on account of certain peculiar chemical compounds they contain. Many of these chemicals have biomedical potentials and hence many of them are being screened for 'wonder drugs' Arabinose nucleosides extracted from the sponge *Tetya crypta* (de Laubenfels) is now used in the treatment of blood cancer and certain malignant tumours with positive results. Cells of some sponges are now employed as mighty tools in immunological studies. Chemicals with antifertility, antimicrobial and antifouling properties have been extracted from several sponges inhabiting our inshore areas.

Some Universities/Research organisations like Andhra University; IIT, Bombay; CDRI, Lucknow; St. Mary's College, Tuticorin, CMFRI, Cochin etc. are now deeply engrossed in the programme of identifying compounds with biomedical potentials from organisams such as sponges, gorgonids, alcyonarians, corals etc. The main handicap with regard to the progress of such investigations is the poor information on 'source material' and their availability.

Many of the lower invertebrate groups such as sponge, gorgonid, alcyonarian etc. are now being exported for a paltry sum. This has resulted in the depletion of many of our erstwhile rich beds in the recent past. Hence, a total ban on the exploitation and export of such raw material should be enforced immediately.

It may be apt to point out at this context that our knowledge on the occurrence, availability and species composition etc. pertaining to many of the lower invertebrate groups are still at infancy, and except in a few groups the information available is also not sufficient for initiating any serious study leading to the extraction or synthesis of 'wonder drug' There is a need to develop sufficient number of personnel in various groups of lower invertebrates for identifying and locating suitable 'source material' that are needed in connection with biomedical investigations in India.

Expertise

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FRESHWATER PORIFERA

Introduction

A single family, the spongillidae, is represented in freshwaters. It includes about 100 species under about 20 genera of which 33 species under 9 genera have been reported so far from India.

Freshwater sponges are common in clean ponds, lakes, streams and rivers. Because of their sessile structure and inconspicuous green, brown, grey or yellowish coloration, they are frequently un-noticed. A suitable substrate for the matlike sponge growth may be provided by almost any stable submerged object including rocks, pebbles, aquatic vegetation, logs, branches and twigs.

Although the taxonomic study of freshwater sponges began in the mid-19th century by Lamarck and others but was in a most chaotic state until the revision was made by Bowerbank (1863) of all the species of *Spongilla*. Gray (1867) first established the criteria for their generic differentiation and erected six new genera in addition to *Spongilla* Lamarck. Carter (1881) ignored Gray's generic names and devised his own system for the inclusion of Bowerbank's species.

After the publication of the first bibliography of freshwater sponges by Weltner (1893), it was chiefly Annandale (1906 - 1919) who began to lay the foundations of an improved and modernised knowledge of spongillid taxonomy. Annandale reestablished some of Gray's generic names, at least at sub-generic level, and added a number of well-defined new genera to the conglomerate systems of Gray and Carter. Additional revisions were subsequently undertaken by Gee (1926 - 1937) Schroder (1926 - 1942) and Arndt (1923 - 1983), to name just a few important contributors, Generic revisions were attempted by De Laubenfels (1936) and Jewell (1952). Penny & Racek (1968) reviewed all the species so far recorded and established 10 genera, including 95 species.

The spongillidae cannot be said to be of any practical benefit to man. The only harm that has been imputed to them is that of polluting waters, blocking up water - pipes by their growth and causing irritation to the human skin by means of their spicules.

Historical Resumé

i) Pre-1900

The beginning of Spongiological Researches

One of the pioneers in the scientific study of the freshwater forms was the H.J. Carter, who commenced his investigation, and carried out the greater part of it in Bombay. His long series of papers (1848 - 1887) published in the 'Annals and Magazine of Natural History' is an enduring monument to Indian Zoology and forms the best possible reference to the study of the Spongillidae.

Contemporary to Carter were two authors whose monographs on the freshwater sponges did much to advance the study of the group, namely, J.S. Bowerbank, whose account of the species known at that time was published in the 'Proceedings of the Zoological Society of London' in 1882 and the veteran American naturalist, Mr. Edward Potts, whose study of the freshwater sponges culminated in his monograph published in the 'Proceedings of the Academy of Natural Sciences of Philadelphia' in 1887. Carter's own revision of the group was published in the 'Annals and Magazine of Natural History' in 1881. Weltner's catalogue of the known species (1895) is of the greatest possible value to the study of sponges.

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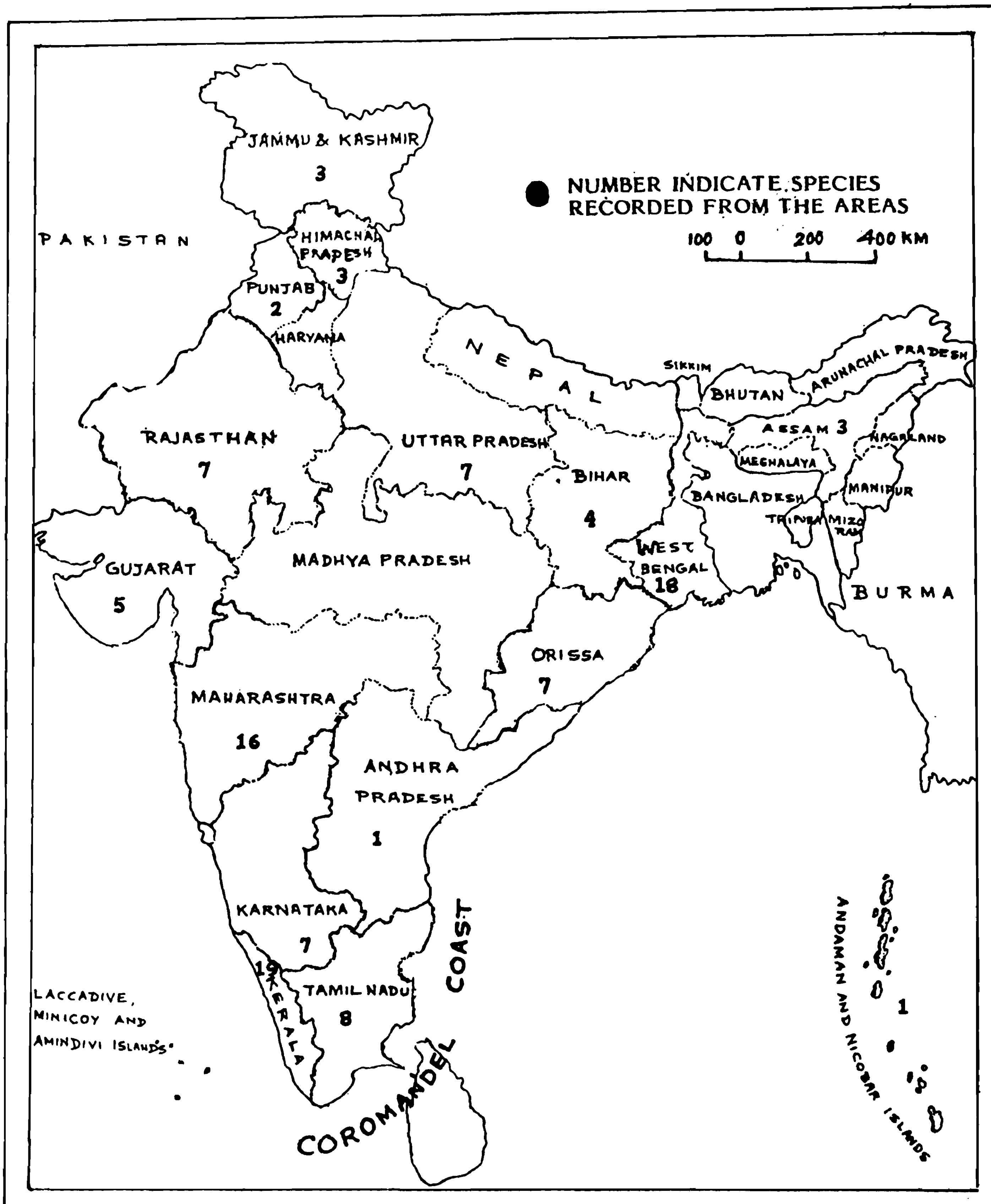

Survey and Identification of Freshwater
Porifera

ii) 1901-1947

The golden era of the study of Freshwater sponges

In the early 20th century it was chiefly Annandale (1906 - 1919) who studied the Indian Freshwater sponges thoroughly and published a series of papers (1906 - 1919). He published 'The Fauna of British India including Ceylon and Burma' in 1911, which includes Freshwater sponges, Hydroids and Polyzoa.

iii) 1948-1990

The present study of Indian Freshwater sponges

After the pioneering work of Annandale (1906 - 1919), the study of Indian Freshwater sponges was practically untouched till the revision of worldwide collection of freshwater sponges by Penney and Racek, (1968).

Based on Penney and Racek (1968) a checklist of freshwater sponges was published by Khera and Chaturvedi (1976) which provided a list of Indian species. Soota, Baskaran and Sexena (1981) described sponges, their ecology and their role as indicators of water quality. Soota and Pattanayak (1982) described nine species and provided keys to all Indian species. Soota, Pattanayak and Sexena (1983) described a new species. Soota, Baskaran and Saxena (1983) described some species and their ecology. Soota and Saxena (1983) described some species of sponges of Rajasthan.

Studies from Different Environs

A review of the study of sponges in freshwater bodies of different states reveals that the states of Karnataka, Kerala, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal are well explored, but the states of Andaman & Nicobar Is., Andhra Pradesh Assam, Bihar, Himachal Pradesh, Jammu & Kashmir, Punjab, Gujarat are partly surveyed and the remaining states are not at all surveyed. The number of species known in each state are given in the map.

Estimation of Taxa

The freshwater sponges belong to a single family spongillidae and the world literature reveals that about 100 species under about 20 genera occur in the world. Amongst these, 33 species under 9 genera are reported from India of which 13 species are endemic.

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Animal Resources of India : 35–40 : 1991

SIPHONOPHORA

Introduction

Siphonophora are abundant in the tropical seas and constitute an important part of the marine plankton. The monographs on this group are those of Eschscholtz (1829), Hukley (1859) Haeckel (1888), Lens & Van Riemsdijk (1908), Bigelow (1911), Moser (1925) Bigelow & Sears (1937), Totton (1954, 1965), Stepanjants (1967), and Daniel (1974). The Siphonophora from the Indian Ocean have been studied by several workers - Browne (1926) from Seychelies, Mauritius and Chagos Archipelago; Sundara Raj (1927), Leloup (1934) and Daniel & Daniel (1963) from the Madras coast; Patriti (1970) from off South East Coast of Africa and Madagascar; Totton (1954) from SE Coast of Africa, SE, NW & S. Indian Ocean, Gulf of Aden, Aqaba and Red sea; Alvarino (1974) from the tropico - equatorial region; Rengarajan (1974) from the West Coast of India; and Daniel (1966, 1974, 1985) from the West and East Coast of India and those collected by R.N. 'Vityaz' along 90° - 110°E longitude down 35°S latitude. In spite of these works there was still a definite paucity of knowledge on the systematics, distribution, abundance and seasonal fluctuation of Siphonophora in the Indian Ocean, sufficient to warrant the publication of a volume on the Siphonophora under the Fauna of India series (Daniel 1985).

There are 180 (valid and 17 doubtful) species of Siphonophora in the world's oceans. Of these, a grand total of 118 valid, one variety and 3 doubtful species are known from the Indian Ocean. Eighty nine species occur in the Indian Seas.

The study of Siphonophora is beneficial because their occurrence and abundance would indicate not only the movement of the water mass but also the plankton in general. The "Indicator" species like *Dimophyes arctica* indicates the upwelling of rich mid to deep water mass to surface which occurs within (13°N lat to 10°S lat) the equatorial belt region. Our fisheries depend on the seasonal abundance of the total plankton biomass.

Classification

Phylum	Class	Order	Suborder	Families
Cnidaria	Hydrozoa	Siphonophora	Cystonectae	Physaliidae
				Rhizophysidae
			Physonectae	Apolemiidae
				Agalmidae
				Pyrostephidae
				Physophoridae
				Athorybiidae
				Rhodaliidae
				Forskaliidae
			Calyophorae	Prayidae
				Hippopodiidae
				Diphydae
				Clausophyidae
				Sphaeronectidae
				Abylidae

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Historical Resumé

i) Pre-1900

The phylum to which the Siphonophora belong is Cnidaria, a name introduced in 1888 by Hatschek, who excluded the Sponges and Ctenophora which had been included in Leuckart's (1847) group Coelenterata. Cuvier (1817) separated the Cnidarians as part of two out of the five classes of the last of four primary groups, Zoophytes or Radiata, in his celebrated arrangement of the animal kingdom in Eschscholtz 1829 reorganized the various coelenterate groups which included in Cuvier's third class, Acalephae. He also separated the Ctenophora and Siphonophora, in the latter of which he still included the Chonodrophora of Chamisso & Eysenhardt, 1821, from the Medusae proper (Discophorae). He dealt with about twenty species of Siphnonophores.

Some of the early detailed systematic work on Siphonophores was done by Eschscholtz (1825-9), Risso (1826), Milne Edwards (1841), Vogt (1851, 1854), Leuckart (1847, 1851, 1853), Gegenbaur (1853a, b) and Kolliker (1853), all of them working on living Mediterranean forms at Nice, Villefranche and Messina. But, of course, many of the earliest names a figures are taken from the Atlases of Voyages of the older naturalists like Lesson (1826) (Voyage... la Coquille, 1822-25), Peron (1807) and Quoy & Gaimard (1824) Voyage...L' Uranie et la Physicienne, (1817-20). Early contributions were the works of Sars (1846), Will (1844) and Huxley (1859) on Siphonophora collected during his voyage in *H.M.S. Rattlesnake*. It is worth to mention the following contributions during the previous century : Claus (1860-89), A Agassiz (1865-1902), Fewkes (1879-89), Haeckel (1887-89), Chun (1882-1913), Bedot (1882-1909) and Schneider (1896-1900).

Eschscholtz (1829) divided Siphonophora into three suborders : Chondrophorae Chamisso, 1821; Physophorae Eschscholtz, 1829 part, and Calycophorae Leuckart, which was followed by Huxley (1859); Chun (1888, 1897b); Haeckel (1888b).

Haeckel's Calyconectae Monogastricae is really the adult or sexual phase (Eudoxid phase) in the life-cycle of the Calyconectae Polygastricae. Similarly, his Physonectae Monogastricae and Cystonectae Monogastricae have been proved to be larval stages in the life history of the Physonectae Polygastricae and Cystonectae Polygastricae respectively. Therefore, these groups have not been recognized by any of the later workers.

ii) 1901-1947

Most of the earlier workers like Lens & van Riemsdijk (1908), Bigelow (1904, 1911b), Browne (1926), Garstang (1946) retained Chondrophorae as one of the tripartite divisions of the Order Siphonophora, though always recognizing the former to be quite distinct in its morphology, relationships and development, i.e. its radial symmetry, with an aboral whorl of simple tentacles, and developing from an 'Actinula' larva (*Conaria*), and showing close relationship with Tubularinans (specially Corymorpha) in the dominance of a large axial polyp with plexiform aboral Coelentron, aboral wreath of tentacles, free Anthomedusan gonophores and an 'Actinula' larva (Garstang, 1946). The other two suborders, viz. Physophorae and Calycophorae (= Siphonantha Haeckel, 1888; Garstang, 1946) are bilaterally symmetrical, with a separate basal tentacle to each polyp, and developed from a solid 'Planula' larva by unilateral precocious (ventral) budding (Garstang, 1946) and show 'relationship with myriotheline in the resemblance of their lateral paddling bracts to the larval tentacles of the actinula of the hydroid *Myriothela*, which are aboral in position and locomotive in function.'

Bigelow (1911b), without designating the status of the group clearly (viz., whether a class, or order), recognized four sub-divisions of the Siphonophorae, i.e., Calycophorae, Physophorae, Rhizophysaliae and Chondrophorae.

However, it was Garstang (1946) who after studying the comparative morphology, phylogeny and relationships of Siphonophora, felt that the evolution of Siphonophora had progressed from a passive flotation, through various combinations of flotation with active modes of locomotion, to a climax of purely muscular methods of swimming and colonial simplification in Calycophorida. He, therefore, reversed the order in which Chun (1897b) and Haeckel (1888b) had arranged the principal groups. He recognized Haeckel's Disconanthae and Siphonanthae to mark the major gap between the Chondrophorae and the remaining groups. He agreed with Chun in recognizing only two divisions, i.e., Physophorae and Calycophorae under the Siphonophora (= Siphonantha) and in classing Cystonectae and Physonectae (= Amphinecta) under Physophorae (= Physophorida).

iii) 1948-1990

Leloup (1954), after a study of embryology and comparative anatomy, divided the Siphonophora into four groups, i.e., Chondrophorides, Cystonectides, Physonectides and Calycophorides. The first three groups we included under 'Physophorides' However, in 1955 (a, b) he recognized the older names, viz., Calycophorae and Physophorae, and he classified the families Rhizophysidae, Physalidae, Velellidae and Porpitidae under Physophorae.

It is interesting to note the gradual increase in the number of species dealt with by systematists. This rose from twenty-six (Huxley, 1859), thirty (Haeckel, 1888), Thirty-two (Lens & van Riemsdijk, 1908), fifty-two (Bigelow, 1911) fifty-seven (Moser 1925), one hundred and thirty (Totton, 1965), one hundred and fifty (Daniel 1974) to one hundred and eighty (Daniel 1985) known to-day.

Studies from Different Environs

The Siphonophora are holoplanktonic throughout their lives. They do not pass through even a very short fixed larval polypoid stage as in the various hydroids, medusae, and Scyphozoa. Most Siphonophores are stenohaline and cannot tolerate high or low salinities and differences in pressure due to depth and temperature. however, they have a wide distribution in the tropical regions of the oceans.

Siphonophora are restricted to different zones in the ocean. Based on their distribution the species of Siphonophora can be grouped under pleustomic, neritic, oceanic, bathy pelagic and antarctic in the ocean. The well known *Physalia physalia* is the only pleustonic surface species. It occurs in dimorphic forms which are mirror images of each other, i.e. the siphosomal elements occur either on the right or left side of the crest.

There are only four species which are neritic, namely *Diphyes chamissonis*, *Lensia subtiloides* *Muggiaca atlantica* and *M. delsmani*. The last mentioned species occurs along the coastal regions of India and along the Burma and Malayan coasts. *M. atlantica* is restricted to the coastal waters of the Arabian peninsula and of the South eastern Africa. The other two species mentioned above do not however confine themselves to the coastal waters. These two are abundantly distributed in the Bay of Bengal.

Oceanic

The oceanic species of Siphonophora are those that are not influenced by the proximity of the coast (continental shelf-neritic zone), occurring in the 200-0 m depth in the central regions of the ocean. The twenty-four species which have bathypelagic distribution are also oceanic forms that are usually restricted to the depths, rarely coming to the surface during the upwelling of cold deep waters.

Eleven species (*A. okeni, D. dispar, D. bojani, S. chuni, L. hotspur, E. mitra, C. contorta, C. appendiculata, A. tetragona, A. eschocholtzi* and *B. bassensis*) contribute the bulk of the Siphonophore component of the zooplankton of the Indian Ocean, and also are not affected by the thermocline during their vertical immigration, whereas *A. rosacea, V. pentacantha, V. glabra, D.*

arctica, L. multicristata and *L. fowleri* appear to be restricted by the thermocline during their upward migration (Daniel, 1977).

Bathypelagic species

Except for two references on bathymetric range of Siphonophora from the Indian Ocean, nothing is known about the depth range of these mid-and deep-water species (Totton, 1954; Daniel 1974).

There are 16 truly bathypelagic species which do not come up to the surface even during the upwelling of deep cold water mass are as follows : *Halistemma amphytridis* (1000-0 m); *Marrus orthocannoides* (1400-700 m) *Erenna richardi* (1900-1500-100 m); *Nectopyramis diomedeae* (1600-650 m); *N. thetis* (1250-800 m); *N. natans* (2580-2480; 1650-950 m); *N. spinosa* (1000-0 m); *Lensia hunter* (1000-0 m); *L. achilles* (1400-1000 m); *L. cordata* (950-650 m); *Clausophyes ovata* (1350-o m);*Chuniphyes moserae* (1260-600 m); *C. multidentata* (1000-200 m); *Crystallophes amygdalina* (1650-950, 700 m); *Heeteropyramis maculata* (1400-250 m); and *Thalassophyes crystallina* (1400-700, -200 m).

Antarctic

Eighteen species of Siphonophora are known from the Antartica Ocean : *Moseria canvoluta, Pyrostephos vanhoeffeni, Marrus antarctius, Rosacea plicata, Vogtia serrata, Diphyes antarctica, Dimophyes arctica, Lensia hardy, L. achilles, L. havock, L. reticulata, Mugguaea bargmannae, Clausophyes galeata, Chuniphyes moserae, C. multidentata, Crystallophyes amygdalina, Heteropyramis maculata* and *Thallossophyes crystallina.* Of these *Moseria convoluta, Pryostephos vanhoeffeni, Diphyes Antartica, Marrus antarctius* are restricted to the Antarctic Ocean. *Dimophyes arctica* is considered as a valuable indicator species of deep cold water masses.

Estimation of Taxa

Out of the 15 families mentioned earlier only one family Rhodaliidae is not represented in the Indian Ocean, mainly because the rhodalids are mid to deep water species and no deep water samplings have been done in the Indian Ocean. (25°N to 45°S Lat., 20°E to 120°E long. During the International Indian Ocean expeditions the plankton collections were made from a depth of 200-0 m except for the collections made by *R.V. Vityaz* along 91°E long. Wherein collections were made from a depth of 1000-0 m. Most of the deep sea species were recorded from this region except the species belonging to the family Rhodaliidae.

Order Siphonophora

Sub Orders	Families	Genera	Species
3	15	67	180
		(incl. 2 doubtful genera	(incl. 17 doubtful species)

Of the 65 genera known from the world oceans, 19 genera, [*Salacella* (1 species) and *Epidulia* (2 species) are doubtful genera] *viz. Tottonia* (1 species), *Romosia* (1 species), *Moseria* (2 species), *Rudjakovia* (1 species), *Stepanyantsia* (1 species), *Mica* (1 species), *Pyrostephos* (1 species), *Angelopsis* (2 species), *Stephalia* (3 species), *Sagamalia* (1 species), *Thermopalia* (1 species), *Rhodalia* (1 species), *Archangelopsis* (1 species), *Dromalia* (1 species), *Prayola* (1 species), *Lilyopsis* (2 species) and *Stephanophyes* (1 species) are not represented in the Indian ocean.

14 families, 45 genera and 120 species are known from the Indian Ocean. Their description, distribution, seasonal variation and abundance were dealt with in the Fauna of India : Siphonophora (Daniel 1985). Of these, 39 genera and 90 species occur in the Indian seas (25°N to 1°S Lat. and 60°E to 100°E Long).

Classified Treatment

The Order Siphonophora (Class Hydrozoa) is divided into 3 sub orders and 15 families. The monotypic family Physaliidae is represented by a single species *Physalia physalis* with two dimorphic forms common throughout the tropical regions of the 3 major oceans. The family Rhizophysidae is represented by 3 species, *Rhizophysa filiformis*, *R. eysenhardti* and a deep sea *Bathyphysa conifera* which occurs in the upwelling regions off Java.

The family Apolemiidae based on *Apolemia uvaria* is a deep sea form and comes to the lower boundary of the thermocline in the Indian Ocean. Of the four species of *Agalma* belonging to Agalmidae three species *A. okeni* (with 2 dimorphic forms) *A. elegans* and *A. haeckeli* (recorded only once) occur in great abundance in the Indian Ocean. *Halistemma rubrum* is also a common species but *H. amphytridis* is a rare cold water deep sea form measuring several meters in length and known only from fragments of its polymorphic structure. *Cordagalma cordiformis*, *Frillagalma vityazi*, *Marrus orthocannoides*, *Lychnagalma utricularia* and *Erenna richardi* are rare species recorded only a few times in the Indian Ocean. Whereas, *Nanomia bijuga* occurs in abundance along the coasta of India.

Bargamannia elongata belonging to the family Pryostephidae is also a very rare species recorded off Minicoy and Java. The monotypic family Physophoridae with monotypic genus, *Physophora hydrostatica* occurs all over the Indian Ocean.

The family Athorybiidae is represented by two genera *Athorybia* (*A. rosacea*) and *Melophysa* (*M. melo*) and both occur in the Bay of Bengal and near land mass.

Of the six species of the genus *Forskalia* (Family Forskaliidae), *F. edwardsi*, *F. leuckarti*, *F. formosa*, *F. tholoides* and *F. cuneata* occur in the Indian Ocean and *F. formosa*, *F. tholoides* and *F. cuneata* are rare, recorded 1-3 times off Madras, between Madagascar and and S. Africa and near Nicobar Islands. *F. leuckarti* is a common species and *F. edwardsi* is a cold mid-water species which comes up during upwelling of deeper waters and occurs near the sub-antartica convergence belt in the Indian Ocean.

The suborder Calycophorae consists of 6 families, 28 genera and 93 species. Of these 52 are rare species recorded only a few times during the International Indian Ocean Expedition.

The remaining common species occur in great abundance and form the bulk of the zoological constituent of the plankton.

In spite of the extensive collections made during the International Indian Ocean Expedition (1.1.O.E. - 1960, 1962-1965) by the nineteen Research vessels from nine countries (from 200-0 m depth) no representitive of the entire family Rhodaliidae (7 genera and 10 species) was recorded from the Indian Ocean.

Detailed information on histology (taxonomic characters), biology, physiology, reproduction, embryological and early development (larval) of many species, genetics (chromosomes) and their bearing on taxonomy are still needed. It is hoped that future workers would take up such studies so as to get a complete knowledge of this group of animals.

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SCLERACTINIA

Introduction

Stony corals (Scleractinia) constitute an Order of the Phylum Coelenterata of class Zoantharia. Corals are exclusively marine with a calcareous exoskeleton in which the living part (polyp) exists. The mesenteris or septa are in multiples of six, hence called Hexacorallia. They are either colonial or solitary and sedentary in habit. Corals generally feed on zooplankton though, part of the nutritional requirements are met from the extracellular photosynthetic products of the symbiotic algae living in the tissue. Reproduction is by both sexual and asexual methods, colony formation takes place exclusively by asexual intra or extratentacular budding. Colonial forms are called hermatypic for they form the chief reef builders while the solitary corals are called ahermatypic. About 700 species of hermatypic corals are described in literature from the Indo-Pacific Ocean but due to taxonomic problems and ecomorphological variations, it is still difficult to precisely classify many, into genetically well defined species.

The classification adopted for Scleractinia (former Madreporaria) by the present taxonomists is that of Vaughan and Wells (1943) as modified by Wells (1956) (*Treatise* on *Invertebrate Paleontology*).

Scleractinia is divided into five Suborders with many families and subfamilies. Most of the families and subfamilies are known only in the fossil forms. The recent or extant stony corals belong to the following five suborders:

Suborder Astrocoeniinna : Colonial, hermatypic, with level or projecting corallites and 1 to 2 cycles (6 to 12) septa. The suborder includes common genera like *Pocillopora, Acropora* and *Montipora,* which are common in our waters too.

Suborder Fungiina : Solitary or colonial, with more than two cycles of septa; septa united by synapticulae. It includes genera like *Fungia, Podabacia, Halometra,* all of which also occur in our waters. Massive chief reef builder *Porites* also belongs to this Suborder.

Suborder Dendrophylliina : Solitary or colonial, coenosteum perforate; Synapticulae absent. These are mostly ahermatypes but a few are hermatypes.*Turbinaria, Dendrophyllia, Tubastreaea* etc. are important genera of this suborder.

Suborder Faviina : Colonial encrusting or massive. Corallites single or form meandering valleys. Septa dentate, basically laminar. Important genera are *Platygyra, Symphyllia, Favia, Favites, Leptastres,* all of which are dominant reef builders of our waters.

Suborder Caryophylliina : Mostly solitary, rarely colonial, corallum cup shaped or turbinate, septa exsert, margins entire or granular. Pali present around the columella.

This group includes many deep water forms and are generally non-conspicuous on surface reefs. The genera like *Caryophyllia, Trochocyathus, Paracyathus; Flabellum.* etc. belong to this Suborder.

The modern taxonomic criteria for the classification of corals are generally based on the nature of skeleton. Polyps are rarely taken into consideration. the growth form such as colonial, or solitary; the shape such as massive, ramose, encrusting, foliaceous, turbinate, discoid or createriform are prime criteria. The number of septa and their teeth; nature and form of columella;

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ornamentation on the surface of the skeleton; nature of coenostem as to solid or porous are all of importance in the identification of corals.

Corals form the most dominant benthic marine community in tropical waters. They are the chief agents in building mighty reefs of different kinds. In India, we have well developed reefs in Gulf of Mannar and Palk Bay, Andaman and Nicobar Islands and Lakshadweep that includes fringing reefs and atolls. A sort of patchy reefs on wave cut aberration of the top of tiny islands as in Pirotan, Paga and Boria are found in Gulf of Kutch. Corals do occur along the west coast of India from Malvan to Cape Comorin though, no well formed reef has not been so far reported. The skeleton of corals contains more than 98% of pure calcium carbonate and form raw material in construction and industrial purposes. In Southern India, reef corals were mined for calcium carbide industry since three decades, causing the deterioration of the shallow reefs. The calcareous sand formed as a result of the bioerosion of the reefs also contains $CaCO_3$ and was mined in Gulf of Kutch. Corals are also used a building blocks in several parts of the world including India and is still a source of lime. Reefs provide protection from sea erosion and is the most effective natural barrier to continental and island shores. Coral reefs have aesthetic value and are of tremendous importance to development of Tourism. Many reef associated organisms such as crustaceans and molluscs - not to speak of ornamental reefs fishes - are of immense value to mankind as food and curios. Of recent, reef organisms are found to contain biochemical compounds that are of value in the treatment of many human diseases. The Marine pharmacology is a fast developing branch of science for which the living raw material is plenty on reefs. However, indiscriminate exploitation of our reefs for industrial purposes coupled with natural interferences have caused great damage to reefs especially in South-east India, Gulf of Kutch and Lakshadweep. It is an ecosystem that needs immediate attention for preservation and conservation of its living resources.

Historical Resumé

Very little work on coral fauna of India was done prior to 1900 though Alcock recorded a few deep sea corals from the Andaman sea and Lakshadweep as early as 1893 based on the cruises of RIMS Investigator. The Cambridge University Expedition under the leadership of Prof. Stanley Gardiner also visited Minicoy at the southend of the Lakshadweep archipelago and made a detailed study of the reefs and reef corals. Brook, (1893) incorporated some species of *Acropora* from Rameswaram in his *Catalogue of the Madreporarian corals in British Museum* (*Nat. Hist*) based on the collection of Foote (1890) and Thurston (1895). Gardiner (1904, 1905) described many corals from Minicoy. However, many of the specific names used by him were subsequently synonymised or emended. Gardiner *op cit* dealt with only Faviina and Fungiina of Minicoy and the rest still remains to be reported. Subsequently, Matthai (1914, 1928) described and revised many corals from Lakshadweep that were described by Gardiner. He also (Matthai, 1924) listed the Fungiina and Faviina from the Indian Museum Calcutta that includes materials from Strait of Malacca and Andaman and Nicobar Islands. Gravely (1927) listed a few corals from Krusadai Island in Gulf of Mannar. The presence of *Acropora, Pocillopora, Montipora, Porites, Fungia* and *Turbinaria* were noticed by Sewell on the reefs of Nicobar in 1922, but no efforts were made to list them on species level. Form the Gulf of Kutch, Gideon *et al,* 1957, recorded four genera of corals. In spite of all the above works, the reef building corals of our waters largely remained unknown till the late sixties of this century.

Of recent years a large number of papers on taxonomy, ecology and resources of our reefs have emerged in many leading publications as a result of painstaking work of Indian and foreign scientists. Nearly a hundred papers on reefs of India including monographs were published since 1968, Pillai and coworkers in a series of papers described the corals of Gulf of Mannar and Palk Bay detailed taxonomic analysis of the fauna from this area has been made in 1986. He has also dealt with the ecological interferences in our reef system. The coral fauna of the Nicobar Islands was fully described and amply illustrated in a monographic work by Scheer and Pillai (1974) which is mainly based on the collections of the 2nd Xarifa Expedition, West Germany. Pillai (1963) described some reefs of Andaman and listed the coral fauna. The coral fauna of Lakshadweep was studied by Pillai from 1967 and has check listed the fauna. Subsequently Pillai and Jasmine described and figured all the known species of corals from Lakshadweep (1980). The coral fauna of Gulf of Kutch was described by Pillai and Patel for the first time (1988). The coral formation and coral fauna from the south west coast of India from Trivandrum to Cape Comorin was also studied by Pillai and Jasmine and a report is under preparation. The major areas of reefs so far covered for taxonomic and ecological studies of our reefs include Gulf of Mannar and Palk Bay from Tuticorin to Rameswaram Island. Almost all the atolls and islands of Lakshadweep have been reported by CMFRI. Corals of Gulf of Kutch from Port Okha to Pirotan Island and some areas of Middle Andamans (The Wandoor Marine National Park) and Nicobars have been studied. Still vast areas of Andaman and Nicobar Islands need study, though Reddiah (1977) gave some description of the reefs of Andaman and Nicobar Islands.

The major aspects of reef studies so far covered by various workers in the last 25 years or so are summarised as follows.

Morphology of reefs and distribution of reef building and reef dwelling organisms (S.E. India, Gulf of Kutch, Lakshadweep).

Taxonomic studies on corals (S.E. India, Andaman and Nicobar Islands, Gulf of Kutch, Lakshadweep and south west coast of India).

Studies on the anthropogenic and natural impact on reef environs (S.E. India, Lakshadweep and Andamans).

The Coral Fauna of India

A total of 199 species of scleractinian corals from India's territorial waters is hitherto recorded from the major coral growing areas of Gulf of Mannar, Gulf of Kutch, Andaman and Nicobar Islands and Lakshadweep. Deep water forms still await investigation. It is possible that a few more species await detection from our waters especially from the Andaman area.

The following is the distributional data:

Area	Genera	Species	
Lakshadweep	27	105	(Pillai & Jasmine 1989)
Gulf of Kutch	24	37	(Pillai & Patel, 1988)
Andaman & Nicobar	59	135	(Pillai, 1983)
Gulf of Mannar and Palk Bay	37	94	(Pillai, 1986)
Total for India Genera 71 species 199.			

Detailed literature survey of recent work is not attempted.

Estimation of Taxa

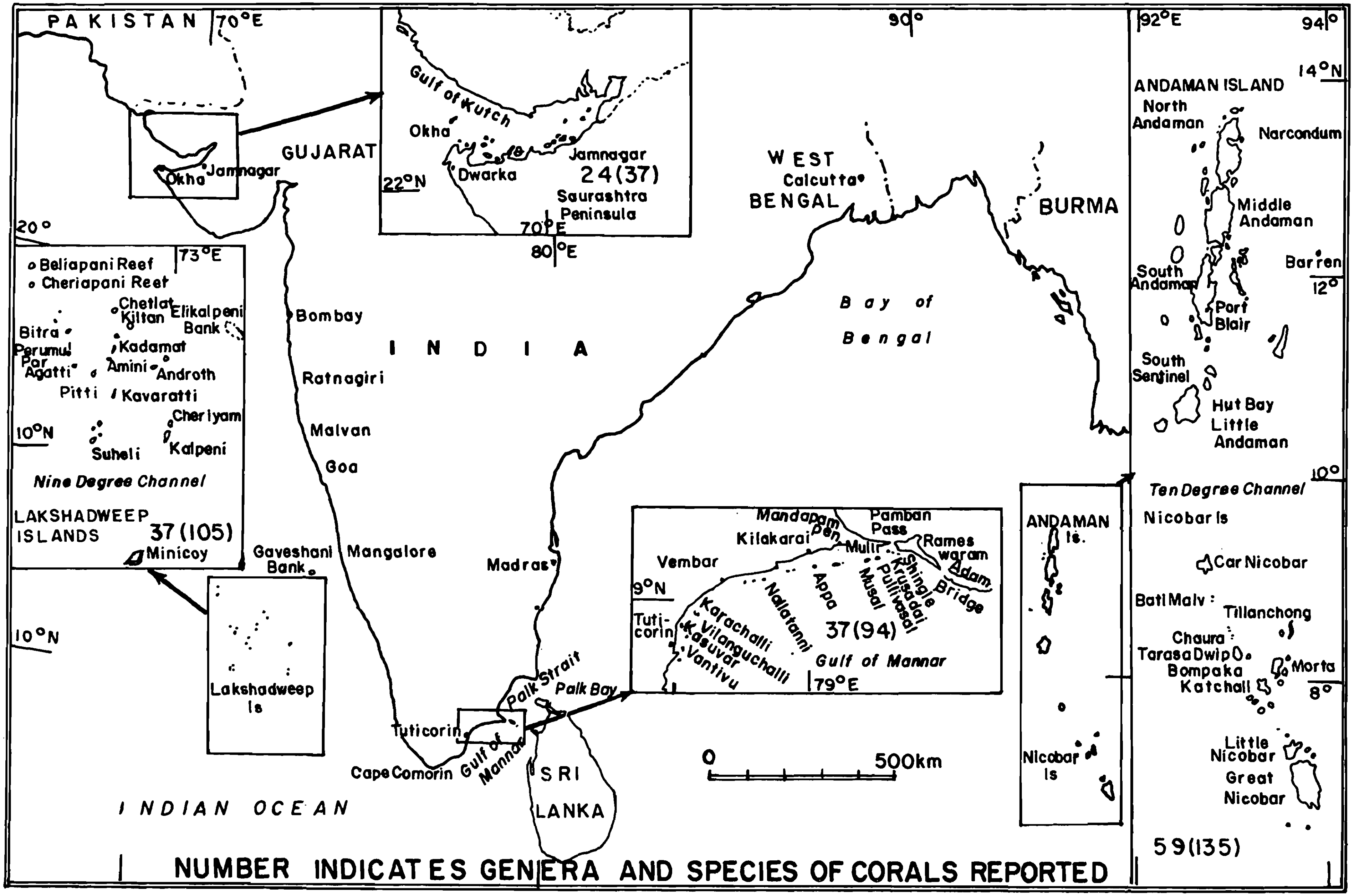
Phylum *COELENTERATA* Frey and Leuckart, 1847

Subphylum *CNIDARIA* Hatschek, 1888

Class *ANTHOZOA* Ehrenberg, 1834

Subclass *ZOANTHARIA* Ehrenberg, 1834

Order *SCLERACTINIA* Bourne, 1900



Scleractinia : Number indicates genera and species of corals reported

The Indian coral fauna includes genera and species of all the five suborders of the order Scleractinia. The suborder Astrocoennina is represented by the families Thamnasterridae with a single genus *Psammocora* (4 known species). Family Pocilloporidae is represented by 4 genera of which *Pocillopora* is the commonest genus in all reef habitats. At least seven species of *Pocillopora* are recorded from India. Family Acroporidae is perhaps the richest in species number all over the Indo-Pacific, the common genera being *Acropora, Montipora* and *Astreopora.* At least 31 species of *Acropora* occur in our waters. *Montipora* of different growth forms is represented by 20 species and *Astreopora* by 2 known species. The Suborder Fungiina has two superfamilies in Indian waters viz. Agariciicae and Fungiicae. *Pavona, Pachyseris, Leptoseris, Gardineroseris* are common genera. A total of 15 species of Agariciicae of the family Agariicidae are known. The genus *Coeloseris* is known only from Andaman waters with a single species. Family Siderastreidae has three genera viz. *Siderastrea, Pseudosiderastrea* and *Coscinarea* each with a single species. The members of this family are not very common on our reefs. Superfamily Fungiicae includes the solitary *Fungia* and allied genera, and the major reef builder *Porites* and *Goniopora.* Family Fingiidae has *Cycloseris* (5 species), *Fungia* (8 species), *Fungiacyathus* (1 species), *Herpolitha* (1 species), *Polyphyllia* (1 sp.) and *Podabacia* (1 species). Fungids are common in Andamans and Lakshadweep but very rare along the main land coast. The superfamily Poriticae of the suborder Fungiina is represented by the family Poritidae. The genus *Porites* with 10 species hitherto recorded is the most abundant coral on our reefs and is mainly exploited for construction work and industrial use. The other genus *Goniopora* is also common and has about 5 species in our waters. A third genus of this family is *Alveopora* and is extremely rare on surface reefs.

The suborder Faviina is represented by families Faviidae, Trachyphyllidae, Rhizangiidae, Oculinidae. Merulinidae, Mussidae and Pectinidae. *Favia* (6 species), *Favites* (6 species), *Goniastrea* (2 species), *Platygyra* (2 species) and *Hydnophora* (2 species) are the common genera of the family Faviidae. They constitute important massive reef builders. *Leptastrea* and *Cyphastrea* are also present in all the reef environs. Another genus of Faviidae is *Echinopora* which cut large foliaceous platforms and is very common in Gulf of Mannar though not common in other parts of India. A total of 30 species of Faviidae is hitherto recorded. The families Trachyphylliidae, Rhizangiidae, Oculinidae, Merulinidae, Mussidae and Pectinidae are not abundantly represented in our waters.

The Suborder Caryophylliina has only two families, Caryophylliidae an Flabellidae. The former has 10 genera, mostly deep water and solitary. Flabellidae is represented by *Flabellum* (the cup coral) and *Placotrochus,* both of which are ahermatypes.

The fifth Suborder of Scleractinia has a single family viz. Dendrophyllidae. Mostly solitary but *Turbinaria* and *Dendrophyllia* are colonial. A total of 7 genera and 18 species are known from our waters.

Current Studies

Scientists of Central Marine Fisheries Research Institute, Cochin are studying ecology and human interferences on our reef systems in Lakshadweep and Andamans. A recent survey in Lakshadweep was made to select suitable islands as biosphere reserves with a view to protecting the endangered reefs. The Central Drug Research Institute, Lucknow and some Universities are screening reef corals and reef associated organisms for biomedical compounds. The Scientists of National Institute of Oceanography reef systems in Lakshadweep. INTACH is having a project to assess the environmental damage on Andaman reefs. The coral fauna of the southwest coast of India is being studied in Central Marine Fisheries Research Institute, Cochin.

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CTENOPHORA

Annandale & Kemp (1915) first recorded Ctenophora in Chilka Lake. Moser (1909) recorded some forms from German Expedition. Menon (1927) provided a preliminary note on a new species, *Ctenoplana indica*. Varadarjan (1934) discovered a species of *Coeloplana* commensal on starfish (in the sea, off Krusadai Island). Aiyar (1939) recorded the occurrence of *Cestum amphitrites* from Madras Coast. Devanesan & Varadarjan (1939) reported the *Coeloplana* spp. discovered by Tattersal at Krusadai and in 1942 they described 3 new species of *Coleoplana* from Krusadai Island.

Expertise

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PLATYHELMINTHES

Introduction

The Platyhelminthes or flat worms constitute one of the major phyla of Animal Kingdom. These animals exhibit a great diversity of form and diverse bionomic relations. They are included in a single phylum due to certain common features, viz. bilateral symmetry, dorsoventral flattening of body, ciliated epidcrims in free living forms and at some stage in parasitic species, absence of coelome or body cavity, an incomplete digestive system, excretory system formed of protonephridia or flame-cells. One or more of these characters may be vestigeal or lacking in parasitic forms. They also have certain common negative features such as absence of metamerism, skeletal, circulatory and respiratory systems. Hyman (1951) defined them as "Acoelomate Bilatoria with a definite anus". Formerly they were divided into three classes viz. Turbellaria, Trematoda and Cestoda. Some authors include Mesozoa and Nemertea also under this phylum, while majority consider them separate phyla. In recent times class Trematoda has been divided into two separate classes viz. Monogenea and Trematoda.

Most of the members of the phylum are parasitic and this phenomenon has greatly influenced the character of the group. Within the phylum there are groups illustrating gradual transition from a free-living mode of life to extreme dependence. The organs useful for parasitic mode of life have been proliferated while those structures which are essential for free living existence have been reduced or discarded. Thus we find absence of locomotary and sensory organs. The absorption of nutrients by the body surface has resulted in progressive regression of digestive system, so much so that in cestodes it is entirely absent. The metabolic rate is probably not affected and efficient excretory system has developed for discharging nitrogenous waste. Their location inside the host body with limited supply of free oxygen led them to adapt to araerobic respiration. Normally the parasite remains within and perishes with the host. For perpetuation of the species the progeny must escape from the first host and find a new host. The larval stages are minute with little capacity to take food and limited locomotive capacity. To cope up with this hazards of parasitism these groups have developed enormous reproductive capacity and interpolated alternative hosts.

The phylum Platyhelminthes comprises four classes : Turbellaria, Monogenea, Trematoda, and Cestoda.

Turbellaria

Turbellarians are generally small, free living carnivorous worms. Mostly they are less than 5 mm in length but the larger forms also occur in the orders Tricladia and Polycladida; some of the terrestrial planarians attain a length upto 50 cms. They are oval to elongate, flattened ventrally and somewhat convex dorsally. The body may be tuberculate or papillate; members of the Temnocephalida have anterior tentacles and a ventral muscular adhesive organ. The smaller species are white or translucent and present shades of gray or brown depending on the ingested food. The larger species are often brilliantly coloured due to presence of pigments in or under the epidermis, and have stripes, bars, or blotched patterns in green, red, yellow, orange and black colours. The anterior end bears the sensory organ, contains the principal ganglionic mass or brain of nervous system and precedes in locomotion. The body is covered by a cellular or syncytseal epidermis beset with cilia or minute rhabdoral spicules. They are primarily hermaphroditic; with often complex reproductive system. The fertilization is internal and life cycle simple. The eggs usually contain large amount of food material in the form of vistelline cells, but the Acoela and Polycladida lack vitelline glands and in some of the polyclads a free swimming larva is produced. Many of the

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Turbellaria are either commensals or parasites : the rhabdocoels in echinoderms and molluscs; the allocoels in Crustaceans; the triclads in crustaceans, echinoderms, molluscs, chelicerate arthropods and selachian fishes. They are said to be the precursors of different classes of the phylum Platyhelminthes. The classification of the group is based on the details of digestive or reproductive systems by different workers. The most accepted classification is based on the form of intestine and comprises the following five orders:

Acoela	Minute, marine forms, mouth ventral, no distinct intestine, gonad in parenchyma, without reproductive or excretory ducts; at times coloured green or brown due to symbiotic algae.
Rhabdocoela	Small, marine, freshwater or terrestrial forms, free living, commensal or parasitic worms, pharynx simple, intestine saccate, gonads compact, testes few, reproductive ducts and simple protonephridial excretory system.
Allococla	Usually larger than rhabdcoels, mostly marine, a few freshwater forms, pharynx of variable type, intestine lobate, testes numerous, prostonephridial system complex.
Tricladida	Large, elongate marine fresh. Water or terrestrial worms. Pharynx plicate, intestine triclad, Gonopore single. Excretory system complicated with numerous nephridiopores.
Polycladida	Large, broad, typically marine forms of shrinking shape and colouration. Pharyrx plicate, intestine much branched, gonads numerous, vitellaria absent; gonadapore common or separate for male and female ducts.

Historical Resumé

The foundation for a sound knowledge of Indian Turbellarians was laid in the first quarter of the 20th century by workers such as White-house, Mexiner, Muth, Kaburaki, Dutta and others. Unfortunately the trend has not been maintained in recent years. Except for a few occasional papers the group appears to have received very little attention.

Mexiner and Muth (1912) reported on a collection of aquatic turbellarians, made in Tibet by Capt. F. H. Stewart, during the year 1907. They dealt with the description of certain species of the families Catenulidae, Dalydellidae, Typhloplanidae under the Rhabdocoela, and *Sorocelis* under the Tricladida.

Whitehouse (1913) described two new species of planarians, viz. *Planaria aborensis* and *P. kempi* from the Abor Hills in the North-east India. Again in 1914, he described eight new species of land turbellarians of the genera *Bipalium*, *Placocephalus*, *Pelmatoplana* and *Cotyloplana*. Further, Whitehouse (1918) gave a detailed systematic account of Indian land turbellarians in the possession of Indian Museum. The collections were earlier made from several parts of former Travancore and Cochin states; Nilgiri Hills; Coimbatore in south India; Kumaon Hills in the Western Himalayas; Kurseong, Cherrapunji (Meghalaya), in the Eastern Himalayas; and some from Sri Lanka. In this interesting paper he dealt with 11 species of *Bipalium* of which six were described as new to science. Further, new species of *Cotyloplana* from Nilgiris and four new species of *Pelmatoplana* from Kumaon, Kurseong, Pattipola (Sri Lanka) and Madathoray (former Travancore state) were described at length.

Based on a very small collection of freshwater and land planarians from Andaman Islands, Kabursaki (1925) dealt with new species, viz. *Planaria andamanensis* and *Bipalium vinosum*. Besides, Kabusami (1918, 1920) also contributed to our knowledge on the freshwater triclad fauna of adjacent countries such as Inle Lake in Burma and Siam in Thailand. Arora (1944) recorded freshwater turbellaria from Kashmir and Kapadia (1947) the occurrence of *Bipalium sp.* in Junagadh (Kathiawar, Gujrat State). Ramakrishna (1953) reported for the first time occurrence of land planarian, *Dolichoplană feildeni* from India. Saxena (1957) gave an account of a new species of *Bipaluim* viz. *B. keshavi*, from Nepal. Chauhan and Ramakrishna (1958) dealt with description of a new turbellarian *Bipalium roonwali*. Kawakatsu (1969) described *Dugesia indica* from Jabalpur. Ramakrishna Rao (1987) studied the systematic and the biochemical contents of polyclad worms from Waltair coast.

Very little attention seems to have been paid to other aspects of study, viz., anatomy, bionomics, physiology etc. Dutta (1925) dealt with the anatomy of a rhabdocoelid turbellaria, *Mesostoma gangetica* and he (1926) described the structure and bionomics of a freshwater turbellaria belonging to Acoela. Ghoshal (1988) gave an account of regeneration in a freshwater turbellarian. Much remains to be done in this group and there is a need to develop expertise in the country.

Estimation of Taxa

Families	Genera	Species
8	15	47

Expertise

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Monogenea

Monogenea are almost exclusively ectoparasites of aquatic vertebrates. According to Baer (1951) at least 95% of the genera have been reported from fishes, primarily the elasmobranchs. Some monogeneans also occurs on the gills, or in the mouth and urinary bladder of amphibians and reptiles and even one species has been reported from the eye of the hippopotamus. The monogeneans are morphologically similar to rhabdocoel turbellarians of the family Graffillidae. They are small worms with posterior portion of the body modified to form a haptor, a disc-like structure, which hooks or suckers or both and is a powerful adhesive organ. The anterior end bears the mouth and pharynx. The intestine may be saccate or bifid and is often branched. Excretory system is duplicate with anterior dorsolateral pore. The worms are hermaphroditic with a single ovary and one of many testes. Eggs bear long filaments. Life cycle is simple and development is direct. The larva is ciliated and has a brief free-swimming period before it attaches to the host.

Class Monogenea is divided into two subclasses (1) Monopisthocotylea with two orders and (2) Polyopisthocotylea with two orders.

Sproston (1946) had listed 679 species spread over 130 genera. The number has definitely increased two fold by now.

Historical Resume

The earliest reference on Indian Monogenetic trematode appears to be that of Bell (1891), who described a new species, *Tristoma histiophori* now know as *Capsala laevis* (Verrill, 1874)from *Histiophorus brevirostris* caught at Madras. Von Linstow (1906) described another new species, *Tristomum negacotyle* parasitic on the body of sword fish, *Histiophorus* fished off Sri Lanka coast. According to Chauhan (1952) this collection was composite and consisted of *Capsala megacotyle* and *Capsala avalis*. Luhe (1906) reported a new species *Epibdella macrocalpa* (= *Benedenia macrocalpa*) from the skin of *Rhinoptesa javerica* caught in Sri Lanka. Stewart (1914) described *Polystovorum kachugae* from the urinary bladder of *Kachuga lineata* from freshwaters of Lucknow. This species is now known as *Polystomoides kachugae*. Thapar (1929) reported the excretory system of *Discocotyle sagittatum* at Lucknow. After Stewart it took more than two decade for another work to appear when Price (1938) described *Dactylogyrus moorthyi* on a collection from *Puntius puckelli* and *P. ticto* made by Moorthy at Chitaldrug, Karnataka. Dayal (1941) reported *Diplozoon indicum* from a freshwater fish *Puntius sarana* at Lucknow. Chauhan (1945) made large collection from marine fishes of Bombay coast and described two new genera, viz. *Bilaterocotyle* and *Pricea* and eight new species. Bhalerao (1945) described *Loimos secundus* infecting the gills of Indian dog fish, *Scolioden sorrakowah* from Rangoon. Thapar (1948) erected a new genus and species *Paradactylogyrus faflaius* from *Catla catla* at Lucknow. Kaw (1950) reported a new species of Diplozoon *kashmirensis* infecting the gill of *Schizothrax* sp. in Dal Lake, Srinagar and also erected a new genus *Eupolystoma* with *E. rajai* as its type collected from the urinary bladder of a frog *Rana* sp. at Pinch, Kashmir. Subhpradha (1951) described a new genus and species *Vallisiopsis cantorta* and another new species *Gastrocotyle indica* from marine fishes at Madras. Ramalingam (1952) added six new species to genus *Pricea* collected from *Gymbium guttatum* at Madras. Chauhan (1950, 1952) described three new species, *Mazocraes orientalis Mazocraeoides prashadi* from marine fishes collected at Puri and *Capsala gouri* from *Thynnus thunnina* taken at Bombay. Chauhan (1953) in his monograph on the Indian Monogenea compiled the description of 30 species described till then besides discussing the classification and phylogeny of the group and a host-parasite list of Indian species. Tripathi (1954) described two new genera, viz. *Bicotyle* and *Megamicrocotyle* and six new species. Tripathi (1957) published a monographic paper in which he added 68 new species, including 13 new genera and three new families to the Monogenea fauna of India. Jain (1958-1961) added a number of new species and new genera from freshwater fishes from Lucknow. Unnithan (1957, 1961, 1964) studied the monogeneans of marine fishes of south western coasts and added a number of new species besides discussing the taxonomy.

Silas (1967) gave a list of monogenous of Scombroid fishes. Gupta and Khullar (1968) reported a new species. *Heteraxinoid pseudosciaenai* besides redescribing a number of known species from marine fishes off Bombay and Calicut. Karyakarte (1967-72) worked on the monogenra of Marathwada fishes. Kulkarni (1969) described Monogenea from freshwater fishes of Hyderabad. Gussev (1974) in a monographic study discussed the systematics of Indian Monogenea described till then and gave an analysis of the world fauna and evolution of the group. Agarwal and Kumar (1980) described a new species parasitic on the gill of *Bagarius bagarius* at Varanasi. Gupta, and Sharma (1981), Gupta, (1983) added new species to the genus *Bifurcohaptor*. Srivastava, (1984) gave an analysis of the Monogenea infecting estuarine fishes. Agrawal, and Singh (1980-1990) in a series of papers worked out the Monogenea of freshwater fishes of Lucknow. Rao (1975) described a new species *Polystomoides sinhai* from the urinary bladder of *Kachuga tectum tentoria* caught from Godavari river in Nizamabad district. Khocha (1971-78) worked on monogeneous marine fishes of Arabian Sea.

Estimation of Taxa

Families	Genera	Species
28	110	295

There is a big lacuna with regard to Monogenea of marine fish. The freshwater fishes also deserve more attention with regard to monogenean infection.

Expertise

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Trematoda

Trematodes constitute an important group among helminths, which occur as parasites of vertebrates in adult condition, inhabiting practically every organ system in the host. In larval condition they complete part of their development in invertebrates, particularly molluscs, and lower vertebrates. There is an alternation of hosts, hence the name Digenea.

Though John de Brie (1379) was attributed as the pioneer worker on the trematodes, Zeder (1800) was the first to attempt the classification of parasitic worms and to divide them into five classes viz i Round worms, ii Hook worms, iii Sucking worms, iv Tape worms, and v Bladder worms. Trematodes were included by him under Sucking worms. Rudolphi (1808) substituted the name Trematoda to Zeder's sucking worms and adopted it as an order instead of class. Dujardin (1845) made the first taxonomic arrangement of trematode genera and grouped Aspidobothrii of the order Trematoda into two families viz. Distomea, comprising endoparasitic forms, and Polystomea, consisting of ectoparasitic forms. Burmeister (1856) separated Aspidogaster and proposed three-fold division of trematodes into Pectobothrii, Malacobothrii, and Aspidobothrii. Till then classification of the trematodes was based mainly on the organ of attachment. Van Beneden (1858) proposed the separation of the trematodes, on the basis of life-cycles, into two orders Monogenesis, including forms with 'direct' development and a single larval stage between sexual generations, and Digenesis, comprising forms with 'indirect' development and alternation of sexual and asexual generations. This new basis, however, did not greatly affect the overall arrangement of trematodes. Carus (1863) amended van Beneden's terminology to Monogenea and Digenea. Monticelli (1892) revived Burmeister's scheme of classification proposing three orders. viz., Heterocotylea, Malacocotylea, and Aspidocotylea, which has found favour with many authors.

Baer and Euzet (1961) removed Monogenea from Trematoda and elevated it to a separate class in the phylum Platyhelminthes. This arrangement was accepted by most of the workers (Mehra, 1970). Baer and Joyeux (1961) recognized three subclasses viz. Aspidogastrea, Digenea, and Didymozoidea. Stunkard (1962) restored Burmeister's system but revised the status of Aspidogastrea. He divided the Trematoda into two subclasses, viz. Pectobothridea with orders Monopisthocotylea and Palyopisthocotylea; the last one is now recognised as separate class named Monogrnoidea and Malaobothridia, with orders Aspidobothrea and Digenea. In the latter he (1963) recognised four suborders viz. Strigeatoidea, Echinostomatoidea, Plagiorchoidea and Apisthorchoidea.

Odhner (1905) subdivided the order Malacocotylea into two suborders (i) Gasterostomata, and (ii) Prosostomata. Poche (1926) recognised van Beneden's 'orders' and divided Digenea into two suborders, (i) Gasterostomata, with a single family Bucephalidae, and (ii) Prosostomata. He further subdivided Prosostomata into two Tribes (i) Fascioboidea with two substribes, 10 super families and 61 families, and (ii) Aspidogastroidea, with a single family. Aspidogastridae. Fuhrmann (1928) followed Poche upto suborder level and accepted 60 families. Faust (1929) agreed with the earlier classification of Burmeister but raised Prosostomata to the rank of an Order, and recognised four suborders under it.

Daves (1946) accepted three orders in Trematoda and two suborders in Digenea. He, however, did not recognise any superfamily grouping. His scheme was accepted by Yamaguti (1958) who recognised "Aspidobothria or Aspidocotylea" as a separate order. Skrjabin (1947-1962) and his collaborators recognised Digenea as a subclass and divided it into two subclasses (i) Gasterostomatoinei and (ii) Prostomatoinei, with two super orders and nine orders. Subsequently Skrjabin *et al.* 1962 dropped the subclass Gasterostomatoinei, relegating it as order Poucephalida.

La Rue (1957) proposed a revision of Digenea, based on life-history data and mode of formation of excretory bladder in larval stages designed to show genetic relationships. He divided subclass Dignea into two super orders, five orders, ten suborders and 84 families. Mehra (1957, 1958, 1962) suggested certain modifications to La Rue's classification recognised only eight orders. Subsequently (Mehra, 1970, 1980) proposed a revision of the classification of Trematoda in which he accepted Monogenea as a distinct class. Under class Trematoda he accepted two subclasses viz Aspidobothrea Burmeister, and Digenea van Beneden. He divided the latter into five orders, 14 suborders and 23 super families.

Most of the modern workers like Stunkard (1946, 1961), Daves (1946), Hyman (1951) and others are of the opinion that the classification of Digenea is still controversial and the grouping of families into higher taxonomic units is tentative, pending more complete knowledge than available at present, concerning all stages in the life cycle of a large number of species and information furnished by the study of both adult and larval stages reflecting genetic relationships and evolutionary histories of the group. The higher grouping has not met with general acceptance.

Historical Resumé

The first reference of Indian trematodes in modern times was made by Gilchrist (1841-1846) in his book "A practical treatise on the diseases of elephants, camels and horned cattle" Later on Cobbold (1859,1862,1869-1882) in a series of papers described parasites of man, elephant, cattle, gangetic dolphin and *Orcaella brevirostris* etc, thus laying the foundation of a systematic study of tematode fauna of the Indian region. Lewis and Cunningham (1872) described *Distoma conjunctum* (= *Opisthorchis naverca*) Lewis and Mcconnell (1876) reported *Gastrodiscoides hominis* from the intestine of man. Banford (1887) recorded spined egg of *Schistosoma indicum* in the large intestine of bullock in Calcutta. *Paramphistomum cervi* and *Gastrodiscus aegyptiacus* were reported by Gibs (1892) from cattle and horse respectively. Same year *Fasciola hepatica* from *Portax picta, F. jacksoni, Dicrococlium pallaii* and *Fasciolopsis rathouisi* were reported by Stossich (1902). Buttle-Reepen (1900) described *Distoma ampullaecaeum* from a cetacean in the Indian Ocean. *Pleurogenes gastroporus* (= *Pleurogneoides gastroporus*) and *Mesocoelium sociale* from amphibian were recorded by Luhe (1901). Fishoeder (1901-1903) reported a number of amphistomes collected from cattle, horses and elephants in India and Sri Lanka. Powerl (1903) reported the presence of *Schistosoma haematobium* from a human host in the country. Shipley and and Hornell (1904, 1905) described *Problitrema richiardii, Distoma palleniscum, Gymnophallus sumateriae* and *Aspidogaster margratifera.* Stossich (1904) reported *Styphlodora hornidun* from *Boa constrictor* Luhe. Newmann and Lingard (1905) recorded *Halipegus longispina, Pneumoneces capyristes Pseudoamphistomum truncatum* and *Gastrodisus aegypticus*. The year 1906 was significant for the discovery of several species of Schistosomes viz. *Schistosoma spindalis, S. indicum, S. bovis Ornithobelharzia bomfordi* (= *Orientobilharzia bomfordi*) from the blood vascular system of domestic animals. The year was also notable for the discovery of *Fasciolopsis macrocalpa, Acanthosolus biodorus, Anaporrhuntu largum, Schistorchis carneus, Stephanochasmus ceylonensis* and Lypcrosomum Squamatum were reported by Luhe (1906) and Linstav (1906). Looss (1907) described *Gastrodiscus secondus* from a mule in Assam and (1908) *Paradistomum ceratophorae* from reptile in Ceylon. Evans and Rennie ('908-1910) worked on the parasites of domestic animals of Burma. Stiles and Goldberger (1910) described several amphistomes of domestic animals from India and Ceylon. Giager (1910, 1915) published a check list of the parasites of domestic animals in India. Mitter (1912) reported *Homalogaster* sp. and Nicoll (1912) described *Styphlodora majae* and *Xenopharynx solus* from cobra. Southwell (1913) described the trematodes of the Pearl Bank of Sri Lanka and reported *Isoparochis hypselobargi* from the air bladder of *Wallago attu*. Lane (1915) recovered *Artyfechinostomum suprartyfex* from a girl in Assam. Stephens (1916) recorded *Ophsthorchis noverca*. Linton and Soparkar (1917) reported the occurrence of *Agamodistomes* in anophiline mosquitoes. Trematodes of fishes of Bengal were reported by Southwell and Prashad (1918). Sewel (1920, 1922) redescribed *Mesocoelium sociable* and recorded *Leucochloridium assamense* respectively. Jackson (1921) described *Fasciola gigantica* from cattle in Burma. *Paragonimus campactus* was reported from mungoose by Vevers (1923). In the same year Mapplestone (1923) published a monograph on amphistomes in which he discussed the status of several Indian species. The amphistome nos. 2 and 3 of Evans and Rennie (1908) were named *Paramphistomum birmiense* and *P. microon* respectively Railliet (1924). All these studies were made by foreign workers on material sent to them or collected by them during their stay in India. By now Indians started coming in the field. Bhalerao (1924) gave the description of *Eurytrema daji* and *Testifrondosa cristata* from the food mammals of Rangoon. He (1925) identified *Isoparorchis hypselobagri* from man sent to him by Chandler who was working on the parasites of cats of Calcutta.

The year 1926 marked the beginning of the study on the trematode fauna of India by several Indian workers. In a series of papers Bhalerao worked out the parasites of house crow, water snakes, bat and the frog in Burma and described several new genera. Chandler discovered eggs of *Schistosoma incognitum* from human faeces, Mehra and Negi described *Tremiorchis ranarum* and *Paragonimus edwardsi* respectively. In 1927 *Opisthorchis pedicellata, O. dendriticum, Mesocoelium meggitti, Strigea annandali* and *Neodiplostomum kashmirensis* were described by Verma, Morgan, Bhalerao Faust. Northup in Rangoon worked on trematodes of Chiroptera while Mehta and Negi described these from frogs at Allahabad in 1928. Phadke and Gulati (1929) described *Pachytrema hewletti* and the species of the genus *Paradiscomum* in Burmese reptiles and from India by Bhalerao and Narain and Das respectively in the same year. In 1930 Baer, Nagaty, Jordan, Verma, Moghe and Thapar added to our knowledge of trematode parasites of the country. In the year 1931 Mehra, Moghe and Thapar added some new forms of trematodes from reptiles, bat and spine. Choudhary published his remarks on the trematodes of the genus *Paradistomum* and Bhalerao reported trematodes of pigs in Bengal.

In the year 1932, Bhalerao dealt with the identity of Schistosomes found in case of nasal granuloma and gave a note on the probability of infection of man and domestic carnivores by *Psoparchis hypsclobagri*. Datta described the etiology of bovine nasal granuloma. Datta, Mehta, Sinha and Pande reported new species of parasites of the group Typhloplama, Pronocephalidae Cephalogonimus and Cephalogonimidae respectively. Mehra and Bokhari also described a new species of the subfamily Telochinae. Moghe reported two new species of trematodes from an Indian ruff. Singh and Hickey investigated the way to control Fascioliasis in cattle in India. Rao and Ayyar studied *heterophyes* species from dogs. Harshey described new forms of the genus *Opergaster* from dogs.

Bhalerao (1933) recorded the trematode infection of Indian elephants, gave preliminary note on the life history of common liver fluke and parasitic gastritis and fluke infection of ruminants under field conditions in India. Datta (1933) expressed his opinion on the cause of persistent debility in equines in this country and attributed it to *Schistosoma indicum* infection. In the same year Mehra erected a new genus *Coeuritrema* and described the new blood flukes of the family Sperorchiidae Srivastava, Thaparand Dayal, and Dayal reported new parasites of Meniuridae and Lecethodendriidae, Asctotrema respectively. Srivastava also discussed the genera Vitellotrema and Genarchopsis. Rao reported his preliminary findings of adult trematodes from *Cercariae indicae* bovine nasal Schistosomiasis in the Madras Presidency and included the description of the parasite which caused this disease and succeeded infecting the experimental calves with the larvae of these parasites.

Mehra, Pande, Srivastava and Thapar and Dayal in the year 1934 added new species of the family Spisorchiidae from turtles and fresh water fishes. Mehra, and Thapar and Dayal also discussed the family of blood flukes and the family Allocreadiidae respectively. Sinha gave an account of a new genus of blood flukes of the family Spisorchiidae. Srivastava erected a new genus *Mehrarorchis*. Bhalerao reported the occurrence of *Schistosoma japonicum* in India and Rahimullah and Das recorded the trematode infection in certain fishes of Hyderabad state. A case of Schistosomic dysentry in dog was reported by Swaminatha. Rao studied two species of Schistosomes, *S. spindalis* and *S. nasalis* and the latter species was claimed as new by him.

The year 1935 seems to have induced many workers in the country to take up the study of trematodes. Bhalerao produced a valuable monograph of helminth parasites of domesticated animals and described some new monostome trematodes from avaian hosts and reported the parasites collected from elephants of Andaman and Burma. Dayal, Lal, Mehra, Pande and Srivastava dealt with new trematodes of the genera *Haplorchis, Monorchotrema, Notocotylus*, family Lecithodendriidae, *Pyenoporus, Catatropis* respectively. Srivastava also described some new distomes from Indian fishes. He also erected new genus *Orientophorus* and described a rare parasite of subfamily Dinurinae. Sinha added a new genus to the family Aspidogastridae. Mehra discussed the classification of the family Lecithodendriidae. Pande gave his remarks on *Anchitrema* and *Lecthodendruim*. Trematodes of birds were reported by Patwardhan, Thapar and Lal. Verma studied the bird parasites mainly dealing with the family Echinostomatidae and Diplostomidae. He rerected the genus *Episthochasmus* apart from describing several new species in the form of notes. Rao and Rao and Ayyar reported further observations on bovine nasal Schistosomiasis and included preliminary report on their findings of Schistosome eggs in faeces of dogs. In his preliminary report Pande discussed acute amphistomiasis of cattle in Assam.

In 1936 Bhalerao published three parts of 'Trematode parasites of India' Lal, Mehra, Srivastava and Verma added new species of the genera *Paramonostomum, Harmotrema, Decemtestis* and the family Bucephalidae. Mehra revised the family Harmotrematidae. Lal revised the genus *Paramonostomum*, added a new species under the genus *Parorchis* and erected a new genus under the subfamily Typhlocoelinae along with a new strigeid parasite of the rare genus Cyathocotyle and another genus Levinseida. Srivastava also added fresh forms of Prosorchinae. Binara while describing *Schistosoma japonicum* discussed the problem of Schistosomiasis in India.

Bhalerao in 1937 continue his researches on the Helminth parasites of India and published his fourth part on Indian trematodes. He also studied the trematode parasites collected from Calcutta Zoo and proposed new genus Pneumotrema. Lal published his results on the trematode parasites of birds in two parts, in which he discussed the value of different characters in claissification of avian trematodes and some new blood flukes of the family Schistosomatidae. Pande studied the trematode parasites of fishes and frogs of U.P. and described three new speices from the former and four for from the latter host. Srivastava reported new parasites of the family Hemiurigae and the genus *Gyliauchan*. He also reported new prasites of the subfamily Discogasterinae and proposed two new genera, *Yamagutia* and *Indolerogenes*. He also reported the parasites of the families Acanthocolpidae, Gorgoderiddae, Bucephalidae besides erecting family Waretrematidae, subfamily Polyorchitreminae under family Heteropohyidae and a new genus *Mehracola*. Two new genera were also proposed by him to accomodate the amphistomes of freshwater fishes. He reported the occurrence of *Paragonimus westermani* in the lungs of cats.

Thapar discussed about.Helminthological studies in India. Harshey described some more new forms of *Opegaster*. Vidyarthi described trematodes of the genus *Diplostomum*.

In 1938 Bhalerao proposed a new genus*Travassosotrema* and published a paper on Schistosomes and Schistosomiasis in India. Dayal, Lal, Pande and Srivastava reported new forms of the genera *Astiotrema, Psilorchis*, subfamily Stomylotre matinae, *Crassiphiala* and *Gylianchen, Pedunculacetabulum* and *Prosthogenomus* respectively. Dayal also erected four new genera, *Neoganada, Phyllochnus, Nizamia* and *Gorgotrema* from fishes. Pande further repoted two new trematodes from Indian cyprinid fishes, revised the genus *Allocreadium* and proposed a new genus of Pleurogenetinae apart from reporting *Harmostomum* from toad. Srivastava eluciated the life history of *Cotylophoron cootylophorum* and added new forms under family Acanthocolpidae and Gorgoderidae.

In 1939 Bawa published a premilinary report on intestinal amphistomiasis in sheep. Buckley published his observations on *Gastrodiscoides hominis* and *Fasciolopsis buski* in Assam. Mehra Mehra, Pande, and Srivastava reported new trematodes of families Spirorchiidae, Pronocephalidae and genera *Lyperosormum*, *Acanthocolpus*, *Aponeurus*, *Hysterolecitha* and *Stomachicola*. Pande also described two new species from India. Bhalerao gave an account of the development of the knowledge of trematode fauna of India. In the same year Srivastava studied the parasites of the family Monorchidae, Haplosplanchnidae Monodhelnidae and Hemiuridae besides reporting *Fasciola gigantica* infection in the lungs of goats.

In the year 1940 Mehra proposed a new genus *Enterohaematotrema* and described new blood flukes of the genus *Hemiorchis* and *Dendrilobilharzia*. He also published his remarks onevolution of blddo flukes. Chauhan described two new species of avian trematodes.

Bhalerao in 1941 reported the bat fluke *Prosthodendrium ovimanosum* in a dog and published a paper on trematodes of Indian fishes. Bhalerao and Gideon reported the occurrence of *Prosthogoniums putschkowskii* in India. Mehra while describing new species of the genus *Opisthorchis* discussed the synonymity of the genera *Gointea* and *Opisthorchis* and proposed a key to species. Srivastava reported new prasites of the genera *Haplochadus* and *Sterrhenurus* and *Lepocreadoides* beside proposing new genus *Indoderogenus*.

Bhalerao, Dayal, Srivastava and Sinha in 1942 reported new trematodes from *Mastacembelus* and of the genera *Diplozoon*, *Lecithocladium* and *Acanthostomum*. Bhalerao also reported two trematodes from ruminants. He published papers on Strigeids *Cephalogonimus* and larval clinostomes. Dayal erected two new genera *Eucreadium* and *Plesiodiscomum*. Srivastava proposed a new genus *Horatrema* and reported blood flukes of dog.

Bhalerao in 1943 reported the occurrence of parasites of the genus *Cephalogonimus* in India and Burma, two new trematodes of fishes and some metaceracarial forms of Clinostomidae. Chauhan, and Dayal dealt with some new species *Aspidogaster* and *Mehratrema* and the family Bucephalidae respectively. Gupta studied the paramphistomid parasites of Lahore. Mehra discussed the validity of the genera *Proalarides* and *Travassostomum* and the species *P. tropidonotus* and *I. natritis*. He also dealt with the classification, distribution and evolution of the family Cyathocotylidae and revised the genera *Holostephanus* and *Cyathocotyle*. Srivastava revised the genus Plagioporus and Opechona and added new forms. He also proposed a new genus *Indocreadium* and published a paper on bovine nasal Schistosomiasis.

In the year 1944 Inamdar and Bhalerao recorded the occurrence of *Psilochasmus longicirratus* in India. Bhalerao also gave some remarks on the identity of immature amphistomes causing diarrhoea domestic animals in this country. Dayal proposed two new genera *Eucreadium* and *Neopodocotyle* to accomodate some parasites of freshwater fishes. Kaw dealt with the parasites of freshwater fishes of Kashmir and reported a new species of the genus *Crepidostomum*. Srivastava studied the trematodes of Indian marine fishes and also elucidated the life history of *Paramphistomum explanatum*, *Gastrothylax crumenifer*, *Dicrocoelium dendriticum* and *Fasciola hepatica* and recorded a new intermediate hosts of *F. gigantica*.

In 1945 Bhalerao recorded the common amphistomes of domestic animals of Central Provinces (now M.P.) and their intermediate snail hosts. Chauhan dealt with certain forms of the family Hermiuridae. Moghe published his findings of a survey on the nature and incidence of helminth infection in cattle, sheep and goat in Central Provinces, Berar and Central India. Mudaliar and Ramaniyachary reported a new species, *Schistosoma nairi* from elephant. Thapar and Sinha described a new amphistome.

Bhalerao in the year 1947 dealt with a new species of the genus *Clinostomum* and also elucidated the life history of *Dicrocoelium dendriticum*. Mehra gave further account on classification of the family Cyathocotylidae. Moghe and Chauhan reported blood fluke infection in cattle, goat and sheep of Central Province, Berar and Central India. Mudaliar and Alway published a check-list of parasites. Rao discussed the problem of Schistosomiasis among sheep and goat in Poona.

In the year 1948 Bhalerao dealt with problem of blood fluke in India. Chatterjee, Dayal and Vidyarthi reported some new forms of the genus *Platynotrema*, family Bucephalidae and Cyathocotylidae respectively. Iyer dealt the immature amphistomes in sheep in Govt. cattle farm, Hosur. Peter and Mudalier elucidated the life cycle of *Gastrodiscus secundus*. Srivastava studied the parasites of marine food fishes and tortoises and erected a new family.

Baugh in 1949 recorded a new avian trematodes of the genus *Psilorchis* and reported *Psilochasmus oxyurus* from India. Chauhan dealt with the helminths collections present in the Zoological Survey of India and Dayal reported trematode infection in India fishes. Sinha proposed a new genus of toroise trematode and Tandon described new form of the genus *Lissemysia*. Sinha proposed a new genus of tortoise trematode under the subfamily Encyclometrinae.

In 1950 Alwar revised the literature on Schistosomes in this country. Baugh, Dayal, Gupta dealt with new trematodes of the genera *Paryphostomum* and *Allocreadium* respectively. Gupta redescribed *Paramphistomum (Cauliorchis) crassum* and Murty reviewed schistosomiasis in cattle. Reddy and Varma reported *Paryphostomum suprartyfex* infection in man. Sinha elucidated the life history of *Cotylophoron cotylophorum*.

Gupta, Rao, Srivastava the year 1951 dealt with some new forms of the genera *Cephalogonimus*, *Phyllodiscomum* family Hemiuridae and subfamily Leptophallinae, genera *Echinochasmus and Asymphylodora*. Gupta and Srivastava proposed new genera *Macrotrema* and Eumasenia respectively Gupta redescribed *Paraphistomum bathycotyle*. Srivastava and Dutt eluciated the life history of *Schistosoma indicum*.

Chatterjee and Dutt and Srivastava, in the year 1952 dealt with two new trematodes of the genera *Platynotrema* and *Ornithobilharzia* respectively. Dayal redescribed *Bucephalopsis karvei* and reported a new species of the family Hemiuridae. Dayal and Gupta studied the trematodes of family Cephalogonimidae. Gadgil and Shah discussed the problems of human Schistosomiasis in India. Lal and Baugh and Lal and Gupta studied histopathologial changes in snail tissue due to larval trematodes. Lal and Mathur studied the parasites of the genus *Prosthogonimus*. Thapar and Tandon worked out the life history of *Fasciola gengantica*.

Anantaram and Balsubramanian, Dayal and Gupta and Singh in the year 1953 reported new forms of the genera *Diplostomum*, *Ganeo*, *Echinochasmus* and *Echinostoma*. Dayal and Gupta described new species of the family Opisthorchiidae and subfamily Haplorchiinae. They also proposed three new genera *Brahamputrotrema*, *Gauhatiana* and *Oudhia*. The year was also notable for the publication of Trematode fauna of India in four parts by Chauhan. New and known species were reported by Gupta, Kant, Lal and Rao and Hiregander. Hawkings, Ray and Mehra reported *Dicrocoelium dendriticum* infection in Himalayan lagoons. Varma described a new species *Fasciola indica*.

Gupta, Jaiswal and Singh and Saxena reported new forms of the genera *Pleurogenes Encyclometra*, *Ganeo*, *Gmmatobrephus*, *Mehrorchis*, *Cephalogonimus*, *Asticotrema*, *Philophthalmus* and *Neodiplostomoides* in 1954. Dhingra studied the spermatologenesis in five species of trematodes. Gupta and Dhillong reported two new strigeids while Singh proposed a new genus *Psilocollaris*. Varma studied the nature, incidence, distribution and central of nasal schistosomiasis and Fascioliasis in Bihar.

Chatterjee and Chauhan in the year 1955 studied the parasites of subfamily Grassiphialinae ana taxonomic position and distribution of *Isoparchis*. Dutta and Dutta and Srivastava illucidated the life history of *Schistosoma indicum* and *Ornithobilharzia dattai* respectively. Ganapati and Rao reported metacercaria in freshwater fishes of Waltair. Jaiswal reported of the genus *Philophthalmus*

Lal described a metacercaria from the eye of a trout while Lal and Baugh studied histopathology of snail tissue due to trematode infection. Tandon recorded *Paramphistorium gotoi*. Chatterjee, Srivastava and Srivastava added new forms of *Echinochasmus, Brachylaimus, Psilostomum, Diplostomum* and *Xenopharynx* in 1956. Gupta reported two new Allocreadiids. Gupta reported trematodes from mrine fiehs of Gulf of Manar. Sinha and Srivastava redescribed *Schistosoma incognitum*.

Some extensive work on Indian trematodes has been published in the year 1957. Dutt and Srivastava developed a new technique of specific diagnosis of animal schistosomiasis, development of *S. spindalis* and suceptibility of equines to this parasite. Gupta, Gupta and Singh described new forms of *Neodiplostomum, Psilochamus* and *Diplostomum* respectively. Goil studied the carbohydrate metabolism in some treamtodes of domesticated animals. Jaiswal reported trematode parasites of fishes and birds of Hyderabad state. Krishnaswami and Anantaraman reported *Paradistomum* infection in Indian reptiles. Srivastava and Trisul reported *Schistosoma turkestanicum*. Tandon worked out the life cycle of *Olveria indica* and reported a new species of *Paramphistomum*.

Chatterjee, Gupta Siddiqi, and Singh dealt with new forms of *Cyclocoelum, Haematotrephus, Ceylonocotyle, Cotylophoron, Astiotrema and Euparadistomum*. Chakravarty and Sinha Jain studied the egg. Mirracidium of *Paryphostomum mehrai*. Srivastava proposed a new genus *Proechinocephalus*. Ahluwalia in 1960 discussed two genera *Emyda* and *Stumkardia*. Mukherjee and Srivastava elucidated the life cycle of *Gigantocotyle explanatum*. Gupta and Srivastava added new species to genus *Fastula*. Rai and Agarwal discussed individual variations in *Xenopharynx solus* and their importance in taxonomy Mehra described trematodes of the group *Staphylorchis* and discussed the phylogeny and evolution of the family Gorgoderidae.

In the year 1961 Bhardwaj proposed two new genera, *Pseudoartyfeehinostomum* and *Mehraformis*. Srivastava added two new species to the genus *Phyllodistomum*. Mehra dicussed the classification of order Echinostomida and erected new superfamilies.

Mehra in 1962 revised the superfamily Allocreadioidea and family Brachylaemidae and erected several new subfamilies. Gupta continued his work on trematode parasites of Indian birds. Srivastava described two new species from fishes and proposed a new genus *Rhynchocreadium*. Sinha worked out trematode parasites of reptiles of Hyderabad. Mukherjee studied the miracidium of *Stenkardia dilymphora*.

By mid sixties many workers came in the field and studies on trematodes got a boost. Many centres for helminth studies developed. Hafeezullah (1971), Hafeezullah and Siddiqi (1970) worked out the trematode parasites of marine fishes of India. Trematodes have been studied by Rai and Agarwal (1961) Fotedar and his collaborators (1959-1984) Gupta (1965-1989), Agarwal, (1967, 1989), Pandey, (1962-1990) Srivastava, (1963-1990), Srivastava and Ghosh Mukherjee (1962-1986), Mukherjee and Ghosh (1967-1900 1967-1969), Gupta, (1956-1986) Madhvi (1971-1989) Karyakarte (1967-1971) Sinha and his collaborators (1962-1989) Hafezullah and Datta (1980, 1981) Mukherjee, and Srivastava (1988, 1989), Ghosh (1979-1989) and many others. Mehra (1970) gave a detailed classification of Trematoda recognising five orders. No volume on Trematode Fauna of India was available till Mehra submitted his first volume dealing with the order Fasciolatoidea. This was published under the Fauna of India series in 1980. Since the volume included species described till about 1963, Srivastava (1982) provided a supplement to this volume updating the volume. Chauhan and Ghosh (1975) reviewed the work done by the ZSI scientists in the last 50 years. Periodic review of the work done in India has been published by Bhalerao (1947, 1948) Thapar (1937, 1947) Srivastava (1960) Chauhan (1962). Studies on Larval Trematodes : The study on larval trematodes in fresh and brackish waters of India apparently have not received as much attention as it deserves. Linton and Soparker (1918) first started the study of Cercariae in India and began with the life history of *Schistosoma spindalia*. Kemp and Gravely (1919) investigated into possibility of the introduction of human Schistosomiasis in India by troops returning from overseas after the first World War. Sewell (1919) studied about the possibility of the occurrence of *S. japoricum* in India. Sopakar (1921) published a detailed account of the cercaria of *S. spindalis* and also few other fork tailed cercariae from *Indoplanorbis exustus* from Bombay. Sopakar (1924) described *Cercaria patialensis* which was redescribed by Anantaraman (1948) and belongs to the family Transversotrematidae.

Sewell (1922) continued the ork on cercariae and published his monumental work "Cercariae Indicae" In this work he modified the scheme of classification given by Luhe (1909) in many respects and attempted to derive the distomes from monostome stem. He laid emphasis on the excretory system and other morphological details of cercariae to show phylogeny and evolution of various groups of Cercariae and their adults. Luhe (1930) gave an account of *C. nicobarcae* and a paper on excretory system of Cercariae in general. Rao (1929) described C. anamola which was redescribed by Sewell (1930). Chatterjee reported *Cercaria allahabadi* from Allahabad, which Singh (1953) confirmed as strigeid larva. Faruqi (1930) described echinosteme larva, *Cercaria mehrai*, the life history which was completed by Jain (1958) and adults were identified to belong to the genus *Paryphostomum*. Rao (1932, 1933) described two new furcocercans cercariae *C. hurleyi* (Strigeid) and *C. saundersi* (Schistosome). In 1933-34, he also discovered the life history of a new Schistosome, *Schistosoma spindalis*, showing that *Cercaria indicae* XXX Sewell, 1922 was its larva. Bhalderao (1943) made a survey of cercariae fauna of irrigated tracts of Nizam's Dominion and suggested their possible relationship to adults parasitic in man and domestic animsls. Buckley (1939) described cercariae of *G. hominis, F. buski* and a new amphistome cercariae.

These studies were followed by a number of workers which in subsequent years has shown promising results. Khaw (1947) reported that *I. exustue* served as intermediate host of *S. indicus*. Srivastava and Deltt (1951) studied in detail the life cycle of *S. indicum* and showed that this cercaria is very similar to that of *S. spindalis*. Dutt and Srivastava (1952, 1955) described the cercaria of *O. dattai* and completed the life cycle. Sinha and Srivastava (1954, 1956) in a series of papers dealt with cercariae belonging to Strigeids, Clinostomes, Spirorchids, Bucephalids and Schistosomes. He also published a detailed account of the life cycle of *S. indicum* in 1958 and the life cycle of *Clinostomum piscidum* in 1959. Premavati (1953) described *C. cruciata*, a Xiphidocercaria and two furcocercons cercariae *C. magnacristate* and *C. quadriglandula*. These belong to sanguinicolid and strigeid groups as shown by Singh (1960). In 1954 she described *C. tuberculatus* from *Melanoides tuberculatus* and two more cercaria *C. caudiglandula* and *C. tuniforka* from the same snail host. Premavati (1955, 1956) described *C. multiplicata*, and *C. reniforma, C. flavidusi* and *C. gomtiensis*, all collected from *Melanoides tuberculata*. Rao, Gadgil and Shah (1953) reported the snail *Paludomus obesa* may be the likely snail host of *S. haematobium*. A year later Gadgil and Shah reported *Ferrissia tenuis* serving as snail host for this Schistosome.

Baugh (1954) described *C. pendulata* and *C. lucknowansis* from *Belamya bengalensis* at Lucknow. Peter (1955) dealt with cercariae fauna of Madras and described *C. mudaliari*. Patki (1956) described C. robertsoni in lophocercans group and discussed their relationship. Agarwal (1956) studied *Cercaria stylata, C. humkheri* from Bajalpur and life history of a new species of Clinostome, *C. giganticum*. Tandon (1957) described the life history of *G. crumenifer*. Srivastava, (1957, 1958) described six cercariae, *C. shibi, C. srivastavai, C. luteoli, C. rajai* and *C mathpurensis*. Tandon (1959) reported the cercaria *Enterohaematotrema palaearcticum*. Srivastava (1958) reported *C. sewaiti* similar to *C. bombayensis* of Sopakar. Peter (1958) reported two new amphistome cercariae. Tandon (1958) described the cercaria of *Fischoederius elongatus*. Mukherjee (1960) elucidated the life histories of *Ceylonocotyle scoliocoelium* and *Cotylophoron indicum* and reported two new amphistome cercariae. In recent years cercariae have been studied by Agrawal (1959), Ganapati and Rao (1962, 1968, 1969) Gupta and Taneja (1969), Hanumantha Rao (1957-1973), Krishna and Sinha (1979), Madhvi & Rao (1968-1970), Madhvi (1980), Mohandas (1971-1979) Pandey and his collaborators (1965-1983) and many others. Mukherjee (1986) published a volume on amphistome cercariae under the Fauna of India series.

In spite of the foregoing work much remains to be done when we take into account. the multiplicity of genera and species available in the country. Ghosh and Srivastava (1990) while discussing the host parasite relationship in reptiles showed that in a total of about 534 species of reptiles only 45 species have been studied for trematode infection.

Estimation of Taxa

A total of 47 families distributed under five orders have been reported from the country. They comprise about 250 hundred genera and 750 species from different hosts.

There is further scope for the work. It appears that in the total host species available in the country only a meagre percent had been screened for helminth infection. The applied aspects and life histories are other fields which need attention.

Expertise

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Cestoda

Tapeworms or cestodes have been known from the ancient times the earlier belief was that both the segmented and bladder worm shapes developed spontaneously in the body of other animals. Earlier scientific records on the tapeworm zoology were made by Tyson (1691) Andry (1700), Frisch (1727), Fabricius (1780) and Bloch (1782). Benham (1901) published a Treatise "The Platyelmia and Nemertini," A treatise on Zoology. In the middle of the last century, Kuchenmeister, Van Beneden, Leuckart, von Seibold and others showed that bladder worms are actually developmental shapes stages of taenoid cestodes and that the egg of cestodes contain larvae which develop into bladder worms in appropriate host. The life history of relatively few species belonging to different groups, have been worked out during the past hundred years. In spite of extensive and intensive study the cestodes remain controversial and puzzling creatures. For quite some time there has been the controvery as to whether the tape worm is an individual or a colony; whether the transformation between onchosphere and later larval types is a true metamorphosis and finally, whether the scolex is at the anterior posterior end of the body.

Rudolphi (1809) while giving the technical names to replace the vernaular names given by Zeder (1800) proposed Cestoidea (from Latin, *cestus* - girdle). The class contains about 4000 to 5000 described specis being parasitic chiefly in the digestive tracts of vertebrates in adult condition and a variety of invertebrate and vertebrate hosts in larval stages. Monticelli (1892) divided it into subclass: (i) Cestodaria-containing families Caryophyllidae Leuckart 1878, Amphiliinidae Claus, 1879 and Gyrocotylidae Benham, 1901, the members of these families being monozoic, since they do not form chain of proglottids; and (ii) Cestoda-comprising all other families members of which are merozoicor polyzoic forming chain of proglottids Fuhrmann (1930-1931) arranged Cestoidea into two subclasses (i) Cestodaria with two orders with single family in each and (2) Cestoda, with five orders and thirty-one families. Some authors replaced the class name cestoidea to Cestoda and subclass Cestoda to Eucestoda. Wardle and McLeod (1952) recognised fourteen orders and fortynine families. Seven of the orders comprised only single family and one order with a single species, the identification of which is equivocal. Yamagenti (1959) listed thirteen orders and fiftyfive families, of which six orders are with single families Wardle, McLeod and Radinovsky (1974) recognised twenty orders. Spasskii (1950, 1968)in Essential of Cestodology made many changes in the classification of cestodes. It may be inferred that the taxonomy of Cestoda is still in unsettled. Acording to Stunkard (1970) Class Cestoda comprises two subclasses: (i) Cestodaria containing monozoitic parasites with lycophoron larvae with ten hooks; and (2) Encestoda: the merozoic or polyzoic tapeworms under subclass Eucestoda comprises five orders viz. (i) Tetraphyllidea (ii) Trypanoorhyncha, (iii) Pseudophyllidea, (iv) Protcocephala, and (v) Ceclophyllidea. All the families are accommodated under these five orders.

Historical Resumé

The earliest reference on Indian cestodes was the publication of report on tape worms of camels by Leese (1911) with discovery of a subfamily of cestodes with yolk glands. Cestode parasites of fishes and birds have been studied by Southwell since 1911. He published a series of papers and monographs on this group apart from contributing two volumes on cestodes in the Fauna of British India series (1930). Hornel (1912) described some cestodes from fishes. Southwell & Prashad (1918) described Hilsa cestodes. A school on cestode studies was developed under Prof. Meggit who published a series of papers on taxonomy and life history of Indian and Burmese cestodes which have enhanced our knowledge. He (1934) proposed a Host Parasite theory and showed its application in case of Cestodes. Sondhi (1923) worked out tapeworms of dogs in Punjab. Aggarwala (1925) reported an unusual location for *Echinococcus* cysts in the body of the sheep. Moghe (1923-1933) described a new *Monopyliddium* and several bird cestodes from central India. Gulati (1929) reported a new *Dipylidium*. Johri (1931-35) and Inamdar (1933-34) made notable contributions on the cestode parasites of Indian birds. Woodland (1923-1926) worked on fish cestodes and considered caryophyllaeidae as a primitive group of cestodes and showed their affinities with the Gyoocotylidae. Verma (1926-1928) described several tetraphyllids and Proteocephalids. Malkani (1933) investigated the problem of scolices of larval cestodes and showed experimentally that the process is helped by surface tension. Bhalerao (1936) reviewed the genus *Avitillina* and described some already known species and two new species from goat and sheep. He (1944, recorded seven species of cestodes from poultry. Burt (1937-1944) in a series of papers described some known and many new forms mainly from birds of Ceylon. He erected seven genera under the families Dilepididae and Dioccocestidae. Many of the genera and species reported by him have since been recorded from India. Inamdar (1942) described a new avian cestode *Shipleya farrani* from a stilt which was later referred to *Pseudoshiploya* Yamaguti, 1959. Chauhan (1947) recorded *Paronia* sp. from a fowl apart from some known species from fishes and birds. Chauhan and Ramakrishna (1959) reported fish John, L. N. (1939-1953) described a number of avian cestodes and erected two new genera *Thaparea* and *Neyralla*. Misra (1945) reported a new species of the genus Oochoristica from lizard. Mudaliar (1939, 1943) described some known and a new species of cesode from domestic. Subramanian (1930, 1940) described new cestodes from fishes in Madras. Woodland (1941) revised the genus *Duthiersia* parasitic inreptiles. Misra (1945) added a new species to the genus *Oochoristica* from a lizard. Hanumantha Rao (1954) reported a new species *Bothriocephalus ganapatii* which he later (1960) transferred to a new genus *Penetrocephalus* besides studying the Mehli's gland complex by histochemical methods. He also described a new species of *Ptychobothrium* from a flying fish. Sharma (1949) described a new *Rhabdometra* from birds. Singh (1948-1964) in series of papers described a new *Rhabdometra* from birds. Singh, (1948-1964) in a series of papers described some known species from fish, snake and birds. He gave keys to the species of genera *Gangasia* and *Ophryocotyloides* besides erecting four new genera under the family Dilepididae from avian hosts and one new genus *Indotaenia* from a flying squirrel in the family Anoplocephalidae. These were based on the material collected by him in sixties from high altitudes of Kumaon region. This survey appears to be the first survey carried out at high altitude. Subhapradha (1951, 1955, 1957) described a number of new species from marine fishes of Madras coast. Johri, (1955-1957) described a number of marine fishes of some new cestodes from fish, lizard, snake, birds and erected two genera *Lallum* and *Hunteroides*. Singh, K. P. 1956, 1959) described a number of new species from avaian hosts including a new genus *Chettusiana* of the family Dilepididae. Chatterji (1954) described two new species from avain hosts. Siddiqi (1960)described a new unisexual genus *Neodioecocestus* from a grebe at Aligarh. He (1960, 1961) in a series of papers described in detail the external characters, cuticle, musculative hook and rostellum excretory system and the nervous system of *Cotugnia digonopora*. Mukherjee (1962) studied the cestodes from Rajasthan and reported eight new species besides known species. This work was published in 1970. Hae (1964, 1965) described three new species from birds. By late sixties and seventies a number of workers started work on this interesting group of parasites and made substantial contributions. Mention may be made of Fotedar (1965) Raina (1968-1975) Saxena (1970) Baugh and Sexena (1975) Gupta (1973) Chishsi (1973), Fotedar and Chishti (1977), Malviya and Dutt (1969, 1971) Shinde (1965-1980) Srivastava, (1986-1985) Srivastava, and Pande (1980), Srivastava, (1981), Capoor (1966-1985), Hafeezullah (1986), Tandon (1981-1988), Malhotra (1978-1989), Ghosh (1975-1990) Luho studied the cestode parasites of amphibia and reptiles besides publishing papers on the bird and mammal cestodes. Srivastava, Pandey and Tayal (1984) studied the bird cestodes of Lucknow and Faizabad districts and described seventeen new and known species besides erecting a new genus. Agrawal (1965-1980) studied fish cestodes from Raipur. Rajyalaxmi (1981-1988) studied cestodes of Waltair coast fishes. Kundu (1985), Kundu *et al.* (1985) studied cestodes of fishes. Tandon (1988) analysed caryophlelgellids of Shillong.

The work on other aspects of cestodes has been rather negligible. Anantaraman (1948, 1951) described the importance of oribatid mites, which serve as intermediate host of *Moniezia* and some other of locephaline cestodes, and also the life history of *Moniezia* from India. He (1954) gave a probable scheme of development in the genus Mesocestoides the life history of which is not fully known. Dutt and Sinha (1961) described the life history of *Choanotaenia infundibulum* and Dutt, Sinha and Mehra (1961) that of *Raillietinia cesticellus*. Though *Moniezia* is the only cestode to have the characteristic inter-proglottidal glands yet almost nothing was known about its morphology, chemical nature and function till Singh and Singh (1958) described in detail the morphology of the glands for the first time. Ghosh and Srivastava, (1988) studied the host parasite relationship in cestodes of reptiles. It was observed by them that out of 435 specis and subspecies of reptiles occurring in India only 12 have been screened for cestode parasites. Further they noted that cestodes have not so far been recorded from turtles throughout the world. Srivastava, Ghosh and Dey Sarkar (1975), Ghosh and Srivastava (1989) discussed ligulosis problem in Dam and reservoirs. With the multiplicity of genera and species of host available in our country much remains to be explored.

Estimation of Taxa

Familes	Genera	Species
33	156	530

Expertise

INDIA

In ZSI

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ROTIFERA

Introduction

The rotifers comprise a group of pseudocoelomate microscopic organisms usually ranging in size between 40 µm - 250 µm while some large species (rarely extending upto 2.5 mm) can be percieved by the unaided eye as minute dots, sacs or rods. They have been invariably treated as a class of the Phylum Aschelminthes or even as a distinct phylum by some authors and they exhibit many structural features in common with Gastrotricha and Nematoda. Clemente (1980) attributed their affinity to Platyhelminthes and postulated that these two groups probably had a common ancestor. According to Sladecek (1983), the rotifers represent a very old group of invertebrates and are presumed to be a product of the aerobic phase in the development of our planet though there is yet no palaentological evidence to support this view.

These fascinating creatures have long been called Rotifera or 'Rotatoria' or 'Wheel-animalcules' as their disc-like anterior end (corona) bears resemblance to a pair of revolving wheels owing to the synchronized beating of their coronal cilia. These are also characterised by a specialized pharynx called the mastax, with its cuticular lining differentiated into trophi which act as jaws. These micro-organisms shows remarkably intricate structure and exhibit endless profusion in their body forms which are morphologically well adapted to their living habits and closely related to their habitats. The vast majority of rotifer encountered under natural conditions are females, males, however, are known relatively for a few species, they are diminutive, degenerate and seldom survive for more than a couple of days. The rotifers show world-wide distribution, possess striking ability to colonise diversified biotopes and indicate rapid turn-over rates. They reflect interesting strategies for reproduction, population dynamics, spatial and vertical distribution and survival while some of them are notable for the ecotypic and cyclomorphic variations and prey-avoidance mechanisms.

Rotifers are mainly found in freshwater which is considered their original habitat. However, during the course of their evolution to the present multiplicity, they have invaded and become adapted to various other habitats. As a result, they are now encountered in a wide range of aquatic and semi-aquatic environs. They are more important in freshwater ecosystems because of their occurrence in practically all biotopes varying from a trickle on the rocks and small tree-holes to large rivers, from bogs to inland salt water lakes and from ephemeral polls to the limnetic, littoral or deepest regions of the largest lakes. This view is supported by the fact that about 95% of the rotifers are known from freshwater habitats while less than 5% of them are known to restrict in marine or brackish waters. Amongst the groups of the animal kingdom which established in freshwaters, only few succeeded in leaving the bottom to inhabit the pelagial region. Rotifers are prominent than almost any other such group to adapt to the open water as about 30% of the rotifer genera live constantly or occasionally in the plankton. Besides aquatic ecosystems, the rotifers occur in decomposing vegetable debris (e.g. manure pits), in mosses dampened only occasionally and in the interstices between the sand grains of lake and river beaches from the Arctic and Antarctic to the Tropics. The rotifers comprise an important component of soil micro-invertebrate communities (the Edaphon). Freshwater environments are predominated by the monogononts while only 20-30% of bdelloids inhabit the shores of these ecosystems. On the other hand, about 95% of the rotifers found in mosses and soil are bdelloids. A majority of these organisms are free-living and solitary, sessile or colonial taxa belong only to a few families. A few species of rotifers are known to take to commensal or synoecious associations with freshwater cladocerans, snails, insect larvae, prawns and other lower crustaceans. Only few species are reported to be parasitic on some colonial or filamentous algae (e.g. *Volvox, Vaucheria*) and aquatic worms (May, 1989).

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Importance: There is yet no evidence that rotifers are injurious to any animal or plant that is of importance to human beings. They, however, comprise an integral link in the aquatic food-chain; the part played by them in the biological productivity is of considerable significance partly because of their rapid turn-over rates and metabolism and partly because many species largely feed on detritus and bacteria and are consequently to a great extent independent of autotrophic production,. The rotifer invariably constitute a dominant component of freshwater Zooplankton and , hence, contribute significantly to their dynamics and production. They often serve as food for fry, fingerlings and adults of various commercially important and culturable species of fishes. It is in this context that during the last couple of decades considerable attention has been focussed on intensive culture of various species of freshwater and brackishwater rotifers as supplementary food for aquaculture practices. These organisms are regarded as valuable bio-indicators to depict the trophic status of water quality of their environments within limnosaprobity (Sladecek, 1983; Berzins and Pejler, 1989) and, therefore, these organisms are being increasingly used in environmental toxicological studies and bioessay experiments. The soil rotifers play an important part in the food balance of these biotopes owing to their abundance and wide range of feeding habits. They aid countless other micro-organisms in promoting the proliferous structure of the soil by constructing their nests between gains, depositing their wastes ans finally adding their own dead bodies.

Nomenclature: Leeuwenhoek (1703) was the first to provide figures and descriptions of rotifers (particularly bdelloids) but considered them as protozoans. Linnaeus (1758) listed three species of these organisms under Zoophyta. Baker (1764) mentioned them as Wheel-Animals but did not attempt any classification. Muller (1773, 1786) and Pallas (1776) described many species but considered them Infusoria. Cuvier (1798) placed them in Kingdom Zoophytes, Class Infusories. The term Rotifera, however, was first applied by Du Trochel (1812) who also regarded them as a biological unit set apart from Protozoa. Lamarck (1816) considered them as section of the order Polypes Cilies among 'animaux apatiques' corresponding to Zoophyta of Cuvier. Ehrenberg (1832) treated them as a class of Infusoria and proposed the term Rotatoria. Ehrenberg (1839) classified Rotifera among the worms. Metschnikoff (1864) established the distinction between them and Gastrotricha. Hastschek (1878) recognised the trochophore larvae and Rotifers as having the same grade of structure. Zelinka (1889) included both Rotifera and Gastrotricha under Aschelminthes. Remane (1929-33) believed them to be the larvae of unknown worms that remained in their larval stage. Various other considerations on this group are detailed in the works of Edmondson (1959), Kutikova (1970) and Koste (1978).

Till recently, the terms Rotifera and Rotatoria have been frequently used for this group. Ricci (1983) questioned the nomenclatural validity of the use of these terms and after critically reviewing the literature recommended that the term 'Rotifera' by Cuvier (1798) should be regarded as the correct name while 'Rotatoria' by Ehrenberg (1832) was proposed as a synonym of the former.

Classification: As mentioned earlier, Rotifera are more commonly included as a Class of the Phylum Aschelminthes while Edmondson (1959) also considered them as a separate Phylum. Various earlier attempts at classification of this group presented a number of anomalies. The first standard classification was proposed by Harring (1913) but the detailed classification of Remane (1929-33) laid the foundation for the systematic work of Voigt (1957) but some changes were subsequently incorporated by Edmondson (1959), Sudzuki (1956), De Beauchamp (1965), Kutikova (1970) and Koste (1978). Other diagnostic works were by Rodescu (1960), Dommer (1965) and Ruttner-Kolisko (1974).

The general system of classification followed in this account is after Koste (1978) and for specific work on bdelloids the publication by Donner (1965) is taken into consideration. The division of class into subclasses and order derives from the structure of the female genitalia while families and lower subdivisions are differentiated on the structure of corona and the types of trophi.

Freshwater rotifers belong to various families of Sub-class: Eurotatoria and marine forms are represented by only one genus (*Seison*) of sub-class Seisona (Family Seisonidae). Bdelloids (Super-order Digonota) comprise an important component of moss-dwelling and soil rotifers.

Historical Resumé

The rotifers were first studied and described by Leewenhoek (1703) following the invention of microscope. Since then, these interesting organisms have drawn world-wide attention of amateur naturalists as well as professional hydrobiologists because of their intricate structure, profusion of body forms, wider distribution and easy availability. However, studies on this group from India date back to later part of the 19th century. Various investigations related to taxonomy, zoogeography and ecology of rotifers from this country are detailed below under three periodic levels:-

i) Pre-1900

This period incorporates the sole contribution of Anderson (1889) who initiated faunistic studies on freshwater rotifers from India. His collections from various aquatic ecosystems in and around Calcutta (West Bengal) dealt with 47 species, including the descriptions of 10 species and two uncertain species.

ii) 1901-1947

The studies during this period commenced with a list of 32 species of rotifers from the slopes of the Sikkim Himalayas, between altitudes of 610m - 2440m (Murray, 1906). This list included 8 species each of the genera *Habrotrocha* and *Macrotrachela*, 7 species of *Philodina*, 3 species of *Rotaria* and one species each of the genus *Adineta*, *Proales*, *Squatinella*, *Colurella*, *Lecane* and *Brachionus*. The predominance of bdelloids in Murray's material was due to the fact that these collections were made from mosses. After a time-lag of nearly three decades, Edmondson and Hutchinson (1934) examined samples obtained by Yale North India Expedition from 52 localities in the Punjab and Northwest Frontier Province (all parts now in Pakistan), 15 localities in the Kashmir basin (altitude between 1585m - 2620m), 24 localities in the then Indian Tibet and the extreme western part of the Tibet Proper (altitude between 3200m - 5334m) and 9 localities from the Nilgiri Hills in Southern India (altitude between 2133m - 2316m). These authors enumerated 99 species (excluding a few doubtful forms) from the mentioned samples that were taken mostly from alkaline waters at moderate or low temperatures. This paper included taxonomic and Zoogeographical notes, morphological variations in *Cephalodella catellina*, *Filinia longiseta*, *Keratella valga* and *K. quadrata* and comments on the rotatorian fauna of high altitudes. Edmonson and Hutchinson also gave a list of 37 valid species amongst those documented earlier by Anderson (1889).

Dr. R. B. S. Sewell, Late Director, Zoological Survey of India initiated work on rotifers in this institute. Sewell (1934) in his comprehensive study of the fauna of Salt Lake, Calcutta referred to five species from brackishwaters i.e., *Brachionus pala* (= *B. calyciflorus*), *B. bakeri* (= *B. quadridentatus*), *B. rubens*, *B. urceolaris* and *Asplancha brightwelli* and two varieties of *B. bakeri*. Of these, *A. brightwelli* was also reported to be common in freshwaters in and around Calcutta. Subsequently, Sewell (1935) gave a classical account of fauna of the tank in the Indian Museum compound and its seasonal changes based on the collections made during 1929-31. This paper dealt with 11 species of rotifers and their seasonal occurrence.

Karlsruhe worked on collections sent by Prof. (Dr.) Chappius, from some lakes in the then Madras Presidency and published three papers. First one dealt with the description of *Lecane sola* from Almati lake and *Monostyla conspicua M. bulla*, f. *diabolica* n. f. from Sholavarum lake. In addition, two new species of *Trichocerca* from Almati lake were documented in second one (1937) and third one (1937) dealt with a new variety and new form of *Brachionus angularis* from

Sholavarum and Almati lake. Ahlstrom's (1940) paper on the rotatorian genera *Brachionus* and *Platyias* referred to the material examined by Hauer (1937). Further, Ahlstrom (1943) in his revision of the genus *Keratella* dealt with a new variety of *Keratella quadrata* from Ootacamund lake, Madras.Little was known about the ecology of rotifers till the end of this period. Edmondson and Hutchinson (1934) referred to pH and water temperature while Sewell (1934) dealt with the salinity of the examined samples. Sewell (1935) made an attempt to explain seasonal changes of the fauna in relation to certain ecological parameters observed earlier by Pruthi (1933). This information was supplemented by Ganapati (1943) in his comparative study of plankton abundance in a garden pond at Madras.

Various earlier works till 1947, even though fewer in number, made significant contributions to systematics and distribution of rotifers in India, gave information about fauna of Salt Lake and initiated ecological studies on this group.

iii) 1948-1990

The period between 1948-1960 included a few taxonomic publications based on the collections by Dr. V. Brehm, Limnologial Institute, Lunz am See, Austria and those examined by J. Donner (an Austrian monk). Donner (1949) described *Horaella brehmi* nov. gen. et. nov. sp. from a tank in Banikpore, Bihar (collection v. Brehm, dated 13.9.1902) and listed another five species of rotifers, three species of cladoceran and two species of copepods from this sample. Further, Donner (1953) referred to Brehm's material from a filtration bed in Madras while describing *Trichocerca (Diurella) ruttneri* from Java and Sumatra, India and Neusiedlersee (Austria). Brehm (1950) in his article on the freshwater of India (Part II) dealt with three species of rotifers, including *Keratella cochlearis* from Palta water works in West Bengal. Subsequently, Brehm (1951) described *Brachinus donneri* an interesting brachionid, from Almati reservoir, Madras.

During 1951-60, contributions to rotifers ecology comprised parts of few studies on plankton ecology. Ganapati and Chacko (1951) studied plankton production and limnology of four fish ponds at the Chetpat fish farm, Madras while Chacko and Krishnamurty (1954) dealt with plankton on three freshwater ponds in Madras city. Dutta *et al.*, (1954) made observations on seasonal and periodic fluctuation in the plankton of Hooghly Estuary between a stretch of 68 miles from Palta to Diamond Harbour. Roy (1955) analysed plankton ecology of Hooghly river at Palta. Alikunhi *et al.*, (1955) examined quantitative variations of rotifers in a few nursery ponds at Cuttack (Orissa), though annual population was not attempted. The studies of Das and Srivastava (1955, 1956, 1956b) dealt with quantitative fluctuations of plankton and their ecology in a fish-pond and some tanks at Lucknow(Uttar Pradesh).

From 1961 onwards, there was considerable proliferation of researches related to systematics and ecology of these organisms from scattered localities and involving participation of workers from various institutions and universities. Different developments are treated separately in three following decades in view of accumulation of vast and diversified literature. The decade between 1961- 1970 included taxonomic studies from Tamil Nadu. Pash (1961) reported six species of lecanids from freshwater tanks and Coovum river in Madras. Hutchinson (1964) resurrected *Filinia pejleri* based on the figure given earlier by Edmondson and Hutchinson (1934) from Ootacamund lake (Madras).

In addition, Michael (1966) described a colonial rotifer, *Conochilus madurai* from Madurai while Wycliffe and Michael (1968) dealt with *Pseudombate acutipoda* an epizoic bdelloid from gill-chambers of *Caridina* sp. From the state of Maharashtra in western India, Arora (1962, 1963, 1963, 1965, 1966, 1966, 1966) presented a faunistic account of rotifers from polluted and clean water bodies in Nagpur city, gave ecological notes for different studied taxa and made observations on cyclomorphosis in *Brachionus calyciflorus, Keratella tropica and Platyias patulus*. Dvorakova (1963) examined rotifers from the Yamuna river and described a new species of the genus *Lecane*.

Nayar (1964, 1965) studied morphometric variations and cyclomorphosis in *Brachionus* *calyciflorus* from Rajasthan and documented (Nayar, 1868) 36 species (including on new species) of rotifers from this state. Nayar (1965b) gave taxonomic notes on Indian species of genus *Keratella*. Further, Nayar and Nair (1969) reported 15 taxa of south/brachionid rotifers from Kerala in India. Wulfert (1966) examined collections, from Ajwa river and Nimeta Water works, Baroda sent to him by Drs. Ganapati and Jayangounder and dealt with 87 species (including 9 new taxa and one new combination).

George (1966) made observations on cyclomorphosis in *Keratella tropica* from Roshnara tank, Delhi. Naidu (1967) initiated systematic investigations from Andhra Pradesh and dealt with 12 species from temporary rainwater puddles at Vijayawada and two old wells at Cuddapah and Chittoor. Subsequent studies of Vasisht and Gupta (1967) and Vasisht and Battish (1969, 1970) contributed 26 species from Chandigarh (Union territory) in North India. Vasisht and Dawar (1968) gave first description of male of *Cupelopagis vorax* from this city while an elaborate account of anatomy and histology of *Lacinularia flosculosa* was presented by Vasisht and Dawar (1970)

Ecological studies indicated considerable impetus during 1961-1970. Arora (1961) made observations on responses of rotifers to variations in some ecological factors (temperature, pH and dissolved oxygen). Arora (1961, 1966) made first attempt to designate trophic indicators amongst rotifers based on his observations in different water bodies in Nagpur city. George (1961) examined abundance of rotifers in five fish tanks at Delhi and later (George, 1966) gave a detailed account of comparative plankton ecology in these ecosystems. Moitra and Bhowmik (1968) studied seasonal cycles of rotifers in a freshwater fish pond at Kalyani (West Bengal). In addition, observations on the rotifer populations of two ponds at Pilani, Rajasthan were made by Nayar (1970). Some more investigations on rotifers as part of general plankton studies were from Karnataka (Gounder and Patil, 1961), West Bengal (Shetty *et al.*, 1966; Moitra and Bhattacharya, 1966; Michael, 1968, 1969), Uttar Pradesh (Devassy, 1965; Roy *et at.*, 1966; Pahwa and Mehrotra, 1966), Bihar (Pahwa and Mehrotra, 1966), Tamil Nadu (Sreenivasan, 1968), Chandigarh (Vasisht, 1968; Vasisht and Dhir, 1970) and Kashmir (Das *et al.*, 1969; Das, 1970).

The number of systematic studies nearly doubled between 1971-980. Vasisht and Battish (1971) contributed four papers dealing with rotifer fauna of North India based on collections from Chandigarh (Union territory) and Patiala (Panjab). Nair and Nayar (1971) reported 18 species from freshwaters in and around Irinjalakuda (Kerala).

Rajendran (1971) described *Conochilus arboreus* n.sp. from Madurai while Michael (1973) gave a preliminary account of rotifers from Tamil Nadu. Nasar (1973) and Laal and Nasar (1977) studied rotifer samples from Bihar. Ten important taxonomic contributions from Andhra Pradesh were made by Dhanapathi which were supplemented by two papers by Chandra Mohan and Rao (1976a, 1977) and Rao and Chandra Mohan (1976a, 1976b 1977). Some studies on the fauna of Jammu and Kashmir were undertaken by Das and Akhtar (1976), Das (1977), Qadri and Yousuf (1977) and Jyoti and Sehgal (1980). Bhardwaj *et al.*, (1978) studied a few colonial rotifers from Haryana.

Rotifer systematics in Zoological Survey of India remained unattended after initial publications of Sewell. This work was taken up again by this author between 1975-1978 as a research fellow in this institute and resulted in important contributions to the rotifer fauna of West Bengal (Tiwari and Sharma, 1977; Sharma, 1978-1980) 1978c, Himachal Pradesh, Haryana and Panjab (Sharma, 1976) and Orissa (Sharma, 1977, 1980). Later on, Sharma (1980) dealt with 38 species of Eurotatoria from Assam State in North-Eastern India while Sharma and Michael (1980) presented a synopsis of taxonomic studies on Indian Rotatoria.

The period between 1971-1980 reflected almost same magnitude of ecological information (in terms of total publications) as in the preceding decade. The studies of Rao and Chandra Mohan (1977), Das (1978) and Vasisht and Sra (1979) dealt with pollution indicators. In addition, Vasisht and Sharma (1976, 1977) and Jyoti and Sehgal (1979) made observations on their ecology from Haryana and Jammu respectively. Tiwari and Sharma (1977) commented on changes in species composition of the rotifers in Indian Museum tank, Calcutta in light of the earlier observations by

Sewell (1935). Various other contributions included rotifers in general plankton ecology and these were from Orissa (Saha *et al.*, 1971), West Bengal(Moitra and *Mukherjee*, 1972; Jana, 1973, 1976, 1979; Sircar and Sen, 1975; Jana *et al.*, 1980; Mondal, 1980), Andhra Pradesh(Seenaya, 1973; Sugunan, 1980), Kashmir(Das, 1971; Kaul *et al.*, 1978; Zutshi and vass, 1978; Khan and Zutshi, 1980; Zutshi *et al.*, 1980), Bihar (Nasar and Dutta-Munshi, 1974; Nasar, 1977), Madhya Pradesh (Mathew, 1977), Karnataka (Prasadam, 1977), Haryana (Vasisht and Sharma, 1975), Uttar Pradesh (Das and Pande, 1978) and Panjab (Vasisht and Jindal, 1980). The only report of production of rotifers from India was by Nandi *et al.*, (1977) who conducted experiments on mass culture of *Brachionus mulleri* (=*B. plicatilis*) in glass aquaria using common inorganic and organic manures.

There was slight decline in taxonomic studies during the last decade of this review i.e., between 1981-1990. The contributions began with the paper by the author (Sharma, 1981) dealing with 20 species of family Brachionidae from Panjab While later work (Sharma and Sharma, 1984) added 35 species to the fauna of this state. Sharma (1983) reviewed status of Indian species of genus *Brachionus* and subsequently (Sharma, 1987a) commented on the brachionid rotifers from this country and their distribution. Various other studies by the author and co-worker dealt with rotifers from North-Eastern India and these related to *Lepadella* species (Sharma and Sharma, 1987a), Family Notommatidae (Sharma, 1987b), Family Lecanida (Sharma, 1987b), *Testudinella* species (Sharma, 1990a) and distribution of brachionids this region (Sharma, 1990). In addition, Sharma (1987c) documented 69 species from Orissa State while Sharma and Sharma (1988) reported 35 species of monogononts from Haryana. A comprehensive account of systematic, distribution and ecology of freshwater rotifer from West Bengal was given by Sharma (1990b). Further, Sharma *et al.*, (1990) documented 55 species of rotifers from Bihar.

Other studies during this period included those from Gwalior (Madhya Pradesh) and dealt with faunistics (Saksena and Sharma, 1981a, 1982; Sharma and Saksena, 1981; Saksena and Kulkarni, 1986a), cyclomorphic variations in *Brachionus calyciflorus* (Saksena and Sharma, 1981), form variations in *B. quadridentatus* (Saksena and Sharma, 1986) and feeding of *Asplanchma brightwelli* (Saksena and Sharma, 1984). Saksena (1984) also gave an account of form variations in Indian loricate rotifers. A few publications dealing with morphology, colony formation and life-history of colonial rotifers were those by Bhardwaj and Duttagupta (1984) and Bhardwaj (1985). Systematic studies on the fauna of Karnataka were attempted by Patil and Gouder (1982, 1989). The rotifer from lentic and lotic water bodies in and around Patna (Bihar) were examined by Ahmed and Singh (1988) while Misra (1989) reported six species from lentic waters at Bhind (Madhya Pradesh). Sarma (1988) gave an account of 27 species (including 25 new records from India) from Kashmir, Delhi and West Bengal.

More attention was focussed on synecology of rotifers during 1981-1990 as reflected by investigations undertaken by Mukhopadhyay *et al.*, (1981); Rao *et al.* (1981); Qadri and Yousuf (1981, 1982); Yousuf and Qadri (1981, 1986); Balkhi *et al.*, (1984, 1987); Laal (1984); Sandhu *et al.*, (1984); Sharma and Pant (1985); Yousuf *et al.*, (1986); Deb et al., (1987), Haque *et al.*, and Sharma (1990). Additional information was also provided in limnological studies by Patil and Gounder (1985) from Karnataka; Bhattacharya and Saha (1986, 1989) from Tripura, and Khan *et. al.*, (1986) from Uttar Pradesh and Vass *et al.*, (1989) from Kashmir, Some contributions by Sampath *et al.*, (1981), Sharma (1983, 1986), Dutta and Bandhyopadhyay (1985) and Saksena (1987) dealt with trophic indicator species of rotifers.

So far only publication from this country dealt with karyological studies in this group; Rishi *et al.*, (1983) made these observations in *Asplanchna brightwelli.*

Recently, studies were undertaken on autoecology, production of mictic and amictic females, production and population dynamics in *Brachnionus patulus*. The results of these investigations are presented in the publications by Rao and Sarma (1985), Sarma and Rao (1985, 1990, 1990) and Sarma (1989).

Studies from Different Environs

Systematic studies on the rotifers from India commenced in the later part of 19th century but initial progress till 1960's was relatively slow and resulted in only 14 papers (mostly by foreign workers). However, important pre-independence works of Anderson (1889), Murray (1906) and Edmondson and Hutchinson (1934) altogether reported about 150 species; this comprised a significant fraction of total species so far known from this country. A considerable proliferation of faunistic researches were subsequently registered between 1961-1990. As a result, the present literature on Indian Rotifera is scattered over 105 papers referring to samples from distant localities from the northern latitudes to those from tropical environs of the southern plateau.

These investigations primarily relate to systematics of freshwater rotifers from the mainland; only a fewer of these works included biogeographical comments on this group. In addition, about 10 publications from this country deal with morphometric variations, form variations and cyclomorphosis in some planktonic and semiplanktonic members of the family Brachionidae. Sharma and Michael (1980) presented a synopsis of taxonomic studies on Indian Rotatoria, listed earlier references and remarked on the number of species and genera documented from different States and Union Territories.

The current status of occurrence of rotifer species (fig.) is marginally altered in some states following additional studies in the last decade.

Although various taxonomic investigations were undertaken from scattered localities from different geographical areas, our present knowledge of the freshwater rotifer fauna of India is still incomplete. This could be attributed to lack of extensive State-Wise or regional faunistic studies based on collections from diversified inland aquatic ecosystems as also highlighted by Sharma and Michael (1980). Further, a good fraction of previous works were focussed on planktonic rotifers only from tropical alkaline water bodies in this country and, therefore, resulted in localized species inventories and in some cases merely extended local distributional limits of species already reported from India. Moreover, many studies dealt exclusively with new taxa or new records. Earlier literature, if viewed in terms of number of publications from different states, presents a misleading picture of overall taxonomic contributions. Till now, eurotatorian fauna of West Bengal is adequately explored and that of Orissa, Punjab, Andhra Pradesh and Jammu and Kashmir is moderately known. Extensive Investigations from different states of this country are still required and some studies are being undertaken by this author and co-workers from various parts of North-Eastern India and from the states of Orissa and Bihar in Eastern India. Even additional collections from hitherto studied regions are likely to add more rare and interesting taxa this fact is evident from earlier record of 110 species from West Bengal (refer Sharma and Michael, 1980), subsequently this figure is presently (Sharma, 1990) raised to 148 species and represents highest diversity so far documented from any particular state of this country. Besides lacunae related to mainland, distant insular freshwater ecosystems of Andaman and Nicobar islands and Lakshnadweep Archipelago remain unexplored; some collections from the former group of islands are being examined by the author.

Amongst various freshwater ecosystems, water bodies infested with different assemblages of aquatic macophytes and rice-fields deserve special mention to examine species composition of their rotifer communities. Michael (1968) listed 30 species of these organisms from a fish-pond of the former category from West Bengal while Sharma (1990) recorded overall diversity of 72 species in these habitats from the mentioned state. In addition, the author (unpublished data) examined 53 species from five such ponds from Bihar. The later biogopes (rice-field ecosystems) are still more interesting as indicated by the records of 30-32 species/individual sample from Meghalaya (Sharma and Sharma, 1987) and upto 54 species/single sample from Assam State in North-Eastern region (Sharma, 1987).

A critical analysis of Indian freshwater Rotifera indicates that various planktonic and semi-planktonic taxa are fairly well documented from this country while periphytic, benthic, colonial, sessile and bdelloid rotifers are still not adequately studied. Morhphometric variations are so far examined in a few brachionid species and could be extended to various other taxa specially based on populations studies from varied geographical areas (under different ecological conditions) and with particular reference to the phenomenon of dwarfing in tropical rotifers (Green, 1977). Some species of the brachionids are known to exhibit ecomorphic variations and these require further analysis from various freshwater ecosystems. Taxonomic studies supplemented with information on basic parameters of water quality and aquatic macrophytic associations (if any) are desirable for any fruitful comparison of rotifer communities from different parts of this country. While genetic and biochemical methods remain beyond resources and expertise of most rotifer systematists, detailed SEM studies will serve as valuable adjunct to classical taxonomy and to resolve nomenclatural discrepancies (Koste and Shiel, 1989).

So far only one paper (Murray, 1906) gave an account of mossdwelling rotifers and reflected predominance of bdelloids (27 species) in these biotopes. Additional studies from these interesting habitats, particularly relating to types of moss, will essentially augment otherwise poorly documented digonont rotifer fauna of this country. This generalisation also holds true for soil rotifers (because of abundance of bedelloids) which remain totally unexplored from India. In addition, investigations on psammo-littoral and marine rotifer communities are yet to be initiated. Brackishwater rotifers are practically unknown systematically. Sewell (1934) in his account of fauna of brackish environs of Salt Lakes, Calcutta dealt with species which occurred primarily in freshwaters and indicate euryhaline nature. Some other species of the former category i.e., *Brachionus plicatilis and Tripleuchalanis plicata* are also documented from inland waters in this country. However, further investigations need to be undertaken in brackishwater ecosystems to record their characteristic elements.

Limnological studies in India were initiated by Sewell (1935) and since then there has been considerable activity of researches in this field (Michael, 1980; Gulati and Wurtz-Schulz, 1980). Rotifers invariably figure in Indian publications relating to general plankton ecology and were reported to comprise a dominant or sub-dominant component of freshwater Zooplanktonic communities. It is not possible to cover all such references within this short review primarily relating to this group. However, about 80 papers from this country provide some worthwhile information on various aspects of seasonal composition, abundance and ecology of these organisms. Although this literature dealt with various freshwater ecosystems scattered over fifteen/Union territories, a large number of these contributions relate to rotifer communities from tropical fish-ponds or tanks. So far, only about 18 publications dealt exclusively with synecology or rotifer populations. A majority of Indian contributions were made from the states of West Bengal, Jammu and Kashmir and Uttar Pradesh. A good fraction of these works (Das *et al.*, 1969; Das, 1970; Khan and Zuthis, 1980; Zutshi *et al.*, 1980; Qadri and Yousuf, 1981, 1982; Yousuf and Qadri, 1981, 1986; Balkhi *et al.*, 1984, 1987; Yousuf *et al.*, 1986; Das, 1989; Vass *et al.* 1989) referring to their species composition and ecology from Kashmir lakes. Jyoti and Sehgal (1979) conducted investigations in a sub-tropical lake near Jammu while Kumaun lakes were studied by Das and Pande (1978) and Sharma and Pant (1985). However, there is so far no published report from sub-tropical or temperate lacustrine ecosystems from North-Eastern India. Only fewer investigators (Devassy, 1965; Mathew, 1977; Sugunan, 1980; Bhattacharya and Saha, 1986, 1990) dealt with rotifer ecology from other lakes and reservoirs in this country. Still fewer studies relate to their ecology from riverine ecosystems (Roy, 1955; Ray *et al.*, 1966; Pahwa and Mehrotra, 1966) while observations in estuaries are those by Dutta *et al.*, (1954) and Shetty et al., (1961).

Rotifers serve as valuable indicators of water quality and first attempt to designate such species from India was made by Arora (1961, 1966). Some additional information was provided by Rao and Chandra Mohan (1977), Vasisht and Sra (1979), Sampath *et al.*, (1981), Sharma (1983, 1986), Dutta and Bandhopadhyay (1985) and Saksena (1987). However, a careful examination of regional ecological conditions is necessary before indicators mentioned by these authors are applied to other parts of this country. Slacecek (1983) proposed Q B/T quotient, and analogen to various phytoplankton quotients, and could be tried by Indian rotiferologists to establish trophic conditions of individual water bodies or even individual samples.

Considerable attention has been focussed world-wide on intensive culture of rotifers as fish-food. First attempt in this country was made by Nandy *et al.*, (1977) and dealt with mas rearing of *Brachionus plicatilis* using common inorganic and organic manures. In addition, recent studies of Rao and Sarma (1985), Sarma and Rao (1987, 1990a, 1990) and Sarma (1989) concerned various aspects of autoecology, population dynamics and production of *Brachionus patulus*.

The above comments reflected limited information on synecology of rotifer communities in freshwater and esturine environments in general and autecology of individual species in particular. Further studies need to be focussed on species compositions, spatial and vertical distribution, biomass production, population dynamics, effect of predation, eutrophication and acidification on rotifer biocoenosis, trophic indicators and intensive culture of selected freshwater and brackishwater species from this country.

Estimation of Taxa

Out of two subclasses of Rotifera, only subclass Eurotatoria is represented in India and it is comprised of taxa that generally occur in a wide range of aquatic and semi-aquatic ecosystems while studies on marine forms of subclass Seisona are not yet attempted. Amongst 29 eurotatorian families recognised by Koste (1978), 24 families are reported from this country and these include 310 species (345 taxa) belonging to 60 genera. Earlier synopsis by Sharma and Michael (1980), however, dealt with 241 species spread over 21 families and 48 genera. The presently known species comprise only about 12.4 % of the World's rotifer fauna. Our knowledge of the fauna of this country is certainly incomplete as reflected by lacunae discussed earlier in this paper and any accurate assessment of the fauna is a difficult aspect but a conservative estimate of over 500 species cannot be ruled out. The number of species documented from this country present a notable contrast to the report of 620 species from Australia (Shiel and Koste, 1987) and over 1400 species from Europe (Dumnot, 1983). Sudzuki (1989) complied a list of 575 species from the Oriental region and commented on relative richness of the rotifers in the Indian fauna; this conclusion may be misleading unless analysed in view of wider ecological conditions in this country, magnitude of taxonomic publications (about 64 % of examined papers by Sudzuki were from India) and unbalanced information form other countries of this region. According to Sudzuki (*loc. etc.*), strangely enough, about 37% of the Oriental rotifers did not appear in India, particular among them was the absence of several tropical species and some cold-water species in its northern territories although their common associates occurred there.

A family-wise break up of Indian Rotifera is given in Table 1.

The rotifer fauna of India exhibits greater specific and generic diversity than other South-East Asian faunas (Table 2) and also concerning members of the dominant families. Further, it shows about 60% similarity (vide Sorenson Index) with the rotifers examined from Malaysia and Singapore (Fernando and Zankai, 1981) and lower similarity (about 42%) with the Sri Lankan fauna.

Green(1972), Pejler (1977) and Fernando (1980) indicated common occurrence of *Brachionus* species to be a notable feature of tropical rotifer faunas while predominance of the lacenids (Family Lecanidae) from tropical Australasia was noticed by Dussart *et al.*, (1984). The above generalisations also hold true for the rotifer fauna of India and, therefore, impart it a broadly tropical character. This conclusion is further supported by restricted occurrence of temperate species particularly those of *Notholca and Synchaeta* to the localities in the northern territories of the Kashmir valley.

Cosmopolitan taxa comprise an important fraction of Indian rotifers while cosmotropical,

TABLE 1

Composition of Rotifer Fauna of India

Families	No. of reported Species	No. of reported Genera
Order PLOIMIDA		
Family Epiphanidae	7	4
Family Brachionidae	37	5
Family Euchlanidae	13	5
Family Mytilinidae	7	2
Family Trichotridae	6	3
Family Colurellidae	25	3
Family Lecanidae	70	1
Family Proalidae	4	2
Family Notommatidae	26	7
Family Gastropodidae	3	2
Family Trichocercidae	19	1
Family Asplanchnidae	7	2
Family Synchaetidae	8	2
Family Dicranophoridae	7	2
Order GNESIOTROCHA		
Family Flosculariidae	13	6
Family Conochilidae	4	1
Family Hexarthridae	4	1
Family Filinidae	5	1
Family Testudinellidae	10	2
Family Trochosphaeridae	1	1
Family Collothecidae	4	1
Family Atrochidae	1	1
Order BDELLOIDEA		
Family Philodinidae	22	4
Family Habrotrochidae	7	1
	310	60

tropical and subtropical components are fairly well reported. Endemic elements are represented by 26 species (32 taxa) and comprise abut 9.4% of the fauna of this country. of these, 14 species belong to *Lecane and Lepadella* and hence confirm to the remarks of Dumont (1983) regarding the occurrence of usual endemics of these genera in the fauna of South-East Asia. Overall paucity of Indian endemics in general and that of the family Brachionidae in particular was believed to be secondary and resulted due to loss of characteristic faunal elements after this subcontinent his Asia (Dumont, *loc cit.*) and invasion of the Oriental faunal elements to the Near East especially during the Pleistocene.

TABLE 2

Comparison between Rotifer Fauna of some South-East Asian countries

	India	Srilanka	Malaysia & Singapore	Phillipines	Thailand
No. of reported species	310	138	143	61	80
No. of reported genera	60	42	40	23	26
No. of reported families	24	19	18	16	17
Dominant families and number of reported species:					
Family Lacanidae	70	32	30	25	20
Family Brachilonidae	37	26	25	10	20
Family Notemmatidae	26	4	15	1	-
Family Colurellidae	25	6	6	5	5
Family Trichocercidae	19	9	12	2	6

Out of the monogonont taxa from the Oriental region, about 51% are detected from India (Sudzuki, 1989). This review also indicated that they comprise an important component of the fauna of this country and are represented by 281 species (22 families and 55 genera). This superorder includes two orders i.e., Ploimida and Gnesiotrocha. The former incorporates 239 species (41 genera) while the later is comprised of 41 species (14 genera). The members of Lecanidae, Brachionidae, No tommatidae, Colurellidae and Trichocercidae (in the stated order) from major fraction of the ploimid fauna. The lecanids relate to *Lecane*-compex including three subgenera (Lecane s. str., *Hemimonostyla and Monostyla*). Various endemic taxa of the family Lecanidae are *Lecane (Lecane) lateralis, L.(L.) luna dorsicalis and L. (L.) vasishti* from West Bengal; *Lecane(Lecane)pawlowski, L. (Monostyla) schraederi* and *L. (L.) neali* from Gujarat; *L. (L.)yamunensis* from the river Yamuna; *L. (L.) sola* from Tamil Nadu; *L. (L.) donnerianus, L.(L.) bidentata* and *L. (L.) eswari* from Andhra Pradesh and *L. (L.) jaintiensis* from Meghalaya. The geographical limit of *L. pawlowski* was extended to West Bengal (Sharma, 1978) while *L. lateralis* was also examined from Orissa(Sharma, 1987). In addition, *L. (L.) Curvilinealis, L. (L.) tesselata* and *L. curvicornis* var. *padaespares* are considered to be apparently identical with *L.(L.) curvicornis* but type-specimens are not available for comparison.

Endemic taxa of the family Colurellidae include *Lepadella kostei* from Gujarat; *L. triprojectus, L.ovalis larga* n. comb from West Bengal; *L.nartiangensis* and *L. patella elongata* n. comb. from Meghalaya. The mentioned two subspecies were originally described as forms. Family Brachionidae includes *Brachionus durgae* described by Dhanapathi (1974) from Andhra Pradesh but its status needs to be ascertained(refer: Sharma, 1983). *Platyias quadricornis andhraensis* is another endemic brachionid documented from this state.

The endemic species of the euchlanis (Family Euchlanidae) are *Euchlanis brrahmae* and *Pseudoeuchlanis longipedis* from Andhra Pradesh; the later represents a monotypic genus described from this country. Other endemic elements from India include *Proales indirae* (Family Proalidae) from Gujarat, *Ascomorpha saltans indica* (Family Gastropodidae) also from the earlier state, *Trichocerca tropis* from Tamil Nadu and *Asplanchnopus bimavaerensis* from Andhra Pradesh.

Order Gnesiotrocha includes suborders Flosculariacea and Collothecacea which are represented by six and two families respectively. Endemic elements of this order are *Conochilus arboreus* (Family Conochilidae) from Tamil Nadu and *C. dossuarius asetosus* from Maharashtra, *Ptygura stephanion* (Family Flosculariidae) from West Bengal and another species of this family (*Sinantherina triglandularis*) from Maharashtra.

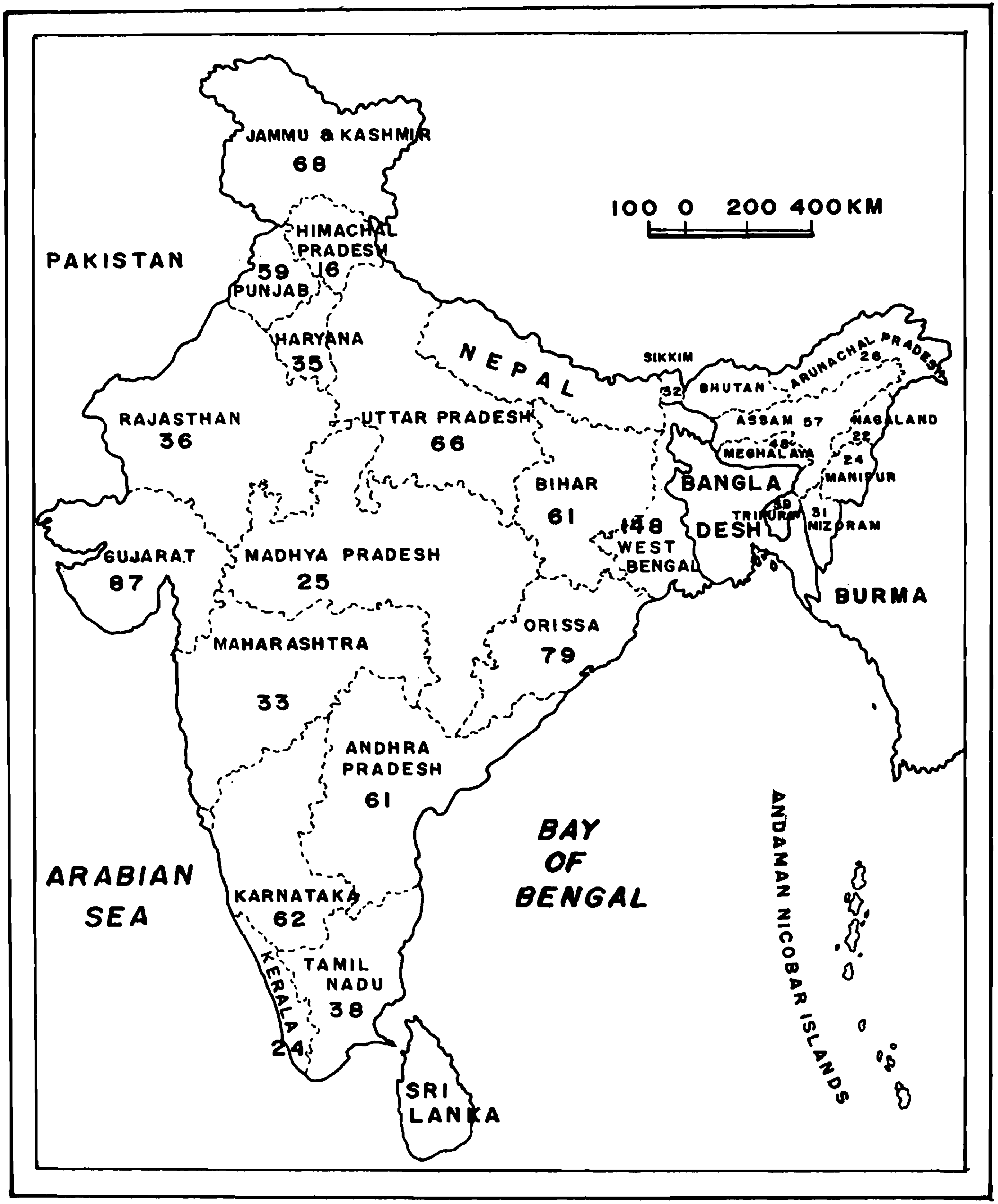

Fig. I. Map of India indicating number of reported species

Map of India indicating number of reported species

So far about 365 species (21 genera) of digonont rotifers (order Bdelloidea) and belonging to four families are known from the world. Of these, 29 species spread over two families and five genera are only documented from India. Endemic elements of bdelloids from this country include monotypic *Pseudoembata* described from Tamil Nadu and *Rotaria ovata* from West Bengal.

Classified Treatment

Sub-Class Eurotatoria

All the rotifer taxa recorded from Indian and this sub continent belong to this subclass which includes freshwater and brackishwater forms and is represented by both of its superorder i.e., Monogononta and Digononta.

Super-order Monogononta

Most studies on systematics, distribution and ecology from the Oriental region, nearly 51% are detected from India,about 40% from Indonesia and Malaysia, approximately 35% from Singapore, 25% from Sri Lanka and about 18% and 16% from Taiwan and Thailand respectively. However,these comprise about 91% of total 310 species presently documented from this country. A number of important monographs (Voigt, 1957;Rodescu, 1960; Kutikova,1970; Koste,1978) deal with this superorder from different parts of the World while simple identification keys are provided by Edmondson (1959), Ruttner-Kolisko (1974) and Pontin (1978) but a comprehensive treatment from the Oriental region or any of its constitutent countries is yet to be attempted. Both orders of monogonont rotifers (Ploimida and Gnesiotrocha) are represented from India. presently

Order Ploimida

This order includes a total of 17 families; of these, representatives of 14 families are reported from this country. However, members of some families have drawn considerable attention in earlier Indian studies.

Family Lecanidae

It is evidently one of the most important families in the rotifer fauna of India is represented by 70% species of the *Lecane*-complex which includes three subgenera i.e., *Lecane* s. str., *Monostyla* and *Hemimonostyla*. The publications of Edmondson and Hutchinson (1934), Wulfert (1966), Dhanapathi (1975, 1976) Vasisht and Battish (1971) and Sharma (1978, 1979, 1987) provide valuable information about systematics of the lecanids from this country while knowledge of their ecology is relatively very poor. In view of various discrepancies reflected in our literature, this family needs revision to ascertain correct status of the documented taxa. 11 species (13 taxa) comprise endemic elements in the Indian fauna. *Lecane nodosa, L.blachei, L.sinuata* and *L. thienemanni* are apparently confined to Asia while the range of *L. bulla diabolica* is extended to Central Asia.Various other biogeographically important lecanids from India include *Lecanae acronyncha, L. bifastigata, L.curvicornis miaminensis, L. hastata, L.lauterborni, L.doryssa, L.haliclysta, L.elongata, L.ligona, L.stokesii, L.pusilla, L.syngenes and L.elachis.* In addition, *L.pertica, L.inermis, L.bifurca, L.obtusa, L.furcata, L.perplexa* and *L.scutata* are of local distributional significance. *L. nartiangensis, L.dactyliseta, L.doryssa, L.pertica, L.inermis, L.jaintiaensis, L.signifera signifera, L.,ligona, L.stokesii and L.scutata* are regarded acidophilic elements. *Lecane aculeata, L.ludwigi, L.sympoda, L.inopinata, L.quadridentata* and *L.stenroosi* could be termed as warm-stenothermal species.

Family Brachionidae

The members of this family are most extensively studied faunistically and ecologically from India. Out of seven genera of this family, four genera are reported from this country. Sharma (1983) gave an account of Indian species of *Brachionus* and later (Sharma, 1987) commented on

Indian Brachionidae and their distribution. More species of the genus *Brachionus* are reported to occur in alkaline water bodies in tropical parts of this country while slightly acidic biotopes particularly in North-Eastern region reflect lesser diversity. Intraspecific variations are documented in *Brachionus calysiflorus*, *B. caudatus* and *B. quadridentatus* while *B. falcatus* and *B. forticula* are observed to indicate ecotypic variations. In addition, morphometric variations from this country are studied in *Brachionus angularis* and observations on cyclomorphosis are made in *B.calyciflorus* and *B. patulus* together with the other member of this family i.e., *Keratella tropica*. *B. angularis*, *B. caudatus*, *B.calyciflorus* and *B.rubens* are considered as eutrophic indicators in Indian waters while *B.falcatus* and *B.forficula* are known to occur in mesotrophic and eutrophic habitats. *Brachionus bidentata crassispineus*, *B.bidentata testudinarious*, *B.bidentata jirovci*, *B.donneri*, *B.patulus mactracanthus*, *B.pterodinoides and B.sessilis* are biogeographically important elements while *B. dimidiatus*, *B.leydigi*, *B.bennini* and *B.mirabilis* are of local distributional interest. Species of this genus invariably figure in ecological studies from this county and are reported to form significant component of planktonic rotifers. Culture of *B.plicatilis* was attempted in this county by Nandy *et al.*, (1977)and various aspects of autecology of *B.patulus* were studied at Delhi University by Rao and Sarma. *Keratella* exhibits lesser diversity than the preceding genus. Amongst various species reported from this country, *K.ticinensis* and *K. javana* are biogeographically interesting; *K.lenzi*, *K.valga* and *K.procurva* show restricted occurrence, *K.tropica* is widely distributed while *K.cochlearis* is an important planktonic rotifer in water bodies in North-Eastern India. Genus *Anuraeopsis* includes only tow species i.e., warm-stenothermal *A.coelata* and cosmopolitian *A.fissa;* the later occurs in eutrophic habitats. Amongst species of *Platyias*, *P.leloupi* was earlier considered to be an interesting Ethiopian element but it is now reported (Sharma, 1987) to exhibit pantropical distribution. *Notholca* included two species which are confined to the northern territories in Kashmir while *N.labis* is recently reported from the river Yamuna (Sarma, 1988) near Delhi. *Kellicottia longispina*, a cold-water species, documented from Sri Lanka is notale for its absence though it is likely to occur in the collections from northern latitudes.

Family Epiphanidae

It has apparently drawn less attention and includes only seven species (four genera); important contributions about their occurrence in this country are by Edmondson and Hutchinson (1934), Dhanapathi (1974) and Sarma (1988). Of the documented species, *Epiphanes clavatula* and *Liliferotrocha subtilis* are warm-stenothermal elements.

Family Euchlanidae

This family includes thirteen Indian species belonging to *Euchlanis*, *Dipleuchlanis*, *Pseudoeuchlanis*, *Tripleuchlanis* and *Beauchampiella* and important taxonomic studies on the euchlanids are made by Edmondson and Hutchinson (1934), Dhanapathi (1976) and Sharma (1979d). Amongst *Euchlanis* species, the boreal *E.alata* is reported only by Edmondson and Hutchinson (loc cit.) while *E.dilatata* is widely reported in plankton collections from this county. *E.triquetra*, *E.meneta* and *Dipleuchlanis propatula* are regarded as acidic water species. Brackishwater *Tripleuchlanis plicata* is examined from freshwater bodies in Andhra Pradesh (Dhanapathi, 1975) and West Bengal (Sharma,1979). The monotypic *Pseudoeuchlanis* is described by Dhanapathi (1975) from Andhra Pradesh.

Family Mytilinidae

Amongst seven species (two genera) of this family known from India *Lophocharias oxysternon*, *L.salpina* and *Mytilina mucronata* are examined only by Edmondson and Hutchinson (1934) and *L.naias* is reported by Wulfert (1966). *Mytilina ventralis* is mentioned to occur frequently in planktonic and periphytic samples in this country. *M.ventralis longidactyla*, *M.ventralis brevispina* and *M.acanthophora* are biogeographically important taxa. The cosmopolitan *M.bisulcata* was reported earlier from peat-bogs (koste, 1978) and has been noticed from a domestic well in West Bengal (Sharma, unpublished); its presence in the potable water is of special ecological interest.

Family Trichotridae

It includes three species of *Macrochaetus* which are represented by tropical and subtropical *M.sericus* and *M.collinsi* and apparently cosmopolitan *M.subquadratus* and these occur in periphytic associations. Amongst species of *Trichotria, T.pocillium* is reported only by Edmondson and Hutcinson (1934) from Ladak while *T.tetractis* occurs widely in this country. *Wolga spinifera* was known to be distributed in Eurasia between 37*N- 52*N (Koste, 1978); recent report of this species from India (Sarma, 1988), therefore, has considerably extended its distributional range.

Family Colurellidae

It comprises an important component (25 species) of Indian ploimid rotifers and is represented by three genera i.e., *Colurella, Lepadella* and *Squatinella*. Various works relating to their taxonomic studies from this country are by Edmondson and Hutchinson(1934), Wulfert (1966), Vasisht and Battish (1971), *Lepadella ovalis* and *L.ptella* are commonly encountered in planktonic collections while *L.aspida* and *L.aspicora* are biogeographically interesting speciers. Various examined taxa from acidic waters in India include *Colurella, Sukata, Lepadella triptera, L.nartiangensis, L.patella elobgata, L.cristata* and *L.dactyliseta.*

Family Notommatidae

This important family of monogonont notifers is not adequately studied in India. It is represented by 26 species of which ten species were reported by Edmondson and Hutchinson (1934) and additional information is provided by Wulfert (1966), Dhanapathi (1975a) and Sharma (1979). Various bigeographically important species recorded from this country are *Cephalodella hiulca, C.panarista* and *Eosphora anthodis.*

Family Gastropodidae

It is so far very poorly documented and most species were listed earlier by Edmondson and Hutchinson (1934) while endemic *Ascomorpha saltans indica* was described from Gujarat (Wulfert, 1966). *Gastropus hyptopus* is an interesting species reported from India and is earlier known to be distributed in Europe, Eastern Asia and North America.

Family Proalidae

Amongst four gencra of periphytic rotifers included in this family, only genus *Proales* is represented from India and remains poorly reported (only two species).Of these, *P.decipiens* is reported only by Edmondson and Hitchinson (1934) while endemic *P.indirae* is described by Wulfert (1966) from Baroda (Gujarat).

Family Trichocercidae

It is another important family of order Ploimida but includes only 19 species from this country; few valuable contributions dealing with these are by Edmondson and Hutchinson(1934), Wulfert (1966) and Sharma (1979). *Trichocerca tropis* comprises an endemic species; *T.flagellata,* described by Hauer (1937) from Tamil Nadu,is now known from Malaysia. *T cyllindrica, T brazieliensis, T stylata* and *T.ruttneri* are other biogeographically important members of this family documented from India.

Family Asplanchnidae

It includes predatory rotifers of genus *Axplanchna;* this genus is represented by widely distributed *A. brightwelli* which is also regarded as an eutrophic indicator while *A. intermedia* and *A.pridonta* indicate restricted occurrence in this county. Genus *Asplanchnopus* includes *A.multiceps* from Ladak, *A.hyalinus* and *A. bimavaraensis* from Andhra Pradesh. The only karyological study from India (Rishi et. al., 1983) dealt with *Asplanchna brightwelli* and indicated acrocentric chromosomes of varying sizes (n = 16, 2n = 32).

Family Synchaetidae

Various species of genus *Synchaeta* reported so far from India and two species of *Polyarthra* i.e., *P. euryptera* and *P.trigla* are examined only by Edmondson and Hutchinson (1934). *P.longiremis* documented by Naidu (1967) from Andhra Pradesh needs confirmation. Arora (1962) described *P.multiappendiculata* from Nagur and it is a synonym of *P.vulgaris* (refer: Koste, 1978) which is apparently widely distributed in plankton collections.

Family Dicranophoridae

This is an important family of order Ploimida but remains very poorly studied in India. So far only six species of genus *Dicranophorus* and one species of *Encentrum* are documented from this country and information about their occurrence is provided by Wulfert (1966), Dhanapathi (1975) and Sharma (1979). Of these, *Dicranophorus epicharis, D.lutkeni* and *Encentrum longipes* are of regional distributional interest.

Order Gnesiotrocha

It is divisible into two suborders i.e., Floscularisc**e**a and Collothecaea which, inturn, include six and two families respectively. All these families are represented in India and contain 42 species belonging to 14 genera. Of these, Flosculariidae contains 13 species (6 genera) and taxonomic information about these is primarily given by Anderson (1889), Edmondson and Hutchinson (1934), Wulfert (1966) and Sarma(1988). *Ptygura stephanion* and *Sinantherina triglandularis* comprise endemic elements. Of the other species, *Ptygura tacita* is known previously from North and South America while *Sinantherrian socialis* exhibits pantropical distribution. Some studies on colonialmembers of this family, particularly relating to life-history and colony formation,were undertaken by Bhardwaj and Duttagupta(1984) and Bhardwaj (1985).

Family Conochilidae is relatively poorly documented and included fewer species of genus *Conochilus;* of these,*C.dossuarius asetosus* and *C. orboreus* are endemic to Indian Rotifera.

Genus *Hexarthra* (Family Hexarthridae) includes only four species of which *H. bulgarica* and *H. bulgarica nepalensis* are biogeographically important.

Family Filiniidae includes five species of genus *Filinia*. Amongst these, *F. opoliensis, F. longiseta* and *F. terminalis* have frequently been listed in taxonomic contributions from this county. *F. pejleri* appears to be pantropical in its distribution. In addition, *F. cornuta* is documented by Sarma(1988) while *F. longiseta saltator* is examined recently from Bihar(Sharma *et. al.*, 1990). *F. longiseta* and *F. opoliensis* are regarded as eutrophic indicators by various workers from this country.

Family Testudinellidae is represented by two genera i.e., *Pompholyx* and *Testudinella*. The former includes two species; of these, *P. complanata* is reported only by Edmondson and Hutchinson (1934) while the later appears to be of considerable importance in plankton collections from various parts of this country. Genus *Testudinella* is represented by eight species (12 taxa) and amongst these *Testudinella bravicauda, T greeni, T. parva parva, T parva semiparva, T. parva bidentata* and *T. tridentata* are recently documented from India by Sharma (1990).

Horaella brehmi (Family Trochosphaeridae) is a phylogentically interesting species of this family. It was represented earlier from North America, Sri Lanka, Australia, India (West Bengal, Bihar) and its distributional range is currently extended (Koste & Shiel, 1987) to 42* in Tasmania.

Family Collothecidae(Suborder Collothecacea) is represented by four planktonic species which were studied only by Amnderson (1889) from West Bengal.

Another family of the above suborder i.e., A trochidae is represented only by *Cupelopagis vorax*. This species was documented by Edmondson and Hutchinson (1934) and its male was described by Vasisht and Dawar (1968).

Super-order Digononta

Order Edelloidea

All digonont rotifers are included in order Bdelloidea which remains so for very poorly studied from the Oriental region. It is represented by about 365 species belonging to 21 genera; of these, only 29 species spread over five genera known from India. Important taxonomic contributions to the members of the order were those by Anderson (1889) and Murray (1906); the later dealt with the collections from moss which contained 27 species of bdelloids out of total 32 species examined by Murray. *Rotaria rotaria* and *R. neptunia* are occasionally noticed in plankton collections from highly eutrophic water bodies.

Current Studies

Very few specialists are now actively engaged in rotifer systematics in this country. The author and co-worker(Dr. Sumita Sharma, Eastern Regional Station, ZSI, Shillong) are currently studying faunas of the states of Meghalaya and Tripura in North-Eastern India. The author is examining collections from Orissa and Andaman and Nicobar Islands and has also initiated studies on the rotifer fauna of Bihar in collaboration with Dr. R.K. Sinha (Patna University). Besides, the author is preparing a monograph of Indian Freshwater Rotifera. An attempt is being made in this department to maintain national reference collections of this group and identification advisory service is extended to research workers of different Indian Universities and institutions. At the moment, some other taxonomic studies are conducted at Jiwaji University (Gwalior) and Kashmir University.

Ecological investigations have been taken up by various workers in routine limnological studies but serious ecological researches are carried at North-Eastern Hill University,Gauhati University, Calcutta University, Kalyani University, Punjab University, Patna University, Aligarh Muslim University, Jiwaji University and Freshwater Biological Station, ZSI, Hyderabad. In addition, investigations on autoecology and production are being attempted at Madurai Kamraj University and Delhi University.

Global studies on the rotifers are, however, much scattered from various classical aspects to application of latest biotechnological methods. Different fields of these studies include systematics, biogeography, sessile and marine rotifers, community structure, ecology, distributional patterns(horizontal and vertical), population dynamics, competition, effect of grazing and predation, feeding behaviour, escape response, ultrastructure, neuro-ethology, neurophamacology, biochemical aspects with special reference to nutritional value, effect of acidification, fertilization and eutrophication on community structure, bioessay and environmental toxicology experiments, population genetics, development of fast growing strains and intensive culture of rotifers as fish-food for aquaculture practices.

Expertise

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Animal Resources of India : 89–94 : 1991

GASTROTRICHA

Introduction

Gastrotricha constitutes one of the most interesting and challenging groups of meiobenthic marine invertebrates. They are minute, unsegmented and acoelomate worms which swim or crawl by means of their ciliated epidermis. The length of the worm is generally less than 1.0 mm, the smallest ones being even less than 0.1 mm, while the largest ones are more than 3.0 mm. The body is elongated, strap-shaped or fusiform and dorsally covered with a variety of cuticular structures as bristles, scales, spines, adhesive tubes, etc., to withstand effects of abrasion in the habitat. The ventral surface is flattened and covered with patches the locomotory cilia for smooth gliding over solid substratum. The cuticle is thin, flexible and transparent. Adhesive tubes supplied with cement glands are used for adhesion to sand grains or vegetation. They are mostly hermophrodites.

The gastrotrichs are highly varied and sufficiently distinctive to be classified as a separate phylum, which is divided into two main orders, the Macrodasyida and the Chaetonotida. The Macrodasyida are exclusively marine and comprise heterogeneous group of animals with great morphological diversity. The discovery and study of those worms during the present century have been a significant landmark in zoology. The longest gastrotrichs are seen in this group with ribbon-shaped bodies well adapted for interstitial life. Anteriorly, head is not always delineated and posteriorly the tail is truncate or round or forked or pointed or drawn to a tapering filament. The most interesting and characteristic feature of macrodasyidans is the presence of numerous adhesive tubes arranged in rows in a bilaterally symmetrical fashion. These tubes typically occur in three groups distributed anteriorly on ventral, surface of head, laterally on ventral surface of trunk and posteriorly along the tail region. However, some exceptions to this general pattern are seen. The posterior part of pharynx is generally associated with pharyngeal openings. These worms are highly thigmotactic, contractile and exhibit leech-like movements to suit life in this turbulent and dynamic environment.

The Chaetonotida are marine, brackish and freshwater inhabitants. They are very small in size, with fusiform body, anterior head lobe and two posterior caudal furca, each with a single adhesive tube. Tufts of long lateral sensory cilia occur on head lobe. Cuticle has a complex ornamentation, often with spined scales. Pharyngeal pores are lacking. Adhesive tubes are limited to 1–2 pairs on tail forks. These tubes are, however, absent in the pelagic families–Dasydytidae and Neogosseidae. The characteristic locomotive cilia on the ventral body surface are transformed into groups of cirri in the genus *Xenotrichula*. All the body parts are largely bilaterally symmetrical. Chaetonotids mostly reproduce by parthenogenesis.

Marine gastrotrichs are mostly interestitial animals living in spaces between particles of sandy sediments, their greatest density and diversity being limited to intertidal and subtidal parts of the sea. They are also known to inhabit from top to 1 m depth below surface. Quantitatively, their densities in marine sediments were reported to range from 50 to 1500 individuals per 10 cm^2 of the sediment. On the other hand, the freshwater gastrotrichs are less common in soft sediments due to absence of adequate interstitial spaces for colonisation, while they are more common in living and decaying benthic vegetation, detritus and floating plants. The chaetonotidans, due to their great powers of locomotion and tolerance to wide range of environmental variation, are mostly cosmopolitan in their distribution. All the gastrotrichs are free-living and harmless. They play an important role in the trophic cycle of aquatic habitats by forming food for larger animals and by contributing to the regeneration of nutrients in the ecosystems after their death and disintegration. As the gastrotrichs also form excellent material for the study of morphological organisation, they

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are being extensive utilised in laboratories of western countries as types for zoology students. They are also used in a variety of experimental and interesting ecological investigations. As these worms are quite sensitive to ecological stress, they are widely utilised as indicators of pollution in aquatic ecosystems. Thus, the gastrotrichs, both in marine and freshwater habitats, offer ample scope for carrying out various types of investigations on taxonomy, biology, ecology and distribution.

Historical Resumé

The earliest gastrotrichs were discovered during different periods of the 19th century and since then a large number of genera and species were described as new to science, particularly on the European and North American coasts. Most of our basic knowledge and conception of the rich variety of gastrotrichs is due to the pioneering contribution made by Prof. Adolf Remane of the Kiel University from North, Baltic and Mediterranean seas. However, in Gastrotricha still remains one of the most neglected groups. While studying the sand-living copepods on Madras coast, Krishnaswamy (1957) reported for the first time the occurrence of marine gastrotrichs on the Indian coast. Later, Ganapati and Rao (1962) in a pioneering effort reported the occurrence of gastrotrichs from the interstitial meiofauna in the intertidal sands on Waltair coast. Detailed investigations of the gastrotrichs from Waltair beach sands resulted in the discovery of 13 known species (Rao and Ganapati, 1968). Subsequent studies of the fauna in this region have resulted in the description of a new species, new genus and new family (Rao and Clausen, 1970). Exploration of the intertidal sediments at several localities on the east coast of India has brought to light more known and unknown species of gastrotrichs (Rao, 1969, 1970, 1980, 1981a, b). On the south-west coast of India, Govindan Kutty and Nair (1969) reported the occurrence of 7 species from intertidal sands, of which one was described as new to science. They have also studied (1974) the behaviour of gastrotrichs in the colonisation of different grades of marine beach sands. Beyond the Indian subcontinent, studies on the interstitial meiofauna of the intertidal and subtidal sediments have led to the discovery of more known and unknown species of marine gastrotrichs from Andaman & Nicobar Islands (Rao, 1975, 1980, 1987, 1988, 1989) and Lakshadweep (Rao, 1983, 1990).

Limited work has been carried out on freshwater gastrotrichs of the Indian subcontinent. Vanamala Naidu (1962), Dhanapati (1976), Rao and Chandramohan (1977) and Sharma (1980, 1987) reported on the occurrence of several known species of chaetonotid gastrotrichs from different wells and ponds in India. There are many areas within the Indian region which remain unexplored or under explored in marine, brackish and freshwater habitats, offering ample scope to carry out taxonomic and ecological investigations on the gastrotrich fauna.

Estimation of Taxa

The number of gastrotrich species at the global level are estimated to vary between 2000 and 3000, with many areas remaining largely unexplored or under explored. Taxonomic features generally utilised in the identification of gastrotrichs include the shape of body, head lobes, tentacles and ciliary tufts, pestle and chordoid organs, structure of mouth and buccal cavity, pharyngeal pores, structure of cuticular armature as scales, spines, hooks, papillae, etc., arrangement of locomotory ciliary bands or cirri, structure of tail lobes and caudal forks, number and disposition of adhesive tubes and the arrangement and structure of reproductive organs.

The Macrodasyida are presently represented by 28 genera belonging to 6 families namely, Dactylopodolidae, *(Xenodasys, Dactylopodola, Dendrodasys)*, Lepidodasyidae *(Lepidodasys, Cephalodasys, Pleurodasys, Mesodasys, Megadasys, Dolichodasys, Paradasys)*, Macrodasyidae *(Macrodasys, Urodasys)*, Planodasyidae *(Planodasys, Thiodasys, Crasiella)*, Turbanellidae *(Turbenella, Paraturbenella, seudoturbanella, Dionodasys, Desmodasys)* and Thaumastodermatidae *(Thaumastoderma, Tetranchyroderma, Acnthodasys, Platydasys, Hemidasys, Diplodasys, Pseudostomella, Ptychostomella)*.

The Chaetonotida are known to comprise 21 genera belonging to 7 families, namely

Chaetonotidae *(Chaetonotus, Musellifer, Aspidophorus, Halichaetonotus, Lepidodermella, Heterolepidoderma, Ichthydium, Polymerurus)*, Neodasyidae *(Neodasys)*,

Xenotrichulidae *(Xenotrichula, Heteroxenotrichula, Draculiciteria)*, Dichaeturidae *(Dichaeture, Marinellina)*, Proichthydidae *(Proichydium, Proichthydioides)*, Neogosseidae *(Neogossea, Kijanebalola)* and Dasydytidae *(Dasydytes, Metadasydytes, Stlochaeta)*.

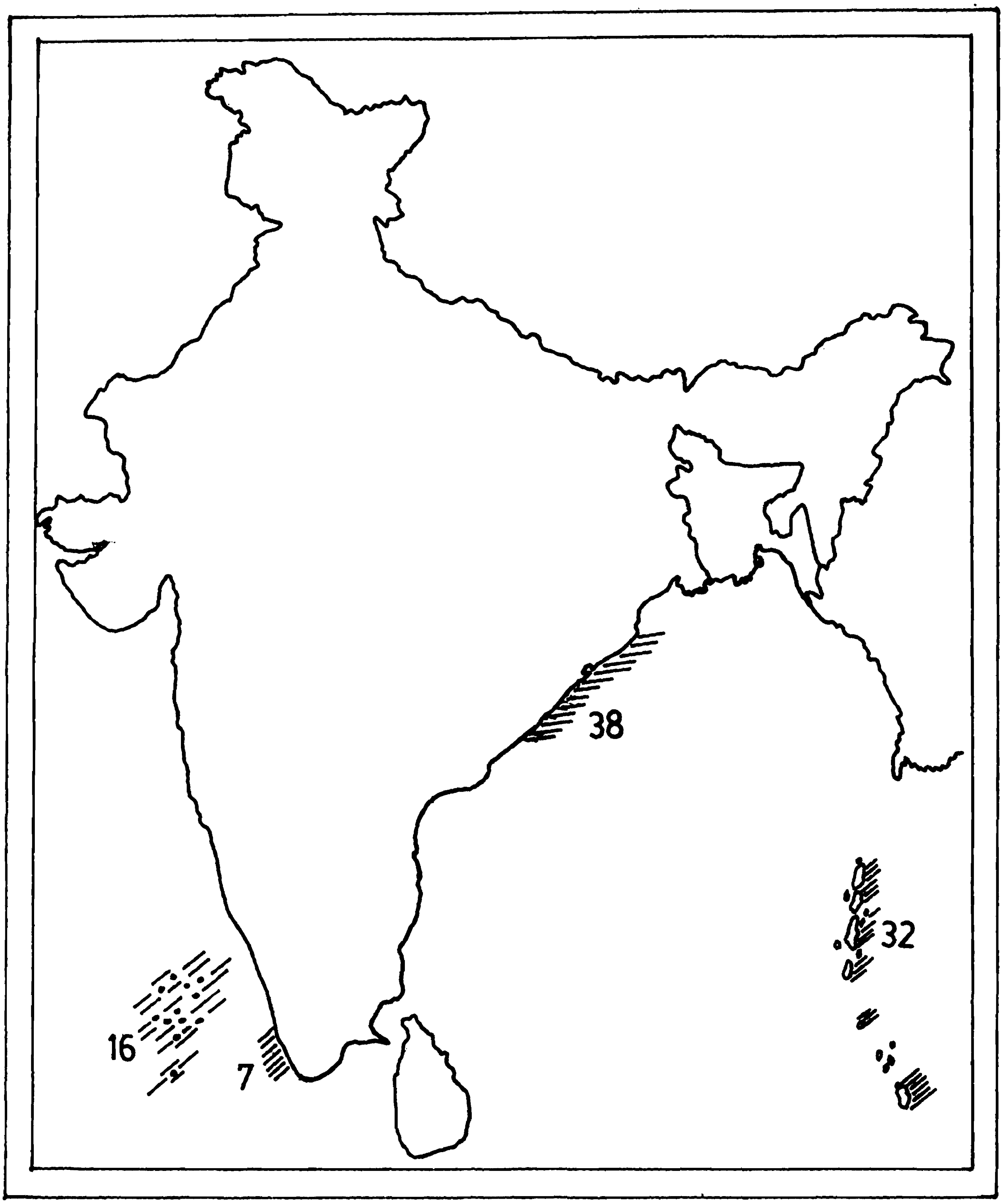
Within the Indian region, all the six recognized families of Macrodasyida and only 3 families of Chaetonotida *viz.*, Chaetonotidae, Xenotrichulidae and Dasydytidae are hitherto represented with the 20 genera *Dactylopodola, Cephalodasys, Mesodasys, Paradasys, Macrodasys, Urodasys, Planodasys, Crasiella, Turbanella, Paraturbanella, Dinodasys, Thaumastoderma, Tetranchyroderma, Acanthodasys, Platydasys, Diplodasys, Pseudostomella, Chaetonotus, Aspidophorus, Xenotrichula* and *Dasydytes*. Any further intensive explorations of marine and freshwater habitats are, however, likely to reveal the existence of more genera unknown in this region. The family-wise representation of the gastrotrich species hitherto recorded from this area is given below.

Family	No. of species Marine	Freshwater	Total	Endemic
Dactylopodalidae	2	—	2	2
Lepidodasyidae	6	—	6	5
Macrodasyidae	7	—	7	6
Planodasyidae	3	—	3	3
Turbanellidae	12	—	12	10
Thaumastodermatidae	16	—	16	13
Chaetonotidae	13	20	33	16
Xentrichulidae	8	—	8	5
Dasydytidae	—	1	1	—
Total	67	13	88	60

The composition and abundance of the gastrotrich genera and species occurring in this region are more or less in agreement with those known from other parts of the world. A perusal of the data presented here shows that out of the 88 species encountered, 60 are endemics, the endemicity being, however, more in Macrodasyida than in Chaetonotida endowed with greater powers of locomotion. These geographical ranges likely to change as more and more areas in the Indian Ocean are intensively investigated, some of the presently supposed endemics joining the ranks of eurytopics. The probable endemism of gastrotrichs in this region, however, appears nearly to be the same as reported for the fauna in other parts of the world.

Studies from Different Environs

Among the Macrodasyida, the Dactylopodolidae are poorly represented on the Indian coast. *Dactylopodola indica* was described by Rao and Ganapati (1968) from the beach sands of Waltair coast and the same later reported from the intertidal sediments on Orissa coast (Rao, 1969), Andaman Islands (Rao, 1980) and Lakshadweep (Rao, 1983). The Lepidodasyidae are represented by 3 interesting species *Paradasys littoralis, P. lineatus, Mesodasys hexapodus* described on the east coast, which are likely to prove endemic to this region, The Macrodasydae are better represented by the two eurytopic species *Macrodasys caudatus* Remane and *Urodasys viviparus* Wilke, while 4 new species of Macrodasys were also described, *M. waltairensis* and *M. hexadactylus* on the east coast (Rao and Ganapati, 1968; Rao, 1970) and *M. indicus* from Lakshadweep (Rao, 1990). Two new species of the family Planodasyidae *viz., Planodasys marginalis* and *Crasiella indica* were described from Waltair and Gopalpur beaches, respectively (Rao and Clausen, 1970; Rao, 1981).



Map showing the areas on Indian Coast where marine gastrotrichs were collected, studied and reported. Numbers indicate the species recorded.

The Turbanellidae are common in the intertidal sediments and the following species were encountered *viz., Turbenella bengalensis, T. india* and *T. eminensis, Paraturbenella boadeni, P. palpibara, P. mesoptera, P. brevicaudatus* (Rao and Ganapati, 1968, Rao, 1970, 1981, 1990). The Thaumastodermatidae constituting the most diversified taxa of marine Gastrotricha are represented by 16 species with many species yet to be described, the morphologically interesting ones being *Tetranchyroderma indica, T. swedmarki, T littoralis, T. paralittoralis, Diplodasys remanei* and *Pseudostomella indica* (Rao and Ganapati, 1968; Rao, 1970, 1973, 1990). The widely distributed species, *Thaumastoderma heideri* Rename was recorded at many places on the Indian coast including Lakshadweep and Andamans.

Among the marine Chaetonotida, except for the ubiquitous species *Aspidophorus marinus* Remane, majority of the species belong to the genera *Chaetonotus* and *Xenotrichula*. The occurrence of the European species, *Chaetonotus atrox* Wilke, *Xenotrichula velox* Remane and *X. subterranea* Remane on the Indian coast is quite interesting. The new chaetonotid taxa described from this region include *Xenotrichula tentaculatus, X. laccadivensis* and *Chaetonotus triradiatus* (Rao and Ganapati, 1968; Rao, 1990). The freshwater gastrotrichs, on the other hand, are mostly dominated by the genus *Chaetonotus* with the record of about 20 widely distributed species. Visvesvara (1963) described two new species from Nagpur in Central India.

Current Studies

Studies on the systematics and distribution of marine Gastrotricha are being presently carried out by G. C. Rao in the Zoological Survey of India. These studies are mostly based on the collections made during different faunistic surveys undertaken by this department along various coastal regions. Outside ZSI, no serious attempts are made to study the gastrotrich fauna. Intensive survey of unexplored and under explored areas are quite likely to reveal the existence of more known and unknown species of the gastrotrichs. Faunistic surveys conducted at several areas on the Indian coast for the past three decades, however, indicated a remarkable and progressive decline of this fauna both in their density and diversity. This was largely due to the increasing effects of human activities, resulting in the degradation of natural environment due to pollution.

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KINORHYNCHA

Introduction

Kinorhyncha forms one of the most interesting groups of invertebrate animals in marine meiobenthos. They are microscopic, spiny, segmented and worm–like creatures living in marine and esturarine sediments. They are generally less than 1 mm in length and mostly brown in colour. Their body is covered with thick cuticle devoid of any cilia and divided into 13 segments or zonites. Head constituting the first zonite is spherical and eversible with several rows of curved spines called scalids. The terminal mouth cone is surrounded by 9 oral styles. Head can be retracted into the few succeeding zonites. The animal moves and feeds in sediment like a worm by averting and withdrawing its head, when the scalids gain hold on the solid substratum. The second zonite is largely plated and forms the neck. Rest of the 11 zonites comprise the trunk bearing lateral, dorsal and terminal spines, which sometimes exceed the length of the specimen. The trunk segments are often subdivided longitudinally into a series of separate plates. Some sand–living forms in exposed beaches have lateral adhesive organs which help them to adhere to substratum and withstand sever wave action. Sexes are separate.

All the kinorhynchs are free–living and harmless, mostly inhabiting the upper few millimeters or centimeters of the fine organically rich marine sediments in shallow coastal waters. Occasionally they are also seen associated with littoral algae and a variety of invertebrate animals. Ecologically, they are eurybenthic occurring from the exposed intertidal upto 5000 m or more in the abyss, euryhaline tolerating a wide range of salt concentration from 7 to 60 parts per 1000 and eurythermic withstanding termeratures varying between –20°C and 40°C. These worms penetrate deep into the coarse intertidal sediments upto 1 m below surface. They are omnivorous, largely feeding on fine organic detritus and microscopic plant and animal matter. Quantitatively, their densities in marine sediments are known to range from few individuals to few hundreds of specimens per 10 cm^2 of the substrate. Kinorhynchs are quite susceptible to ecological stress in the environment due to effect of organic pollution, which largely affects their population density and diversity.

Historical Resume

The published records indicate that Kinorhynchs were first discovered in the collections of intertidal meiofauna made from algae on the French Normandy coast (Dujardin, 1851), the same subsequently resulting in the description of the first species *Echinoderes dujardini* by Claparade (1863). Since then, the slow and steady research on this group resulted in the description of about 100 species from different parts of the world, in addition to a large number of unreliable descriptions made based on juvenile specimens (Zelinka, 1928; higgins, 1988). But, nothing was known of this group in the Indian fauna until Krishnaswamy (1957) reported their occurrence from Madras coast while studying the sand–living harpacticoid copepods. Later, Ganapati and Rao (1962) recorded kinorhynchs from the interstitial fauna of Waltair coast and subsequently reported 3 species, *viz., Echinoderes bengalensis* (Timm), *Cateria styx* Gerlach, *Cateria* sp. from the area (1966, 1968). As part of his studies on Indian Ocean Kinorhyncha, Higgins (1968, 1969a, b) described 4 new species *viz., Cateria gerlachi, Condyloderes paradoxus, Sphenoderes indicus* and *Neocentropohyes satyai* from meiodbenthos at different localities in the seas around India. Four more species were subsequently reported from Andaman Islands (Higgins and Rao, 1978), of which one species *Echinoderes andamensis* was described as new to science. The genus *Pycnophyes* was also recorded by them for the first time from the Indian Ocean. In the Arabian Sea, 3 Kinorhynchs

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viz., Echinoderes ehlersi Zelinka, *Echinoderes* sp., and *Cateria gerlachi* Higgins, were recently reported from the littoral sediments on Lakshadweep (Rao, 1990).

Estimation of Taxa

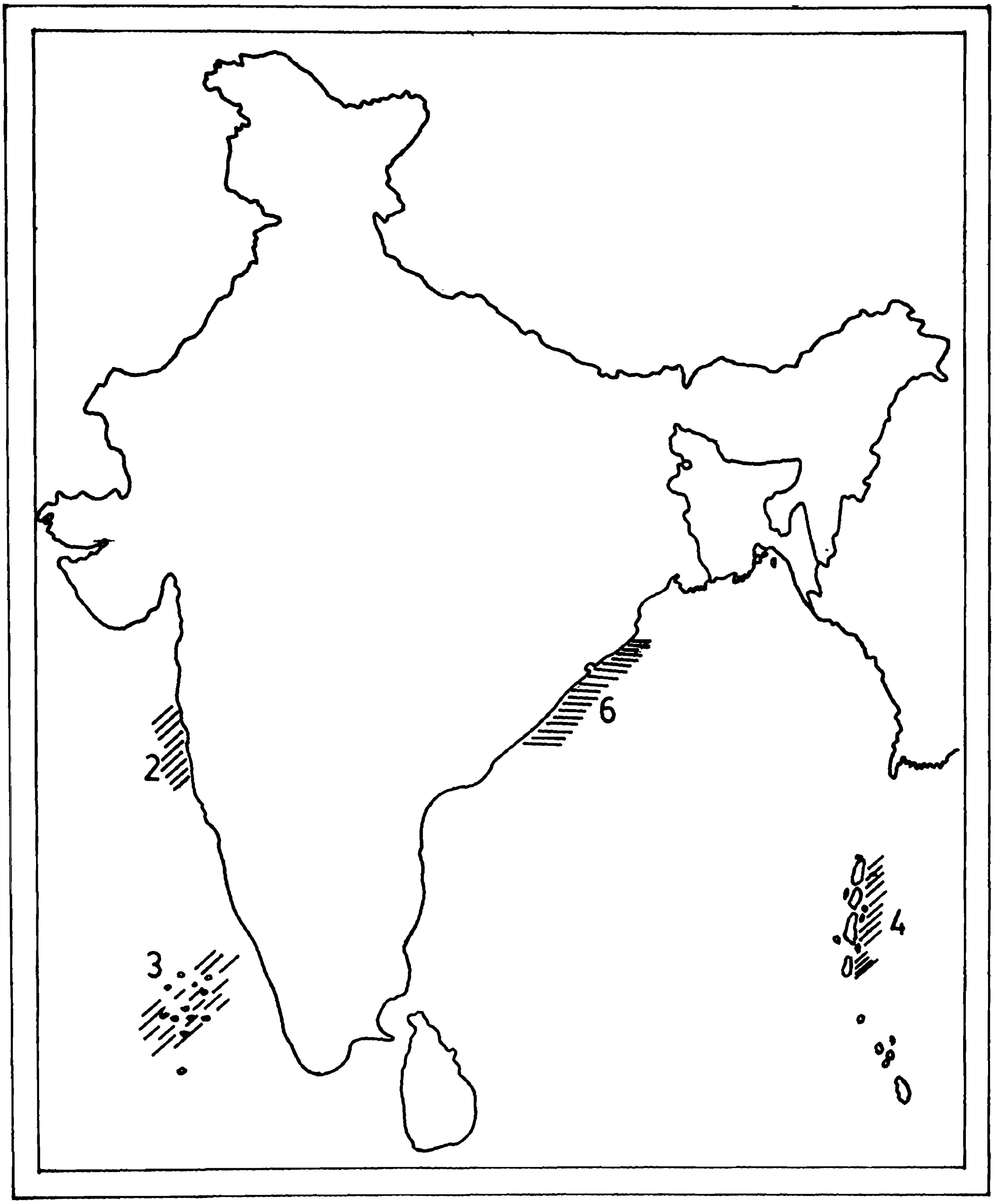
The phylum Kinorhyncha was earlier referred as Echinodera, the name being based on the recurved spines on the eversible head of these animals. Although Kinorhyncha was treated earlier as a class of the phylum Aschelminthes, due to its distinguishing characters it was recently raised to the status of a phylum. The structure of oral styles, eye-spots, number and disposition of plates, spines, adhesive tubes, etc., are largely taken into consideration for their classification. the phylum is divided into two main orders, the Cyclorhagida and Homalorhagida based on the number of neck plates. The Cyclorhagida is again divided into 3 suborders based on the structure of the closing apparatus, the Cyclorhagae, Conchorhagae and Cryptorhagae. The Cycloraghae has two families, the Echinoderidae with a single genus *Echinoderes (42 species) and the Centroderidae with 3 genera,* Condyloderes *(2 species),* Campyloderes (3 species) and *Centroderes* (2 species). The Conchorhagae represents a single family, the Semnoderidae with 2 genera *Simnoderes* (3 species) and *Sphenoderes* (1 species). The Cryptorhagae has a single family Cateriidae with the single aberrant genus *Cateria* (3 species). The order Homalorhagida consists of a single suborder Homalorhagae with two families. the Neocentrophyidae include two genera, *Paracentrophyes* (2 species) and *Neocentrophyes* (1 species). The Pycnophyidae includes two genera *Pycnophyes* (23 species) and *Kinorhynchus* (17 species) All the six known families of the phylum Kinorhyncha are represented in littoral sediments in the seas around India. But, out of the 11 known genera, only 5 were hitherto encountered, namely *Echinoderes, Condyloderes, Sphenoderes, Cateria, Neocentrophyes* and *Pycnophyes*, representing the 10 species given below.

Species	Location	Distribution
Echinoderes bengalensis (Timm)	Bay of Bengal	Endemic
Echinoderes ehlersi Zelinka	Indian Ocean	Endemic
Echinoderes andamanensis Higgins & Rao	Andaman Islands	Endemic
Echinoderes sp.	Lakshadweep	Uncertain
Condyloderes paradoxus Higgins	Bay of Bengal	Endemic
Sphenoderes indicus Higgins	Bay of Bengal, Arabian Sea	Endemic
Cateria styx Gerlach	Atlantic and Indian Oceans	Eurytopic
Cateria gerlachi Higgins	Bay of Bengal, Arabian Sea	Endemic
Neocentrophyes satyai Higgins	Bay of Bengal	Endemic
Pycnophyes sp.	Andaman Islands	Uncertain

A perusal of the data presented here shows that despite their weak powers of locomotion many of these kinorhynch species are widely distributed in the seas around India, although their present endemism to the Indian Ocean is yet to be confirmed with intensive exploration of other areas.

Current Studies

Kinorhynch research at the global level received very little attention from the beginning and this holds true even to this day. Very few workers are presently engaged in their study. The research probably received a major set-back due to the microscopic size of these worms and the difficulty of their separation from muddy sediments. Further, because of their morphological similarity, kinorhynchs are often mistaken as copepods in the meiofauna collections. However,



Map showing the areas on Indian Coast where Kinorhyncha were collected, studied and reported. Numbers indicate the species recorded.

many areas on the Indian coast still remain unexplored or under explored for collection of these worms. At present G. C. Rao is working on the taxonomy of this group in the Zoological Survey of India based on the stray collections made during the general faunistic survey on Indian coast. On the global level, R. P. Higgins is the only active worker and world authority on this group, having made a valuable contribution to the knowledge of these worms from different seas. He has also re-described several of the little known species. As no detailed investigations were hitherto made on the biology, ecology distribution and population dynamics of Kinorhyncha anywhere in the world, the phylum offers ample scope for researchers.

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NEMATODA

Introduction

The Phylum Nematoda consists mostly of cylindrical, sometimes fusiform or rarely saccate multicellular organisms which are usually microscopic in size. It is because of their shape, they are popularly called roundworms or threadoworms. Nematodes have appendageless and nonsegmented body , with a body cavity and complete digestive and reproductive tracts. They are one of the most economically important, diversified and perhaps the largest groups of invertebrates. According to Platt and Warwick (1983), nematodes occur in a wide range of habitats which is unsurpassed by any other metazoan group. In fact, they are found in all kinds of environment and habitats, sometimes even in uninhabitable habitats like hot spring, ice, desert, etc. Cobb (1914), a legendary nematologist has stated, ".... if all the matters in the universe except the nematodes were swept away, our world would still be dimly recognisable .... we would find its mountains, hills, valleys, rivers, lakes and oceans represented by a film of nematodes" According to him every species of vertebrate is infested usually with two species of nematodes. Since there are about 50,000 species of vertebrates, they should harbour some 100,000 species of nematodes. If to this the nematodes associated with invertebrates, plants and those living in soil and waters are added, it would perhaps be fair to estimated 500,000 species are free-living in soil and water while others are parasites of arthropods, molluscs, vertebrates, or plants. Out of this huge estimated number, only 9,000 species were known till 1950, whereas the present figure is about 20,000 known species. At present, descriptions of about 300 new species are being published every year.

It is difficult to estimate the exact loss due to nematode parasites of man, animals and plants. Stoll (1947) estimated about 2,000 million people infected with nematodes over the world. Only one disease, "river blindness" or "onchocerciasis" has been reported in some 20 million people in Africa. More than 50 species have been reported parasitising the human body, of which about a dozen have been found causing serious disease, e.g., ascariasis, filariasis, trichniasis, etc. The average loss due to plant nematodes has been estimated up to 15%, which may, at times, be up to 90% , as in instances like the ufra disease in rice infestation of cyst nematodes or root-knot nematodes, etc., on agricultural crops. Poinar (1983) has reported the losses amounting to four billion dollars due to nematodes in the United States of America alone. However, some nematodes have also been found very useful as good model experimental animals or the basic research in nutrition, physiology, genetics, aging, etc. Sometimes they take part in maintaining natural balance in the soil, and some are used as indicator of aquatic pollution and biological agent for the control of insects and phytophagous nematodes.

The marine, brackish and freshwater nematodes are usually studied independently as free-living nemotodes. In fact, these nematodes have not been paid much attention in India, though they constitute a substantial part or the known nematodes species. Marine nematodes are most diversified in sizes and shapes, and the most abundant in Meiofauna. According to poinar (1985), about 0.1-1.0 million individuals may be found per sq.m. They are considered as free-living because they live in water or soil without any parasitic relationship with animals or plants. Since they feed on micro-organisms, they are also called Microbotrophic nematodes, meaning, utilisation of micro-organisms for nourishment.

The classification of nematodes is based on morphological characters. Traditionally, the nematodes are divided into two classes, viz., Adnophorea (Aphasmida) and Secrenetia (Phasmida.) Class Adenophorea comprises two subclasses (Chromadoria and Enoplio) and the following 9 Orders:

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Araeolaimida (free-living, aqautic and microbotrophic nematodes), *Monhysterida* (free-living, aquatic and microbotrophic), *Desmodorida* (free-living, aquatic and microbotrophic), *Chromadorida* (free-living , aquatic and microbotrophic), *Desmoscolecida* (free-living, aquatic and microbotrophic), *Enoplida* (free-living,aquatic terrestrial, predators and microbotrophic), *Dorylaimada* (free-living, microbotrophic, some plant and vertebrate parasites), *Monochioda* (free-living,microbotrophic and predators) and *Mermithida* (parasites of invertebrates).

These Orders consist of 35 superfamilies and 90 families.

The Class Secernentia includes the following seven Orders:

Rhabditida (terrestrial,microbotrophic, and parasites of plants, insects and vertebrates), *Tylenchida* (parasites of plants and invertebrates), *Aphelenchida* (predators, microbotrophic and parasites of plants insects and other invertebrates), *Strongylida* (parasites of vertebrates), *Ascaridida* (parasites of invertebrates and occasionally of invertebrates), *Oxyurida* (parasites of invertebrates and vertebrates), and *Spirurida* (parasites of vertebrates and invertebrates).

These Orders are based on 55 superfamilies and 120 families.

In main groups, *i.e.*, (A) the animal nematodes (parasites of vertebrates and invertebrates) which are generally included under Helminthology, and (B) the plant, soil and other nematodes which are dealt under Nematology. The latter group also includes the predaceious nematodes in soil and freeliving nematodes in fresh water, marine, brackish and hypersaline environments. These groups differ so significantly that the scientists involved in helminthology and nematology have different priorities and use different parameters in the identification because of the diversities. In view of these facts, it is preferred to provide the account of nematodes under two headings.

ANIMAL NEMATODES

Historical Resumé

Our knowledge of nematode parasites of man and animals dates back to 2700 B.C. in the ancient history of China and to 1553 B.C. in Egypt. Hippocrates in 430 B.C. was the first to record the pinworm, later named as *Enterobius vermicularis*. It will be worthwhile to mention here the names of some earlier workers who have contributed significantly to our knowledge of nematode parasites : Aristotle (384-322 B.C.), Celsus (53 B.C. - 7 A.D.), Columella (100 A.D.), Galen (130-200 A.D.), Vegetius (400 A.D.), Albertus Maqnus (1200-1280 A.D.) and Caesalpinus (1600 A.D.). Leidy, Virchow, Herbst and Leukart also made important contributions in the field during the 16th-18th century. Linnaeus (1758) in his Systema Naturea (10th edition) placed all kinds of worms under the Kingdom Vermes. In 1878, Sir Patrick Manson reported an interesting finding that the nematodes are responsible for causing human filariasis transmitted by a mosquito. Zeder (1800) was the first to use the term *roundworm* as a class of parasitic worms.

In the nineteenth century, a number of helminthologists in Europe were attracted to work on the basic and applied aspects of nematodes of medical and veterinary importance. A few of them are mentioned here : Baird, Carter, Cobb, Cobbold, Diesing, Dubini, Dubini, Dujardin, Giles, Linstow, Looss, Meyer, Molin, Muller, Parona, Railliet, Schineider, etc.

During the twentieth century, a large number of foreign helminthologists have contributed to the taxonomic as well as applied knowledge of animal nematodes of Asian, European and American countries *e.g.*, Baylis, Buckley, Chabaud, Chitwood, Cobb, Leipper, Magrolis, Petter, Skirjabin, Yamaguit and others.

i) Pre-1900

In India, a few European helminthologists had contributed some taxonomic information during the send half of the nineteenth century. Carter (1855, 1858) and Cobbold (1876-1884) in England, von Linstow (1899) in Germany, Parona (1889) in Italy and Raillet (1899) in France were the first to pay attention to the Indian Nematodes. The staff of the Indian Museum Calcutta, collected or received nematodes and sent those to these european helminthologists for identification. Carter (1859), later an Assistant Surgeon in Bombay, made important observations on *Dracunculus*, nematodes from the brackish water as well as on those from open drains of Bombay.

ii) 1901-1947

During the early twentieth century, significant contributions have been made on the nematodes from India by the British officers of medical and veterinary sciences. Boulenger (1920-1924), Chandler (1925-1928), Gaiger (1910-1915), Lane (1913-1921), Linstow (1904-1908), Maplstone (1903-1932) and Ware (1924) studied the nematodes of elephant, pigs and other animals dying at the Zoological garden, Calcutta. Their publications included the descriptions of many new species and new host records. Maplestone (1929, 1930) also worked on the seasonal variation of hook worm. Gaiger (1910, 1915) published a list of nematodes recorded from domestic animals in Punjab. The Zoological Survey of India, Calcutta, has made a valuable contribution by collecting animal parasitic nematodes from the Calcutta Zoo and other places. Dr. Annandale, the first Director of Z.S.I., handed over this material to H.A. Baylis of the British Museum (Natural History), London, who, in collaboration with Daubney (1922, 1923) published a number of new species and new host range of these nematodes. Many new species were described by Chandler and Maplestone working at the School of Tropical Medicine, Calcutta. The Indian Museum, Calcutta and the European Helminthologists have played a vital role in increasing the knowledge of nematodes from this subcontinent up to the first quarter of this century.

Thaper (1924) was the first Indian to describe a species of *Kiluluma* while Mahaskar reported Ancylostomiasis for the first time from Madras in the same year. In 1925, Thapar proposed the new genus *Echinopharynx* and prepared a monograph on the Oxyuroids of Reptiles. In the meanwhile, Karve (1927-1944) reported a number of amphibian and reptilian nematodes. Mirza (1929, 1933), Mirza and Singh (1934) and Mirza and Basir (1937) published good papers on the taxonomy of animal nematodes from Aligarh. Agarwal (1930) and Kulkarni (1935) reported a species of *Procamallanus* each. Baylis (1936, 1939) authored the two valuable volumes of "Fauna of British India" which provided the accumulated knowledge of nematodes from the whole subcontinent.

Among the Indian Helminthologists during the pre-independence period, Mirza (1929-1957) at the Aligarh Muslim University, Thapar (1924-1950) at the Lucknow University and Singh (1938-1965) at the Osmania University, Hyderabad, established good schools of nematode studies. Bhalerao (1932-1948), another pioneer worker in Indian Helminthology, also contributed significantly on the taxonomy of nematodes of the Indian sub-continent initially from Rangoon and later from Indian Veterinary Research Institute, Izatnagar. A brief but valuable review on the various species of *Filaria* was prepared by Basu (1939). In the meantime, a number of taxonomists - Anantaraman, Chatterji, Chauhan, Desia, Ghosh, Guha, Iyanger, Lal, Pande, Ray, Saha, Srivastava, Vaidyanathan and others started reporting species from different parts of the country. Some of the Indian helminthologists contributed significantly and also on the applied aspects of nematodes of economic importance, during this period, viz., Acharya (1939) on the control of poultry nematodes, Chopra and Rao (1939) on the treatment of filariasis, Mukherji (1940) on the control measures against hookworm, Rao (1943) on filariasis, Sarwar (1945) on pathological reactions in *Setaria*, Sen (1945) on Ascariasis, Shastry (1946) on the distribution of elephantiasis. Thapar (1941) provided a review on the control measures against nematode pests. Moorthy (1941) investigated the developmental stages of *Dracunculus medinensis* from southern India.

iii) 1948 - 1990

During the post-independence period, Basir, Mirza, Pande, Singh, Srivastava, Mehra, Thapar and a few other continued their valuable contributions in the field of taxonomy, biology, pathogenecity, control, etc., of nematode parasites of vertebrates and invertebrates. Keeping in view the growth in helminthology at different centres in India, the first volume of the *Indian Journal of Helminthology* was published in 1948 by the Society of Indian Helminthologists. Thaper and Mirza played the key role as the founders of the society. S.P. Gupta, Khera, and Sanwal described a number of new species and genera from Lucknow during 1950s. It will be worthwhile to mention here the monograph on the nematode parasites of Arthropoda by Basir (1957). Ali (1956) conducted a survey of nematode parasites of fishes and birds of Hyderabad while Chakravarty and Majumdar (1959) initiated the work on different aspects of animal nematodes in West Bengal. Later on, Ali joined the Marathwada University, Aurangabad, Maharashtra, where he encouraged Farooqi and Kalyankar to undertake the work on animal nematodes. They published a series of papers on the nematodes from Marathwada region during 1960s. Johnson, a student of Basir, established a good school at the Jodhpur University, during the same period. Ansari (1964) published a comprehensive monograph on the morphology and some applied aspects of *Setaria cervi* whereas D.S. Jairajpuri (1963) initiated the research work on the nematodes of birds at Aligarh. Sood (1967-1980) published a series of papers on the nematodes from India. N.K. Gupta and his co-workers (1973-1980) described a large number of nematode species from the Punjab University, Chandigarh, while Fotedar and Dhar (1970-1980) contributed significantly from Srinagar, Kashmir. In the eastern region, Majumdar at the Burdwan University, Manna at the Calcutta University and Soota, at Z.S.I., Calcutta, made good contributions in different fields of nematode parasites. A few other contributions may also be mentioned here *viz.*, Bhaduri (1948), Chowdhuri (1949), Das and Mukherji (1949), Malhotra (1949), Patel (1948), Premvati (1960), Rai (1958) and others. Bashirullah from Bangladesh and Bilquees, Rashid and Rehana from Pakistan, have also contributed much in the taxonomy of animal nematodes.

Research in ZSI

As mentioned earlier, the Zoological Survey of India, Calcutta, has always been a centre of taxonomic studies of nematodes since the pre-independence days. In the post-independence period, Chauhan (1947) described a new filarid worm *Squamofilaria choprai* from the lung of sea tern of Maldive Islands. Chaturvedi and Kansal (1977) have published a checklist of Indian nematodes. Soota and Chaturvedi (1971), Soota and Dey Sarkar (1975-1984) reported a large number of species of vertebrate nematodes from the northeastern region of India. Soota (1983) has updated our knowledge of nematode parasites of Indian fishes by compiling the descriptions of about 200 species, and providing the keys for their identification. N. Majumdar (1965, 1985) has also described a few new species of nematode parasites from birds. Alvi (1975) at the High Altitude Zoology Field Station of Z.S.I., Solan, has studied the morphology, biology and control measures of fowl caecal nematode of the family Heterakidae.

Approximate number of families, genera and species of animal parasitic nematodes in India

Orders :	9
Families :	50
Genera and Species :	1,000

Areas Covered

It is generally felt that our basic knowledge of the vertebrate nematodes has been satisfactorily assembled and organised. Most of the areas of the country have been surveyed for the nematode parasites of vertebrates.

Outside the Zoological Survey of India, most of the institutions studying nematodes, are engaged in taxonomic work. Some scientists at IVRI and a few universities are involved in the applied work also.

Areas to be Explored

Due to the economic importance of nematode parasites of insects (entomophilic nematodes), an independent branch of nematology called '*entomophilic nematology*' has been developed in recent years. The nematodes belonging to mermithid group have been confirmed to act as a very important biological agent in controlling insect pests. Though Basir from the Aligarh Muslim University (AMU), Rao from the Osmania University and a few others have contributed significantly to the taxonomic knowledge of insect nematodes, our knowledge on this group still remains meagre. Recently, D.S. Jairajpuri and her students have initiated the work at AMU and published about 15 papers on the taxonomy of these nematodes. In fact, not only the entomophilic nematodes but also the nematodes of invertebrates as a whole need more attention in the coming years.

Present state of our knowledge of Indian fauna in relation to that of the world fauna :

In comparison to the knowledge of nematode fauna of other parts of the world, our knowledge of vertebrate nematode parasites from India is satisfactorily build up. However, the nematode parasites of Indian invertebrates are poorly known.

Expertise

INDIA

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PLANT, SOIL AND OTHER NEMATODES

Historical Resume

Though the knowledge of animal nematodes is very ancient, the plant and soil nematodes were not discovered until the 17th century mainly because of their small size and the technical difficulties involved in their isolation from the soil and plant tissues., Borelus (1956) recorded the first free-living soil nematodes (vinegar eelworm = *Turbatrix aceti*), while Needham (1743) was the first to discover the wheat gall nematode, now known as *Anguina tritici*. However, Tiwari and Mitra (1973) from Z.S.I., Calcutta have translated two stanzas from Sanskrit anthology of the thirteenth century which refer to symptoms of certain plant diseases caused by *Krmayo*. The word *Krmayo* has been considered as pertaining to worms or plant nematodes by them. Linne' (1767), Scopoli (1977), Steinbuch (1799) and others recorded the species *Anguina tritici* and noted it to be a serious pest of some other cereal also. Berkeley (1855) recorded the second plant parasitic nematode, *Meloidogyne* sp., while observing the galls produced on greenhouse grown cucumbers in England. Two years later, in 1857, Kuhn found yet another important nematode species which is now known as *Ditylenchus dipsaci* from the malformed floral heads of fuller's taesel.

The economic importance of plant parasitic nematodes was first realized when the production of commercially important sugarbeet crop suddenly declined in Germany in the second half of the 19th century. In 1859, Schacht discovered a serious disease on sugarbeets caused by a species of cyst nematodes which was later named as *Heterodera schachtii* by Schmidt (1871). Due to serious losses in the production of sugarbeets caused by *H. schachtii*, serious efforts were made by many subsequent workers (Kuhn, Liebcher, Molz, Muller, Chatin, and others) to study its life history, habits, distribution and methods of control. In the meantime Muller (1768), Bory (1824), Dujardin (1845), Carted (1859), Eberth (1863) and a few others reported a large number of species of free-living nematodes from the fresh and salt waters.

According to Thorne (1961), the monograph on Anguillulidae by Bastian (1865) marked the beginning of nematology. In this monograph, Bastian described 100 new species of plant and soil nematodes, but the descriptions and illustrations were rather poor. Butchli (1873) for the first time provided detailed descriptions of free-living nematode species and also gave a few parameters for differentiating the genera and species. De Man, a Dutch nematologist, published an excellent and authoritative monograph on plant, soil and freshwater nematodes, in 1876. The De Manian formula for giving body dimensions of nematodes is still universally used in taxonomic studies on plant and soil nematodes. the excellent compilation of accounts of 202 species belonging to 27 genera of free-living and plant nematodes, by Orley (1881), became a valuable source of reference for nematologists in subsequent years. All these significant contributions of the nineteenth century attracted many scientists to nematology during the early 20th century.

A real breakthrough in the history of nematology came when N.A. Cobb joined the U.S. Department of Agriculture, in 1907. He (1890-1933) published a series of excellent papers on the taxonomy of freshwater, marine, soil, plant nematodes, etc. Detailed morphological studies were carried out and new terminologies were coined by him. the illustrations prepared by Chambers for the scientific research papers of Cobb are still unmatched. An interesting phase of nematology started when Christie and others started to Work on applied aspects of some important species of plant parasitic nematodes, in 1936. The history of nematology will remain incomplete without mentioning the valuable contributions made by nematologists like Micoletzky, Hoffmanner, Fusch, Menzil, Stefanski, Linford, Steiner, Goffart, Schneider, Chitwood, T. Goodey, Shuurmans Stekhoven, De Coninck, Thorne, etc., during the first half of the 20th century. The books by Chitwoods (1937, 1950) and De Coninck (1965) on the morphology of nematodes revolutionised the taxonomy of nematodes. Thorne's monographs (1936-1975) are landmarks in the history of nematology. Among those who pioneered the work in nematology during the last four decades are : Taylor, Golden, Allen, Tarjan, Krall, Paramonov, Mulvey, Raski, Seinhorst, Ooostenbrink, J.B. Goodey, Timm, Jones, Jeyns, De Coninck, Andassy, Coomans, Geraert, Croll, Loof, Lamberti, Luc, Jairajpuri, Siddiqi, Fortuner, Wieser, Sauser, Yeates, V. Ferris, Maggenti, Van den Berg and some others.

The work on the taxonomy of other nematodes (marine, brackish and freshwater, etc.) has been carried out satisfactorily during the lst fifty years. The following nematologists have made significant contributions: Andrassy, Bird, De Coninck, Gerlach, Goodey, Haspaslach, Hopper, Khera, Platt, Reiman, Timm, Warwick, Wieser, and others. Perhaps this group could not emerge as an independent discipline because of their limited role in the economy.

After the second world war, due to the awareness of the roie played by palt nematodes in limiting agricultural productivity, nematology has emerged as an independent discipline of biological and agricultural sciences. A significant breakthrough in the development of nematology was achieved when the publication of the first international journal, *Nematologica*, began in 1956. At present, ten international journals of high standard are published from different parts of the world which are exclusively devoted to papers on plant and soil nematodes. Some research papers are also published in peripheral journals. Every year a large number of papers are published on different aspects of nematodes like taxonomy, morphology, ecology, genetics, physiology, pathogenecity, crop losses, soil amendments, host-parasite relationships, control, etc.

In recent years, taxonomic studies have become more important because of the fact that correct identification is the pre-requisite for all applied/experimental work. sometimes all the money and energy could go waste due to wrong identification of the species involved, specially while controlling nematode pests by crop rotation. It has been noted that many closely related species of *Heterodera, Meloidogyne, Paratylenchus, Ditylenchus* and other genera have different host preferences. Unless correct identification is made, it will be difficult to select proper crops. Achievements in finding out the resistant crop varieties also depend largely on the correct identity of the nematode pests.

Research in India

The work on plant and soil nematodes in Indian started rather late, though a considerable work as been done on different aspects of animal nematodes. The first plant parasitic (root-knot) nematode was reported by Barber (1901) from tea gardens of southern India. Butler (1906), working at Agricultural Research Institute, Pusa (Bihar), encountered another species of root-knot nematode on black pepper in Kerala. In 1913, he also reported ufra disease of rice caused by *Tylenchus angustus* (= *Ditylenchus angustus*) in East Bengal, now Bangladesh. thereafter, he (1919) published a detailed paper on ufra disease and its control. Cobb (1913) reported a species of *Criconema* (= *Hemicriconemoides*) from around the roots of mango tree in Bangalore (Karnataka). Some more stray reference are available prior to 1959 (Krishnan, 1933; Ayyar, 1934; Dastur, 1936; Luthra and Vasudeva, 1939; Thaper, 1941: Thomas, 1948; Khera, 1951; Sanwal, 1951, 1954; Singh, 1952). Goodey (1951) described two new species, *Ditylenchus drepanocerecus* and *Aphlenchoides spherocephalum*, from India.

The Department of Zoology of Aligarh Muslim University became the first centre in India to initiate research on the taxonomy of plant and soil nematodes. It was under the able and dynamic leadership of (late) Prof. M.A. Basir that M.R. Siddiqi began his research on nematodes in 1955. Professor Basir has already made valuable contributions on animal nematodes, including an authoritative monograph on insect nematodes. Siddiqui published his first paper on nematodes in 1959. His contribution in the taxonomy of nematodes has left a landmark in the history of nematology. In the meantime, Das (1960) from the Osmania University published a valuable paper on the nematodes of Andhra Pradesh. E. Khan and S.H. Khan also joined the team of Professor Bair in 1960. In 1961, M. Shamim Jairajpuri was enrolled as a Ph.D. student under the guidance of Dr. Ather H. Siddiqi, a parasitologist of international repute. In 1961, F.G.W. Jones of Rothmasted Experimental Station, U.K., visited Aligarh and imparted advanced training in nematology to Siddiqi, Jairajpuri, S.H. Khan, E. Khan, and others. These young and dedicated nematologists published about 100 papers on the taxonomy of plant and soil nematodes and described more than 150 new species from 1961 to 1965. Most of these papers were published in journals of international repute. Drs. M.R. Siddiqi and E. Khan left the Zoology Department in 1964, the former joined the Botany Department at A.M.U., Aligarh and the latter IARI, New Delhi. Dr. Siddiqi later (1967) proceeded to U. K. as a nematologist at the Commonwealth Institute of Helminthology (now International Institute of Parasitology). In the meantime Baqri (1966) started work on plant and soil nematodes under the guidance of Prof. Jairajpuri. Drs. Jairajpuri (1961-1990) and Siddiqi (1959-1990) are counted amongst a few foremost nematode taxonomists in the world who have described more than 300 new taxa including several families, superfamilies and orders.

The Nematology in India developed with rapid pace after 1965. The Aligarh centre played a key role in taxonomic research in the country. Jairajpuri (1976) was the first in India to initiate work on nematode behaviour and biological control of nematodes. His books on the taxonomy of Dorylaimida, biological control of nematode pests, predatory nematodes and other publications on Tylenchida, Dorylaimida and Mononchida have become landmarks in the history of nematology of India. Azmi (1976-1980), I. Ahmad (1980-1990) and Bilgrami (1983-1990) have contributed significantly in collaboration with Jairajpuri on behaviour and biological control of nematode. It is interesting to note that out of about 700 research papers published on nematode taxonomy (Orders Tylenchida, Aphelenchida, Dorylaimida and Mononchida) from India to date over 300, including monographs and books, have been published from the Zoology Department of Aligarh Muslim University. Of the remaining papers, about 50% have been published by taxonomists trained in this department : E. Khan (1964-1990) at I.A.R.I., New Delhi; Baqri (1974-1990) at the Zoological Survey of India, Calcutta; Sultan (1978-1990) at the Punjab Agricultural University, Ludhiana; Bajaj (1977-1990) at the Haryana Agricultural University, Hissar; Rahman (1985-1990) at the Assam Agricultural University, Jorhat; Dhanachand (1980-1990) at the Manipur University, Imphal; and M.L. Khan (1982-1989) at Dr. Y.S. Parmar University, Solan.

Realizing the importance of nematodes during early 1960s, Dr. Abrar M. Khan, a plant pathologist of international repute, in the Department of Botany of the Aligarh Muslim University, organised research in nematology on basic as well as applied aspects. Subsequently, a second centre of nematology was developed in the Botany department of AMU, Aligarh. Saxena, Alam, W. Khan, Haseeb, Farooq, Rashid and a few others worked on applied aspects, while S.I. Husain started work on the taxonomy of nematodes under the able leadership of Abrar M. Khan. Khan and his co-workers (1960-1990) have published a large number of papers in journals of international repute, mainly on control, pathogenecity, disease complexes, and other applied aspects. Alam (1974-1990) Husain (1965-1989); W. Khan (1973-1989) and Saxena (1964-1989) have made valuable contributions in different fields of nematology. Meanwhile, Edward and Misra (1961-1969) from the Naini Agricultural Institute, Allahabad, also contributed to the taxonomy of criconematids of India. Kannnan (1960, 1961) reported a few species of plant a soil nematodes from the Madras city.

In 1962, the basic work on nematodes was initiated at the Indian Agricultural Research Institute by Prasad, Swarup and Chawla. At the same time, A. R. Seshadri and his co-workers undertook a research project on the potato cyst nematode in the Nilgiri Hills, Ootacamund, Tamil Nadu. The Government of India and the Indian council of Agricultural Research realised the economic importance of phytophagous nematodes and created an independent Division of Nematology at Indian Agricultural Research Institute (I.A.R.I.), New Delhi, in 1966. Dr. A.R. Seshadri, a great schemer and organiser, was appointed as the first Head of the Division of Nematology in 1967. He organised research work in different fields of nematology, and the Division of Nematology at I.A.R.I. became a centre of international repute within a short span of time. Prasad, Swarup, Mathur, Sethi and Dasgupta mainly worked on applied aspects, while Khan, Sanwal and Chawla published valuable papers on the taxonomy of nematodes. The outstanding contributions made by these scientists (1963-1990) have enhanced the prestige of I.A.R.I. over the world. Meanwhile

K.K. Nirula (1960-1966) at Central Potato Research Institute, Simla, conducted several surveys for the cyst nematodes and root-knot nematodes and worked on different applied aspects of these nematodes. S.M. Ali started taxonomical studies of plant and soil nematodes at Marathwada University, Aurangabad and Khera organised research at Jodhpur University, in 1964.

During the last 25 years, remarkable progress has been made in nematological research in India. Many young workers have received training by attending the South East Asia Post-graduate Nematology Courses (1967-79) organised jointly by the Aligarh Muslim University; I.A.R.I., New Delhi; and the Agricultural University, Wageningen, The Netherlands. Recently, in December, 1988, an advance training course on nematode pest identification was organised at Aligarh course on nematode pest identification was organised at Aligarh under the leadership of Prof. M.S. Jairajpuri, the then head of the Zoology Department, A.M.U., Aligarh. About twenty young candidates were selected from all over India who intended to undertake taxonomic research in plant nematology. The Nematological Society of India was founded in 1969 and its official publication, *Indian Journal of Nematology,* was first published in 1971. This was a great achievement, as the *Indian J. Nematol.* became the third international journal in the field of nematology. During 1965-1970, D.S. Bhatti at the Punjab Agricultural University, Ludhiana (later shifted to Hissar); B.N. Mathur and B.S. Yadav at the Rajashthan Agricultural University, Jaipur and Udaipur respectively; Y.S. Rao at Central Rice Research Institute, Cuttack; S.N. Das at Orissa University of Agriculture & Technology, Bhubaneswar; Setty at the Agril. College, Hebbal, Bangalore; Sitaramiah at the Univ. of Agril. & Tech., Pant Nagar; and N.C. Sukul and M.K. Dasgupta at Visva Bharati (Santiniketan), established good research centres on nematology. Realising the economic importance of nematode pest, the Department of Science & Technology, New Delhi, sponsored All India Co-ordinated Research Project on Nematode Pests of Crops and their control, in 1977, to the Government of India/Indian Council of Agricultural Research Institutes and different agricultural universities. The same project is now being sponsored by ICAR at 14 centres. This has helped many institutes to develop as a centre of nematology in recent years. At present over 200 nematologists are actively involved in research at more than 25 centres, mainly located at Aligarh (Zoology); Aligarh (Botany); IARI, New Delhi; Hissar; Ludhiana; Solan; Central Potato Research Institute, Simla; Central Plantation Crops Research Institute, Kasargod and Krishnapuram; Udaipur; Kanpur; Jhansi; Bangalore; National Bureau of Plant Genetic Resources, New Delhi; Pantnagar; Trivandrum; Anand; Cuttack; Bhubaneswar; Jorhat; Raahori; Sriniketan; Santiniketa; ZSI, Calcutta; Pusa (Bihar); Coimbatore; Barrackpore; Jaipur, Sopore and Jabalpur. Post-graduate teaching has also been initiated at almost all the agricultural universities. Aligarh (Zoology); IARI, New Delhi; ZSI, Calcutta; PAU, Ludhiana; and HAU, Hissar, are being recognised as the centre of taxonomic studies.

The progress of research in nematology has been quite impressive in the field of taxonomy, ecology, behaviour, biology, pathogenecity, estimation of crop losses, disease complexes, physiology, control, including soil amendments, etc. A large number of research papers are published every year from India in the Indian Journal of Nematology on different aspects of nematodes, including taxonomy. some of the papers on taxonomy of nematodes from India re also published in international journals like Nematologica, *Revue de Nematologie* and *Nematologia Mediterranea*, etc. Nearly 2500 research papers have been published on plant and soil nematodes till date, from India. The break up of the papers published in different fields is given below :

TAXONOMY, SURVEY & DISTRIBUTION	700 papers
i) Taxonomy of Tylenchida	225 papers
ii) Taxonomy of Dorylaimida	200 papers
iii) Taxonomy of Mononchida	40 papers
iv) Taxonomy of miscellaneous groups	40 papers

EXPERIMENTAL

i)	Ecology & behaviour	200 papers
ii)	Biology	50 papers
iii)	Pathogenecity	150 papers
iv)	Control	500 papers
v)	Miscellaneous (screening of crop varieties, physiology, techniques, etc.)	400 papers

Besides the papers mentioned above, about 100 popular articles/reports in English and other Indian languages have also been published on phytophagous nematodes.

As has been mentioned earlier, the marine, brakish, and freshwater nematodes have been paid little attention in India. The ecosystems mentioned here, are inhabited by the nematodes belonging to Orders Dorylaimida, Chromadorida, Araeolaimida, Monhyterida, Desmoscolecida, Enoplida, Trefusiida, Rhabditida, etc. Only a few scientists names may be mentioned who have worked on these nematodes, in India, *vis*., Ali, Carter, Khera, G.C. Rao, Ganpati, Sinha, Baqri, Choudhury and others. Rao and Ganpati (1968) have reported 108 species from Indian coasts, all as new records. Khera (1968-1974) has significantly contributed on the taxonomy of freshwater nematodes.

Research in ZSI

The work on plant nematodes started rather late. Chauhan and Ramakrishna (1958) were the first to publish a review work on the common plant and soil nematodes from ZSI while Khera, a well known nematologist, was the first to initiate research work on plant nematodes when he joined ZSI in 1969. He encouraged Chaturvedi to undertake a research project on the nematodes associated with the jute crop in West Bengal. Chaturvedi and Khera completed the survey work in the jute growing districts of West Bengal and published a good number of papers on nematodes, including a technical monograph. In the meantime Ramvir Singh, now posted at I.A.R.I., New Delhi, also joined ZSI. He worked on the ecology, biology and taxonomy of nematodes associated with vegetables in and around Calcutta. Khera (1969-1977), in collaboration with his students, published over a dozen papers on different aspects of nematodes (taxonomy, biology, ecology and pathogenecity), besides his individual valuable contribution in the taxonomy of freshwater nematodes. While studying the meiofauna, Rao and his co-workers (1968-1969) have reported a large number of species of nematodes from Indian coasts, mostly new records.

A separate section of Nemathelminthes was created in ZSI, Calcutta, in 1974, and Dr. Qaiser H. Baqri was its first Officer-in-Charge. Baqri and Khera started a new series of papers entitle "Nematodes from West Bengal (India)", in 1976, which is still being continued. Baqri and Jana (1980-1985) have published about ten papers on dorylaims from West Bengal.

Dr. Baqri worked as a Principal Investigator of the All India Co-ordinated Research Project on Nematode pests and was assisted by Naseem Ahmad and Das. Baqri and his co-workers have completed district-wise intensive and random surveys in West Bengal and Sikkim for the nematodes associated with paddy crop and citrus plants. Baqri *et. al.* (1982-1990) have established that the rice root nematode (*Hirschmanniella gracilis*) and the root knot nematode (*Meloidogyne graminicola*) are the key pests of paddy crop in West Bengal. *Scutellonema brachyurum* and *Tylenchulus semipenetrans* have been found as serious nematode pests of citrus plantation in Darjiling district of West Bengal and three districts (East, West and South) of Sikkim. Allometric and morphometric variations of all the important pests of paddy and citrus have also been discussed by them. In addition to the survey and taxonomic work, crop losses in paddy due to *H. gracilis* and the effect of different sources of nitrogen on *H. gracilis* population have also bee estimated (Ahmad, Das & Baqri, 1984; Baqri, Basu and Ghosh, 1988, respectively). The work on the ecology of *H. gracilis* has also been carried out (Das, Ahmad and Baqri, 1985). Baqri, individually or in

The work on the ecology of *H. gracilis* has also been carried out (Das, Ahmad and Baqri, 1985). Baqri, individually or in collaboration, has published more than 80 research papers in national and international journals (including revisionary papers, a monograph on the nematodes associated with citrus from Sikkim, and book on the nematode pests of rice). These papers report more than 400 species from soil around roots of various agricultural crops, of which about 100 as new to science. Chaturvedi and Khera (1979) have reported their results on the population dynamics of nematodes associated with jute crop; embryology, life cycle and host parasite relationship of *Meloidogyne javanica.*

Sinha, Baqri and Choudhury (1985-1990) have reported many species from the estuaries of Sunderban, West Bengal. In the meantime, Dr. A. Chatterjee was appointed as Officer-in-Charge of Nemathelminthes Section, in August, 1985. He has good experience in the field of control, specially in isolation and identifying nematicidal principles from plants, and also in manipulating plant growth regulator and nitrogen fixing bacteria. At present, he is working on the nematodes associated with vegetables and mulbary plants in West Bengal.

Recently, Prof. Mohammad Shamim Jairajpuri, one of the foremost nematologists in the world, joined as the Director of Zoological Survey of India, in February, 1989. Presently Prof. Jairajpuri and Baqri are involved in the identification of the nematodes from Andaman and Nicobar Islands, a fragile ecosystem. They have also submitted a book for publication on the nematode pests of rice crop, with special reference to Indian nematodes. The book reports the descriptions and illustrations, biology, symptomology, and control measures of important rice nematodes. In 1991, Prof. Jairajpuri, in collaboration with Dr. W. Ahamad of Aligarh, has published a monumental book in the history of nematology, *Dorylaimida*. The book incorporates the diagnoses of superfamilies, families, subfamilies and genera of the Order Dorylaimida. His another book, published in 1990, on the biological control of nematodes, in collaboration with Alam and I. Ahmad of AMU, Aligarh, has received appreciation at international level.

No. of Families, Genera and Species known from India

Order	Families	Genera	Species
Tylenchida	17	85	560
Dorylaimida	16	110	480
Mononchida	7	15	60
Miscellaneous orders (No.7)	40	95	250
Total	80	305	1350

Areas covered

Family-wise

Heteroderidea; Meloidogynidae; Pratylenchidae; Hoplolaimidae; Criconematidae; Dorylaims; Mononchs.

Survey-wise

Random surveys have already been conducted in most of the states of India. However, attention has been paid only to identify the important nematode pests of agricultural crops.

Areas to be explored

Family-wise

Intensive surveys of economic crops should be conducted in every state for the endoparasitic and semi-endoparasitic nematodes (Heteroderidae, Meloidogynidae, Nacobbidae, etc.). Special attention has also to be paid to identify the virus vector nematodes belonging to the families Longidoridae, Xiphinematidae and Trichodoridae of the Order Dorylaimida. Our knowledge of the Indian nematodes belonging to the Orders Rhbditida, Enoplida, Monhysterida, Chromadorida, etc., is insignificant.

Survey-wise

Random surveys are necessary to explore the fauna of plant and soil nematodes in Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, Tripura, Pondichery and Goa. The bigger states like Madhya Pradesh and Bihar also need more attention. Attempts should also be made to gather information on the nematode fauna of different ecosystems, *e.g.*, mangrove, desert, island, estuary, marine, fresh water, high altitude, forest and sewage, etc. A co-ordinated approach involving different centres is likely to produce more fruitful results.

Indian Fauna in relation to World Fauna

It is estimated that the hitherto known species of plant and soil nematodes from India are about 1/5th of the total known fauna of the world.

As far as the plant parasitic nematodes are concerned, nearly all the widely distributed and important species associated with agricultural crops in most of the states of India have been identified. On the other hand, the identification of economically less harmful (parasites of low significance), more useful (Predaceous) and other soil inhabiting nematodes is being ignored by most of the taxonomists. This is the main reason that our overall knowledge about plant and soil nematodes still remains poor in India.

Our present knowledge on marine nematodes from India is almost insignificant, though the number of known marine nematode species is about 1/5th of the total known nematode fauna of the world, *i.e.*, 4,000 out of 20,000 hitherto known species. Unfortunately, only about 200 species of marine nematodes are known from India. About 500 nematode species are known from freshwater ecosystems over the world, whereas we know about five dozen species from India. The knowledge of nematode fauna from brackish and other hypersaline environments in India is similar to freshwater nematodes.

Expertise

INDIA

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ACANTHOCEPHALA

Introduction

Acanthocephala or thorny headed worm is an important group of animal endoparasites occurring widely in adult stages, and are of direct economic importance to man. Their life history involves one or more hosts,generally invertebrates or lower vertebrates. Very little is known about the damage caused by these worms and their impact on the economy of man.

Historical Resumé

Redi (1684) and Leenwenhock (1695) were the earliest workers on record to have noticed Acanthocephala. However the term Acanthocephali (meaning organisms with hooks on the head) was first used by Koelrenther (1771) for a group of helminths and he named a fish parasite as Acanthocephalus. In 1776, Zoega and Muller independently named the same parasite as Echinorhynchus. Later, Muller (1777-1788) described several forms under the genus *Echinorhynchus*.

Zeder (1800) gave these worms the name Haken wurmer (hooked worms) because of the characteristic hooks and spines invariably associated with the head. Rudolphi (1808) established the order Canthocephala to accommodate these worms, variously known as Acanthocephali and Huken wurmer. Till 1890, the order contained a single genus *Echinorhynchus* Zoega.

The rapid accumulation of diverse forms under a single genus necessitated the reappraisal of the group. Hamann (1892) was the first to attempt a systematic classification of the order Acanthocephala, recognising a number of genera and families. He established the genera *Gigantorhynchus* and *Neorhynchus*, bringing several species included earlier in *Echinorhynchus* under his new genera. He further erected two new families viz. Gigantorhynchidae and Neorhynchidae to accommodate each of his two new genera.

Since then rapid progress in systematics of this group was made by a number of parasitologists, especially, Luhe (19 04, 1912) Kostylew (1915), Travassos (1917, 1926), Ward (1913), Southwell (1933), Van Cleave (1923) and Maplestone (1926). Earlier classifications of this group were based on two main premises, some workers divided the taxonomic hierarchy on the basis of nature of nuclei in the hypoderm and lamnisci; others like Southwell and Macfie (1925) took others cognisance of the nature and character of the prostate glands and proposed a tentative classification using this character. Based on the structure of probosis hooks and body spines, Thapar (1927) divided the class Acanthocephala in three orders viz. Apororhynchidea, Echinorhynchidea and Acanthogyridea.

Van Cleave (1928) erected the families Pallicentidae and Hebosomatidae, utilising not only the proboscis hooks and body spines, but also laying special stress on the nature of nuclei in the subcuticula. Myer (1933) accommodated twelve families and fifty eight genera known till then into two new orders, viz. Palaeacanthocephala and Archiacanthocephala, elevating the order Acanthocephala to the status of a class. He relied in his scheme of classification on the presence or absence of trunk spines and nature of lacunar system. Van Cleave (1936) added another order, Eoacanthocephala and divided it into two suborders Gyracanthocephala and Neoacanthocephala. The same author (Van Cleave 1948) made a comprehensive review of the whole group and elevated. Acanthocephala to the status of a separate phylum. Hyman (1951) agreed with Van Cleave and recognised, Acanthocephala as phylum but did not accept Van Cleave s classification as such She recognised only three orders in it. viz. Archiacanthocephala, Palaeacanthocephala and Eoacanthocephala and discarded the two classes of Van Cleave. Petroschenko (1956) did not accept

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the status of phylum and divided class Acanthocephala into three subclasses viz. Neoechinorhynchinea, Echinorhynchinea and Gigantorhynchinea. Golvan (1958, 1961) modified the classification of Acanthocephala laying too much emphasis on the number of cement glands, ignoring the significance of trunk spines. Yamaguti (1963) proposed a modified classification of the group. He accepted Acanthocephala as a class under phylum Nematehelminthes and recognised four orders namely(1) Apororhynchidea Thapar, 1927, (2)Neoechinorhynchoidea Southwell and Macfie 1925), (3) Eminorhynchoidea Southwell and Macfie 1925 and (4) Gigantorhynchoidea Southwell and Macfie 1925.

The position of Acanthocephala in systematic hierarchy has been controversial and as yet there is no agreed opinion among parasitologists about its status.

Cuvier (1817) included these parasites among flatworms. Leuckart (1848) considered Acanthocephala near to cestodes and included both of these as two separate orders in the class Anenteraeti. Vogt (1851) distinguished two groups among these worms, viz. flatworms and round worms calling the former as Platyhelmia and the latter as Nematelmia which contained gregarines nematodes, acanthocephalans and goraiaceans. Gegenbaur (1869) amended Vogt's Nematelmia to Nemathelminthes. Schneider (1866) combined these and some other groups into Chaetognatha on the basis of musculature. Hamann (1891) went into the question of the relationship of Acanthocephala on the basis of similarity between the embryo and pseudometamerism present in Moniliformis and some other larger forms and considered them more related to cestoda than to Nematoda with which they shared in behaviour of nuclei and similarity in musculature. Choloakovsky (1897) agreed with Hamann's contention and considered cestode and Acanthocephala to have common origin. Grobben (1908) proposed a new phylum Aschelminthes to include Acanthocephala along with Nematoda, Nematomorpha,Gastrotricha and Rotifera, etc. More or less this arrangement was also accepted by Rauther (1931) and Meyer (1932, 1933). Van Cleave (1924, 1941) discussed the relationship of Acanthocephala and concluded that this was related to Cestoda. He proposed elevation of Acanthocephala to the status of Phylum near Platyhelminthes. Recently, Amin (1982, 1985) discussed the classification of Acanthocephala and treated it as a phylum. This view was accepted by Arai (1989). The nearness of Acanthocephala to Platyhelminthes is more or less accepted now.

Work done in India

The earliest record of acanthocephalan parasites from India was made by Chandler (1923) who described *Centrorhynchus erraticus* from the intestine of a cat from Calcutta. Thapar (1927) was the first Indian Zoologist to have initiated studies on Acanthocephala. He not only described a new genus and species. viz. *Acanthogyrus acanthogyrus* from the intestine of a carp, *Catla catla*. at Lucknow but also proposed a tentative classification of the group. Datta (1927) described a new species of *Echinorhynchus* from crow. Subramanian (1927, 1936) worked out the acanthocephalan parasites from Burma. Van Cleave (1928) erected a new family Filisomidae to accommodate a new genus and species *Filisoma indicum* obtained from the intestine of a fish collected from Chilka Lake, Orissa. Verma and Datta (1928, 1932) reported acanthocephalan parasites of birds. Further contributions to our knowledge of Indian Acanthocephala were made during thirties and forties by several workers. Bhalerao (1931, 1937) described a new species of *Pallissentis* from the intestine at a fish from Nagour, and another from fowl. Moghe (1931) made general reference to the group. These studies were followed by a host of workers in subsequent years. Thus Datta (1936, 1937, 1940, 1947, 1953) added several forms including a number. of new species and two new genera (*Mehrarhynchus* and *Raosentis*) from fishes. Further contributions on the acanthocephalan fauna of India were made by Podder (1937, 1938, 1941), Datta and Podder (1938), Sen (1938), Kaw (1941, 1948, 1957), Das (1950, 1952, 1957), Moghe and Das (1953), Sarkar (1953, 1954, 1956), Datta and Soota (1955, 1956), Soota and Sen (1956), Agarwal (1958), Farooqi (1958), Gupta (1958), Tripathi (1959), Pal (1963), Nath and Pande (1963), Sahai, Sinha and Rai (1967, 1971), Gupta and Lata (1968). Soota, Srivastava and Ghosh (1970) described Acanthocephala from Andaman and

Nicobar Island. These papers deal with adult parasites, mostly described from fishes, but also include forms obtained from other vertebrates like amphibia, reptiles, birds and mammals. In recent years, very little work has been done on this group and it is confined to fish Acanthocephala. Notable contributions have been made by Sood (1972), George and Nadakal (1973), Sen (1975), Jain and Gupta (1979), Farooqi (1980), Soota and Bhatacharya (1981, 1982), Agrawal and Singh (1982) and few others. Verma (1973) gave the key to the species of the genus *Acanthogentis*. Anantaraman and Anantaraman (1975) gave a synopsis of the Acanthocephala described from India till then. Rengaraju and Das (1976) reviewed the taxonomy of Acanthocephala and mostly adopted Van Cleave's classification without going into its merits. Rengaraju (1979) described *Porrorchis indicus*. Not much works has been done in India on the larval and juvenile stages of Acanthocephala. Sita (1949) studied the life history of *Moniliformis moniliformis* a parasite of rat. Gupta (1950) described developmental stages and juveniles of *Centrorhynchus ptyasus* parasitising rat snake. *Ptyas mucogus*. Das (1950,1952,1957) recorded several new as well as known species of Acanthocephala from amphibians and birds dealing with adult, juvenile and larval stages of several species belonging to genera *Controrhynchus*, *Meiorhynchus*, *Pseudoporrorchis*, *Arhythmorhynchus*. Ghosh and Chauhan (1975) reviewed the work done in the Z.S.I. in last fifty years.

Estimation of Taxa

Twenty five families distributed under four orders have been recorded so far from various parts of the globe.

Estimated number of families, genera and species in India are detailed below :

No. of families	Genera	Species
15	24	110

The work done on this group in the country is too meagre when viewed in the light of host species available in the country. The work has been sporadic and systematic survey based on host species and their distribution is desirable.

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SIPUNCULA

Introduction

The Sipuncula, popularly called pea-nut worms, are common inhabitants of shores of polar, temperate and tropical seas. They have also been collected from the floor of the ocean, at great depths.

Rondelet (1555) for the first time described and figured two sipunculans as micro and macrorhynchoterous worms. Later, Bohadsch (1761) described a specimen to which Linnaeus (1766) gave the name *Sipunculus nudus*. Sipunculans were placed under Gephyrea (Greek *gephyros* = a bridge) by Quantrefages (1847) along with echiurans and priapulans, under the assumption that they form a link between the annelids and the holothurians. This concept was in vague for over a century though Sedgwick (1898) promoted sipunculans to the rank of a Phylum, Sipunculoidea. Recently, Stephen (1964) emended the name of the phylum as Sipuncula replacing Sipunculoidea of Sedgwick (1898) and Sipunculida of Hyman (1959), with sipunculan as a common name.

Sipuncula comprises unsegmented, coelomate, bilaterally symmetrical and soft-bodied invertebrates. They are cylindroid in shape, with body regionated into a slender anterior introvert, and a plumper posterior trunk. The introvert is highly muscular, and retractile in nature and lies along the same axis of the trunk, but sometimes displaced ventrally. The mouth lies at the anterior extremity of the introvert and is usually surrounded by tentacles, generally followed by a zone of hooks. In some, the anterior end of the trunk is armed with a calcareous cap. The anus is situated dorsally in the anterior region of the trunk. The posterior end is blunt, pointed, acorn like or provided with a cap. The trunk bears papillae of various shapes and sizes, being more dense at both ends than in the middle, or localised regionally and sometimes modified as holdfast or may even be totally absent.

Phylum Sipuncula has been divided into two classes consisting of four orders and six families (Cutler & Gibbs, 1985), which are as follows :

Class	Order	Family
Sipunculidea	Sipunculiformes	Sipunculidae
	Golfingiiformes	Golfingiidae
		Themistidae
Phascolosomatidea	Phascolosomatiformes	Phascolosomatidae
	Aspidosiphoniformes	Aspidosiphonidae

In the class Sipunculidea, the tentacles enclose the centrally placed mouth on the oral disc; introvert hooks, if present, are simple, sharply pointed and usually scattered; spindle muscle not attached posteriorly.

In Class Phascolosomatidea, the tentacles are arranged in a single crescent or near circle dorsal to the mouth but enclosing the nuchal organ; peripheral tentacles absent introvert hooks recurved and arranged in rings; spindle muscle attached posteriorly.

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Sipunculans inhabit all possible habitats right from the intertidal region (Mean High Water Spring Tide) up to the abyssal depths of about 9,600 m of the marine environment. Their size also varies from a few millimeters to 60 centimeters in length.

They are benthic forms with crawling and burrowing mode of life, excluding one species which is a swimming form. These marine invertebrates are detritus feeders and their feeding habit, specially of the larger forms, helps them to rebuild the substrate in a manner somewhat similar to earthworms and holothurians. By their feeding and burrowing habits and also their ecological association with other organisms, the sipunculans carved for themselves a special status in a marine biotic community.

The boring activity of sipunculans causes a good deal of erosion to the coral and rock substrate by mechanical abrasion or chemical action. Their association with other animals ranges from predator-prey relationship and commensalism to parasitism.

Historical Resumé

The knowledge of sipunculans from the Indian coast is fragmentary. The earlier investigations were carried out in a rather haphazard manner from different coastal belts of India.

Lt. Col. Hardwicke collected a specimen from India which was described by Gray in 1828, but unfortunately, no specific locality was mentioned. At present, the species is restricted to the mangrove zone of India, particuarly the Sundarban.

The pioneering work on the Indian sipunculans dates back to 1903 when sipunculans of the Minicoy Island in the Lakshadweep, collected during Gardiner's expedition to the Maldive and Laccadive Archipelagoes, were studied by Shipley (1903). Unfortunately, many of the species described by Shipley (*loc. cit.*) were synonymised. Moreover, this collection was not traceable in any of the museums of Great Britain. This work followed by Annandale's (1907) report on an anonymous species from the brackish water ponds of Port Canning, Lower Bengal (= southern West Bengal), and then by Gravely's (1927) work on the fauna of the Krusadai Island in the Gulf of Mannar and Prashad's (1936) publication on a small collection of sipunculans from the Indian waters.

For nearly three decades after Prashad (1936), no publication appeared on this group, in India, though work on this group progressed rapidly in other parts of the globe. Johnson (1964, 1969, 1971) of the Pilani University, Rajasthan, described several new species from stray collections from Port Blair, (South Andaman Island), Port Okha (Gujarat), Minicoy Island (Lakshadweep) and Krusadai Isalnd in the Gulf of Mannar, as also some new records from the Indian waters. Subba Rao (1970, 1975) reported a brackish water form and studied chloride regulation in the same species. Rajulu (1969, 1975) studied asexual reproduction and biochemistry of the coelomic fluid in some sipunculans. Reddiah (1975) dealt with the sipunculan habitat in peninsular India.

For the last one and a half decade (1975-1990) a good progress has been made in the Zoological Survey of India, in the taxonomic studies on sipunculans. Haldar studied the forms from the Indian seas in 1975, Andaman and Nicobar Islands in 1976 and 1978, estuarine forms in 1985 and 1989, and Lakshadweep (in press), in the collection of the Zoological Survey of India. Recent contributions on this group from the estuarine ecosystem of the Hooghly-Matla and Chilka Lagoon have been finalised. In an extensive study, Haldar (in press) has dealt with the Indian coastal sipunculan fauna with view to up-dating our knowledge on this group.

Manavalaramanujam (1978-1982), studied histochemical nature of the cuticle and related structures, mechanism of calcification of shields, myohemerythrin and mucus in sipunculan worms.

Studies from Different Environs

As has already been stated, habitats of sipunculans include sandy, muddy and hard substrata, from intertidal to abyssal depths. They inhabit such varied niches as under surfaces, clefts and interstices of rocks, rubbles, boulders, corals, etc., sand pools, mangroves and even estuarine or brackish environments.

Most of the earlier studies on sipunculans were of taxonomic and faunistic nature, and contain only casual references to the nature of the habitat. Later investigations contained some information on the general nature of the environment from where the specimens were collected. There had been only very few studies pertaining to the group with emphasis on the habitat, and all were related to the shallow water fauna. Johnson (1964, 1969, 1971) studied the taxonomy, ecology and zoogeography of some forms from Port Okha, Port Blair and Minicoy Island. Shallow water forms collected from different parts of the Indian coast were being reported from time to time which had been consolidated by Haldar (1975-1990). In these publications, insular ecosystems of the Andaman and Nicobar Islands, and Lakshadweep had been thoroughly explored so far as the intertidal forms were concerned.

Our knowledge of the deep sea forms of sipunculans is very poor. The intertidal and shallow water forms of the RIMS 'Investigator'-collections were studied by Haldar (1975). During the international Indian Ocean Expeditions (1963-1964), foreign vessels "Anton Bruun" and "Te Vega" explored the Arabian Sea and the Bay of Bengal, and the material was studied by Cutler (1977), and Cutler and Cutler (1979). Reddiah (1975) studied the sipunculan habitat in peninsular India.

Indian universities are not lagging behind in sipunculan research. Among these, Pilani University has been in the forefront. Johnson (1964-1971) studied the taxonomy and zoogeography of this group and described several species. Subba Rao (1970 & 1975) of the Andhra University has thrown some light on the salinity tolerance and chloride regulation in a sipunculan worm. Rajulu (1969, 1975*a*, 1975*b*) noted asexual reproduction (1969), and made biochemical studies on the coelomic fluid of two species (1975*a*, 1975*b*). Manavalaramanujam (1978*a*, 1978*b*, 1980*a*, 1980*b*, 1980*c*, 1981*a*, 1981*b*, 1982) investigated histochemical studies of the cuticle and related structures of two species, mechanism of calcification of shield, myohemerythrin and mucus in sipunculan works.

Sipunculans of the estuarine ecosystem have attracted still less attention. Earlier work of Annandale (1907) was on an unnamed sipunculan from Port Canning, southern West Bengal. Haldar (1985) reported faunal wealth of this group from the Indian estuaries. Recent contributions on this group from the estuaries ecosystem of the Hooghly-Matla, and Chilka Lagoon are being finalised by Haldar.

Estimation of Taxa

Sipuncula of the world comprises 202 species in 17 genera under six families. Of these, nearly half the number of species in genera have been recorded from the Indian Ocean. The sipunculan fauna of the Indian coast is fairly rich, represented by more than one-third of the total species known from the Indian Ocean.

It may be noted that the family Phascolionidae, though represented by a good number of species from different oceans, including the Indian Ocean, has not so far been reported from the Indian region. The members of this family live in deeper waters which have not been explored properly in the Indian region.

Of the 38 species known from India (Haldar, in press), 18 species are rock-borers and at least two species are mud-burrows, while seven species are sand-burrows, 11 species occur under rocks, stones and coral boulders or on sand. Truly deep water forms are still unknown either from the Arabian Sea or from the Bay of Bengal. Though Hyman (1959) stressed on the exclusive occurrence of the sipunculans in the marine habitat, at least three species have been reported in from the estuarine habitat of some parts of the globe, subsequently. Recently, two species have been reported from the estuarine and brackish water zone of India also (Ganapati and Subba Rao, 1970; Haldar, 1989; in press).

Genera		No. of species World Ocean	Indian Ocean	Indian Coast
Family	Sipunculidae			
Genus	*Sipunculus*	10	6	5
	Xenosiphon	1	1	—
	Siphonosoma	10	5	4
	Siphonomecus	1	—	—
	Phascolopsis	1	—	—
Family	Golfingiidae			
	Golfingia	12	6	—
	Nephasoma	23	8	3
	Thysanocardia	3	2	1
Family	Phascolionidae			
	Phascolion	23	14	—
	Onchnesoma	4	1	—
Family	Themistidae			
	Themiste	24	10	2
Family	Phascolosomatidae			
	Phascolosoma	36	21	10
	Apionsoma	6	5	3
	Antillesoma	1	1	1
Family	Aspidosiphonidae			
	Aspidosiphon	44	21	7
	Cloeosiphon	1	1	1
	Lithacrosiphon	2	2	1
Total		202	104	38

Distributional Pattern of sipunculan fauna in India

Region	No. of species
Arabian Sea : Off-shore waters	4
Bay of Bengal : Off-shore waters	4
Lakshadweep	17
Andaman Islands	25
Nicobar Islands	14
Northwestern coast (Gujarat & Maharashtra)	15
Southwestern coast (Kerala)	7
Southwestern coast (Tamil Nadu, Islands in the Gulf of Mannar)	14
Northeastern coast (Andhra Pradesh, Orissa & West Bengal)	7

Classified Treatment

In addition to the taxonomic studies, a few other aspects of sipunculans have been studied. Ganapati and Subba Rao (1970) studied the salinity tolerance of *Siphonosoma australe*, while chloride regulation in the same species was studied by Subba Rao (1975). Asexual reproduction by budding in *Sipunculus robustus* was reported by Rajulu (1975). Manavalaramanujam studied several aspects of sipunculans such as histochemistry of the cuticles in *Sipunculus robustus* and *Eloeosiphon Aspergillum* (1980*a*, 1980*b*), biochemistry of the same species (1980*c*), histochemistry of mucus in *Thmiste lageniformis* and *S. robustus* (1980*d*). The myohemerythrin concentration and mechanism of calcification of the anterior shield in *Cloeosiphon aspergillum* were reported by Manavalaramanujam (1981, 1982).

Current Studies

In the Zoological Survey of India, mainly the systematics and geographical distribution of sipunculans are being studied at present, with emphasis on state-wise faunal accounts. The projects on sipunculan fauna of the Lakshadweep, Hooghly-Matla estuary and Chilka Lagoon have been completed. The current project is on the fauna of Gujarat coast. Outside the Zoological Survey of India no work on sipunculans is being carried out at present.

Outside India, several scientists, particularly those from U.S.A., U.K., France, Spain, Australia and Russia, are engaged in revisionary, ecobiological and physiological and developmental studies as also on evolution, classification, etc.

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MOLLUSCA

Introduction

The Molluscs are of great antiquity and diversity. By the time the first fossils were known in the Cambrian period, about 600 million years ago, molluscs were already distinguished into their major classes. It led malacologists to conceptualize the existence of a soft-bodied ancestral archetype mollusc in the Pre-Cambrian period. The ancestral mollusc, which crawled about on rocks and other hard substrata of the oceans gradually passed through transitional turbellariform stage, transitional molluscan stage and evolved into the advanced molluscan stage by the Cambrian period.

Molluscs are a structurally heterogeneous group, since a slug is strikingly different in structure from a freshwater mussel or from an octopus or a snail. The shell, by which majority of the molluscs are known, is absent in several forms. A mollusc has to be recognised on the basis of a combination of traits or characters. When a number of such characters are involved in the identification, the relative importance of each such character becomes variable, depending on the weightage given to that particular one. It has posed problems in the classification of Phylum Mollusca.

The term 'Mollusca' was first adopted by Linné (1757), but the concept of the group developed by Cuvier (1791) approximates to modern ideas. According to gross morphological, anatomical and biological features, Phylum Mollusca has been divided into three subphyla and seven classes, which are as follows :

Phylum	Subphylum	Class
Mollusca	Aculifera Placophora Conchifera	Aplacophora Polyplacophora Monoplacophora Gastropoda Bivalvia Scaphopoda Cephalopoda

In numerical abundance the phylum is second only to Arthropoda (not considering the microscopic Nematoda). Estimates of the number of species in Mollusca vary between 80,000 to 1,00,000. According to one estimate there are 50,000 species of gastropods, 15,000 species of bivalves, 500 species of polyplacophorans, 400 species of cephalopods, 300 species of scaphopods, 130 species of apalcophorans and 5 species of monoplacophorans. A more conservative estimate gives the number as 31,463 marine 8,765 as freshwater and 24,503 terrestrial species (Winckworth in Eales, 1949).

Molluscs are soft-bodied animals and have colonized all possible habitats, extending from deep seas to highest altitudes (4500 m). They are, however, more abundant in littoral zones of tropical seas. The classes Apalcophora, Polyplacophora, Scaphopoda and Cephalopoda are exclusively marine and account for 2% of the total living species. The two large classes, namely, Gastropoda and Bivalvia have extended into freshwater and the former even on to land. The two classes together constitute 98% of the known living molluscan species.

Molluscs have successfully adopted to different ecological conditions. They act as important

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components in the production of biomass. They are the first living creatures to have hard shells, and the earlier man was perhaps attracted to these shells. The association of man and molluscs dates back to prehistoric times as evidenced by their remains in Mohenjadaro, Harappa and others places. A large number of shells were unearthed in the kitchen middens of ancient men. Besides the aesthetic appeal of their shells, the soft parts of molluscs are edible. Some of the molluscs can be used as potential sources of biomedical compounds, which are used in the manufacture of drugs. They also produce commercially valuable products like pearls and raw material for the shell-craft industry. Molluscs support viable fisheries in several countries, including India. Shells, snails, cuttle-fishes, squids, etc. are foreign exchange earners for India. Certain snails serve as intermediate hosts of several trematode parasites, spreading diseases in livestock and man. They choke the filtered water pipe systems and water inlets of coastal thermal power plants, Shipworms and piddocks bore into marine timber structures causing heavy losses. A few of the land snails, when they occur in abundance, pose a serious threat to agri-horticultural and commercial crops.

Historical Resumé

Molluscs were collected in the beginning out of amateurish love or curiosity of shells. Collections were made at random and preserved for further study. Collections had accumulated through the efforts of individuals, who were otherwise engaged in the expeditions or topographical surveys. Their attention was naturally drawn to land molluscs. The incidence of schistosomiasis after the First World War, led to a search for its possible intermediate host in India, which in turn promoted studies on the taxonomy and distribution of freshwater molluscs. The launching of RIMS Investigator in 1881 A.D. formed an important milestone in the study of marine molluscs. Thus studies were initiated on land, marine and freshwater molluscs of India even before the establishment of the Zoological Survey of India.

i) Pre-1900

Studies on Indian molluscs were promoted by the Asiatic Society of Bengal (1784) and the Indian Museum, Calcutta (1814). The Journal of Bombay Natural History Society started in 1886 provided yet another avenue for Indian malacologists to report the results of their researches. The scientific staff attached to the Palaeontology Division of the Geological Survey of India also contributed to the knowledge on Indian molluscs. The successive Superintendents of Madras Government Museum undertook several dredging operations in the Gulf of Mannar and supplied material for research.

Although the collection of molluscs had started in the later half of the eighteenth century, it was occasional and sporadic in nature. It took another few decades for a malacological publication to appear. Benson, in 1830, was perhaps the first author to publish a scientific paper on Mollusca. Between the years 1830 and 1865 Benson published a total of about 90 papers dealing with the land and freshwater molluscs of the Indian subcontinent. During the later half of the nineteenth century many malacologists have emerged on the scene: Beddome (1875-1906), Blanford (1860-1904), Godwin-Austen (1874-1922). Hutton (1949), Melvill (with Sykes and also Standen, 1888-1904), Nevilll G. & H. (1871-1888), E. A. Smith (1878-1903). Stoliczka (1969-1873) and W. Theobald (1859-1889).

Col. R. H. Beddome was essentially a botanist, who was appointed in the Forest Department. He collected good samples of molluscs, especially land operaculates from the hill ranges and forests of Central and South India. All his collections were studied by W. T. Blanford, with whom he published a Fauna volume. After his death all the collections were donated to the British Museum (Natural History), London.

W. T. Blanford (1832-1905) was primarily a geologist attached to the Geological Survey of India. He had explored a large part of the subcontinent and had acquired first hand knowledge on the distribution of animal life. He published a series of about 40 papers, either himself or in collaboration with his brother, H. F. Blanford and contributed a total of about 400 printed pages on molluscs. He was responsible for the inception of official "Fauna of British India" series to which he contributed five volumes on vertebrates. However, he could not complete the first volume that he had begun on land and freshwater Mollusca, which was left to be completed by his life-long friend, Col. Godwin-Austen.

Ferdinand Stroliczka, who came to India in 1862, had wider zoological interest and could not concentrate much on molluscan studies. During his Second Yarkand Mission (1873-74) and several other expeditions, he collected a number of molluscs which were studied by Nevill and others. He was the first malacologist to draw attention to anatomical details through his publication on the species of *Onchidium*. The good work that he contemplated did not progress much.

The first effort to consolidate the then existing malacological knowledge was found in Hanley and Theobald's Conchologia Indica (1876) which was aimed at facilitating the labours of those who may aspire to produce a more perfect conchology. About 1885 species classified under 88 genera of land and freshwater molluscs of India and adjacent countries were enumerated in that well illustrated work.

In 1878, Geofferoy Nevill (d. 1885) who was Assistant Secretary and Librarian in the Indian Museum, published the first part of his 'Hand List of Mollusca in the Indian Museum' followed by part II in 1885. Although Nevill introduced many nomen nuda and thereby caused confusion his works gave an improved classification and exact localities of each collection. In addition to these, Nevill along with his brother, H. Nevill brought out a series of papers on marine and freshwater molluscs. Hiscontributions on molluscs of Bay of Bengal, Sri Lanka, Ladakh and Burma contain a number of new species, largely of gastropods. The collections in the Indian Museum which now form a part of the National Zoological collections were well maintained and catalogued by Nevill. After his retirement the collections have passed through many hands and several species catalogued by Nevill were lost for ever to Science.

In 1889, Theobald published the first part of Index of Genera and Species of Mollusca in the Hand List of the Indian Museum, Calcutta.

The most valuable contributions to knowledge on land molluscs were by Godwin-Austen (1834-1923), who took up study of molluscs at the instigation of Dr. Blanford. From the time he came to India in 1851 and till his death Godwin-Austen took keen interest in the study of molluscs and developed an intimate and extensive knowledge on the subject. He explored the great mountain ranges of Baluchistan and the sub-Himalayan ranges starting from Kashmir on the west to Garo and Naga Hills in the east and participated in the Dafla Expedition 1874-75. Besides many scientific papers on land molluscs, Godwin-Austen published volumes on Land and Freshwater Molluscs of India (1882-1910). He studied Zonitidae and land operculates with great acumen and illustrated profusely with his own drawings. His publication on the genus *Glessula* was very comprehensive and authoritative. He described about 450 new species mostly belonging to the families Ariophantidae, Cyclophoridae, Diplommatinae etc.

Throughout the period the stress had been mainly on the collection and study of land molluscs, occasionally including freshwater forms. In the last two decades of the century attention was diverted to marine molluscs. The publication of Alder and Hancock's (1866) monumental work on Opisthobranchs of South India and Sri Lanka was an important step in that direction. There was a general build up of interest in marine biology which heralded the formation of a Committee by the Asiatic Society of Bengal in 1871. It included distinguished biologists such as Blanford, Stoliczka, Anderson, Oldham and Woodmason. It led to the establishment of the Marine Survey Department in 1874. J. Woodmason, a deputy of the Trustees of the Indian Museum undertook pioneering deep sea biological investigations in the Andaman and Nicobar Islands, even before the establishment of the Department. His material was studied later by Preston. After Alder and Hacock, G & H. Nevill (1871) took more interest in the study of marine molluscs. An important aspect in the study of

Indian Ocean Malacology was the work of the Royal Indian Marine Survey Ship, 'Investigator' which was launched in 1881. Natural History Notes from RIMS Investigator were initiated in 1885 and the first few appeared in the Journal of Asiatic Society of Bengal and later a maximum number had appeared in the Annals and Magazine Natural History, London. E. A. Smith (1889–1905) had enumerated a total of about 400 species based on Investigator material and of which 176 species were described as new to science. Smith alone had been the author of 162 species. Illustrations of the Zoology of RIMS Investigator pertaining to Mollusca were published in 23 supplements from 1898 to 1909.

Abercrombie (1893, 1894) collected and studied molluscs from the Bombay coast. His collections, which consisted of about 400 species, were originally donated to the Manchester University Museum, but now found in the British Museum. Melvill (1885–1928) in collaboration with Abercrombie (1893), Sykes (1897) and Standen (1898) described molluscs from the coasts of Bombay, Andamans and Madras. Melvill Standen are particularly remembered for their studies on the marine molluscs of the Persian Gulf and the Arabian Sea, which were collected by F.W. Townsend between 1893 and 1915, while laying the Telegraph cables. About 2000 species (of which 600 new species) were enumerated from Townsend's collection alone and altogether Melvill is credited with the authorship of about a thousand species. Many of his types are now available in the British Museum, Cardiff Museum and Manchester Museum.

Thurston (1890, reprinted in 1894), Superintendent of the Madras Govt. Museum, published an account on the molluscan fauna of Pearl and Chank fisheries in the Gulf of Mannar.

The contributions, during the period, in general, included faunal lists, taxonomy often with anatomical details, distribution and field ecology of mostly land molluscs, and to a lesser degree of marine and freshwater moluscs. Most of the collections, with the exception of those studied by Nevill and E. A. Smith, had been deposited in the British Museum, Cardiff Museum, Manchester and Cambridge University Museum and other museums in England.

ii) 1901-1947

It is the most productive and significant period in the history of Indian Malacology. The establishment of the Zoological Survey of India in 1916, gave an impetus to organized malacological research. The period is marked by the presence of luminaries of Indian Malacology, like Preston (1903–1916), Annandale (1907–1925), Hornell (1910–1951), Prashad (1918–1934). H. S. Rao (1923–1941), Seshaiya (1928–1949), Winckworth (1926–1940) and others.

Indian Museum was still playing prominent part by encouraging malacologial research. In the year 1907, Thomas Nelson Annandale, the then Superintendent initiated two new scientific journals, *Records of the Indian Museum* and *Memoirs of the Indian Museum*. Several important findings had been published through these two journals. S. W. Kemp, Asstt. Superintendent of the Indian Museum lead the Abor Expedition in 1911–1912 and brought to light several interesting land molluscs, which included a total of about 45 species of operculates (Cyclophoridae). The collections were studied by Godwin–Austen (1914) and E. G. Ghosh (1913).

The studies on land molluscs, which culminated in the publication of three Fauna volumes (Blanford & Godwin–Austen, 1908; Gude, 1914, 1921), were on the decline and the main thrust had shifted to freshwater molluscs.

The incidence of schistosomiasis in the troops returning from South Africa during World War prompted the authorities to take up a study of the etiology of the disease and its possible intermediate host in India. Annandale was entrusted with these investigations, and in his search for the intermediate snail host he travelled as as far as Seistan in Eastern Persia and to several places in India. Thus he was induced to take up studies on the taxonomy and distribution of freshwater gastropods. Annandale made significant contributions to freshwater malacology and had been the pioneer in medical malacology. He had also studied the molluscs of hill streams, lakes and published a monograph on molluscs of the Chilka Lake (1924). Annandale (1923) had reviewed the advances in our knowledge of the fauna of the fresh and brackish waters of India. He had provided material for the revision of many families of freshwater molluscs and revised the most common families, Vivaparidae and Lymnaeidae in collaboration with Sewell (1922) and Rao (1925) respectively.

Prashad and H. S. Rao, who had their initial training under Annandale took to serious study of molluscs. Prashad was a giant among contemporary malacologists. He investigated the anatomy of several freshwater gastropods and bivalves and revised some families. His contributions on the families Pilidae,.Viviparidae, Unionidae and Corbiculidae are widely referred and followed by later workers. His other significant works on marine molluscs include the revision of the family Nuculanidae and a monograph on the bivalves of the Siboga Expedition. H. S. Rao made useful contributions to the comparative anatomy of freshwater gastropods and on the growth rate of some commercially important species. Hora (1925, 1926 & 1928) made some important observations on the aestivation of the succineid molluscs and land slugs.

Besides those working either in the Zoological Survey of India or on the material supplied by the institution, there were a few Zoologists, who devoted their time to the study of land or freshwater molluscs. Important among them were, E. N. Ghosh (1912–1920), who studied the anatomy of a slug and some bivalves, and Seshaiya (1928–1949), who investigated the style sacs and the anatomy of certain freshwater gastropods. Other important contributions were Germain's Catalogue of the Planorbidae of the Indian Museum (1921–1922), Bahl's studies on *Pila* (1928) and Bhatia's work on *Anadenus*.

The studies on marine and brackish water molluscs had received considerable importance. Molluscs of Chilka Lake, and of estuaries and brackish waters along the east coast were described in a series of papers by Preston (1908, 1914, 1916), Annandale & Kemp (1916–23) and Prashad (1927). Preston also described several new species from Andaman and Nicobar Islands. Panikkar and Gopala Aiyar (1939) dealt with brackish water animals. Paul (1924) recorded the growth and breeding of certain sedentary organisms.

During the period, Zoological Survey of India had been the nodal agency for malacological research. It established a good relationship with museums in Europe. The Royal Natural History Museum, Brussels was one such institute which had close links with the Survey. Indian collections of chitons and cephalopods were studied by Leloup (1926–1953) and Adam (1939) of that institute respectively. Massy (1919) studied the Investigator material of Cephalopods and reported *Bathyteuthis abyssicola* from a depth of 2000 fms. Eliot (1906, 1919) reported on the nudibranchs of the east coast of India.

Shell–fish resources were given their due share of attention. James Hornell, the Director of Fisheries to the Government of Madras from 1907 to 1924, had highlighted the edible value and commercial importance of molluscs. He contributed a series of papers on various aspects of Shell–fishery. Marine Zoology of Okhamandal (1909), Sacred Chank (1914) and its races (1916), edible molluscs of Southern India (1917) and common molluscs of Southern India (1922) were some of his significant contributions. Rai (1928, 1932) gave an account of the shell–fishes of West coast. Biology and fishery of the edible oyster were studied by Awati and Rai (1932). For the first time an account of the pearl oyster of Indian waters was given by Prashad and Bhaduri (1933). At the instance of Dr. Sewell, the then Director, Zoological Survey of India, H. S. Rao (1939) made a special study of shell–fisheries of Andamans and reported on the breeding biology, bionomics, distribution etc. of *Trochus*. Moses (1927, 1940, 1947 and 1948) dealt with the fishery of *Placuna* and Cephalopods of the Gulf of Kutch. Devanesan (1940, 1944) reported on the bionomics of sacred chank and shell–fish fished by "Lady Goschen" (1927–1930).

Gravely's (1941) work on shells and other animal remains found on the Madras beach is still useful in the identification of many species of marine molluscs.

Vredenburg, whose contributions to the knowledge of fossil molluscs are well known, had discussed variations in *Pleurotoma conqener* (1917, 1919) from the Andamans and also the peculiarities in the distribution of the family Doliidae (= Tonnidae). Prashad (1927) described a new deep water, *Pyrula sewelli* from the Laccadive Sea (180 fms.).

Harold Charles Winckworth, who was in the army as a surgeon had profound interest in natural history. He explored many localities along the east and west coasts of India, also Andamans and Sri Lanka. His contributions (1926, 1933) on marine molluscs, which included a few new species of chitons and nudibranchs were of systematic and descriptive value. Crichton (1940) enumerated the species of Madras coast.

The interest in molluscan studies had been on the increase and more number of workers were drawn to malacology. The advent of a number of investigators in the field of marine malacology had changed the scenario. Veerabhadra Rao emerged on the scene with his publications on opisthobranchiate molluscs (1936, 1937).

iii) 1948-1990

During the decade 1940 and 1950 there was a general slow down in the research activities of the Zoological Survey of India which was the only institute then engaged in general zoological studies. All the old workers had made their exit from the scene of active research and the National Zoological collections had suffered a heavy loss due to Varuna floods in 1943. Besides, the collections were also shifted from Varanasi to Calcutta. All the efforts of the scientists and staff of the Survey were diverted to the retrieval of damaged collections and their rearrangement. But elsewhere there had been a gradual proliferation of malacological research since scholars of various universities had been encouraged to take up studied on molluscs. The establishment of Central Marine Fisheries Research Institute in 1947 had also given a further boost up to malacological research. The realisation of the importance of marine timber boring organisms in our economy had made Forest Research Institute to sponsor schemes on these timber boring and fouling organisms. Thus institutional support to malacological research had been on the increase.

For the last four decades the successive scientists in charge of the Malacology Division in the Zoological Survey of India have been contributing to the knowledge of Indian Molluscs by undertaking their own research programmes and also by extending identification and advisory services to those working outside the Survey. Ray (1943–1969), the first Officer–in–Charge of the Mollusca Section after independence, described a number of new species of land, freshwater and marine molluscs. Although he attempted revision of Indian mitres and Indo–Pacific cowries (unfinished), Ray's contributions were in general of systematic and descriptive nature. His book on molluscs of Maungmagan serves as a reference for synonymy and distribution of several marine species. He brought out the importance of molluscs in chokage of filtered water pipe systems and also as fossils. He was succeeded by Rajagopal (1965) who studied the systematics of shipworms in the initial years (1961, 1964 and 1973), but later published detailed accounts on the molluscs of Kashmir (1968) and the Chitons of Andaman and Nicobar Islands (1972) in collaboration with Subba Rao. Rajagopal and Mukherjee (1978) summed up our knowledge of the molluscs of Coromandel coast. Subba Rao, who is currently the head of the Malcology Division, had developed a team, which is studying the systematics, ecology and distribution of land, freshwater and marine molluscs. The investigations are aimed at filling up the lacunae in our knowledge. Since the systematics of land molluscs are well known. The present studies have given importance to their ecology and economics. Subba Rao (1975) conducted pestiferous snail survey and drew our attention to some important pestiferous snails and the data collected under the programme of Pestiferous Snail Survey had formed the main bulk of the material of the technical monograph by Raut and Ghose (1984). Beside, investigations were also carried out on the breeding and growth rate in some common land molluscs (Subba Rao *et al.*, 1989).

Subba Rao and Mitra (1979) published a comprehensive account on the molluscs of the Pune district. Subba Rao (1989) has updated our knowledge on the freshwater molluscs of India and adjacent countries. His Handbook on Freshwater molluscs of India would serve as a valuable guide to all those interested in the subject. Malacologists in the Zoological Survey of India have prepared

State of Art reports on estuarine molluscs and on marine molluscs belonging to the families, *viz.*, Mitridae and Donacidae. Current studies include inventorisation of malacofauna of different states of India. Roonwal (1962) and Das (1980) have studied marine timber boring molluscs, while Agarwal (1977, 1981, 1983) investigated the growth rate and biology of some common freshwater molluscs.

Among universities, Annamalai has been in the forefront of malacologial research. From 1929 to 1960 under the guidance of Prof. Seshaiya and later under the direction of Prof. Natnarajan, malacological research assumed a new significance. Ramamoorthi (1949, 1950, 1955, 1960) investigated the chromosomes, chemical embryology and aminoacid contents of some common freshwater gastropods. Meenakshi (1951, 1954, 1956) studied the physiology of digestion and aestivation in the common Indian apple snail. Cytological studies by Jacob (1958, 1959) and Natarajan (1972) are very significant. Govindan's investigations on neritids (1974) and Kasinathan's on cyclophorids (1979) have thrown light on the biology of these molluscs: Kasinathan and his associates have been studying the molluscs of Vellar estuary and biochemical properties of molluscan secretions (Kasinathan and Shanmugam, 1985, Rajendran and Kasinathan, 1987).

Studies on various aspects of molluscs were undertaken under the guidance of Prof. Ganapati in the Zoology Department of Andhra University. Systematics, biology, neurosecretion and distribution of wood boring molluscs were studied by Nagabhusanam (1959, 1960) and Lakshmana Rao and Ganapati (1959). Molluscan fauna of the Kakinada Bay were studied by Radhakrishna. Rao, Balaparameswara Rao (1975) and Sarma (1976) in collaboration with Ganapati (1968, 1964, 1968) have studied the interestitial fauna, biology of *Cellana radiata* and molluscs associated with marine algae in that order. The work that was started at the Andhra University had been continued at the Nagarjuna University first by Radhakrishna and later by Balaparameswara Rao and their students. After Ganapati, studies were carried out on histochemistry and histopathology of certain marine and freshwater molluscs under the guidance of Prof. Hanumantha Rao. Physiology of certain marine molluscs was investigated by Prasada Rao and his students.

Freshwater molluscs of Andhra Pradesh and the molluscs of mangroves in the Krishna estuary have been chosen for special investigations at the Nagarjuna University (Janakiram and Radhakrishna, 1984, 1987); Murthy & Balaparameswara Rao, 1977; Balaparameswara Rao and Sukumar, 1981, 1982; Rambabu et al, 1987). The subjects like biology, physiology especially neurosecretion of marine, freshwater and land molluscs have been pursued under the guidance of Prof. Nagabhushanam at Marathwada University. Investigations were carried out on thiarids (Muley, 1975–78, Muley and Nagabhushanam 1975, 1977); pulmonates (Kulkarni and Nagabhushanam, 1975) and marine bivalves (Mane and Nagabhushanam, 1977).

Nagabhushanam built up an effective school of malacology and made significant contributions to knowledge on neurosecretion in molluscs (Nagabhushanam, 1974, 1977; with Lohgaonker, 1972; with Lomte, 1974; with Muley, etc.)

The funding of schemes on 'Marine timber boring organisms' by the Forest Research Institute of India had encouraged research on woodboring bivalves. Nagabhusanam (1953) studied the shipworms occurring in Visakhapatnam harbour. Sreenivasan (1959, 1961) investigated the functional morphology of *Martesia*. Important studies on shipworms were also carried out at the University of Kerala by Nair (1954–1966), Nair and Gurumani (1957). Nair and Sarasawthy (1968). Studies on marine timber boring and fouling molluscs are being carried out by the Marine Wood Preservation Centres of Forest Research Institute at Waltair and at Goa, in which the investigations are led at present by Santha Kumaran (1983).

Satyamurti, curator of the Madras Government Museum has brought out three comprehensive volumes, two of them dealing with Molluscs of Krusadai Island and another one on land and freshwater mollusc collections in the Madras Govt. Museum.

On the west coast of India, Palekar (1955, 1957), Palekar and Bal (1955) published accounts on the destruction caused by marine organisms to timber. Durve (1960) studied the biology of Indian oysters. Subrahamanyam et al (1949, 1951 and 1952) dealt with the marine molluscs of Bombay coast. Molluscs of Pirotan Island and Gulf of Kutch were studied by Gideon *et al.*, (1957) and Kundu (1965) respectively. Significant contributions to our knowledge of molluscs of Gulf of Kutch were made by Narayanan (1968, 1971 & 1974) and Sarvaiya & Chaya (1983).

Physiology of molluscs was the subject of interest pursued at various Universities. Among these Calcutta had been in the forefront followed by Marathawada University. Ghosh (1960, 1962–1964) thoroughly investigated the anatomy and embryology of *Achatina fulica* Bowdich. A number of important investigations have been carried out in the Ghosh's Laboratory at Calcutta University. Reproductive systems of some important freshwater molluscs (Chatterjee, 1970), excretory structures (Mandal, 1971) biology of some parasitized gastropods (Dasgupta, 1973) pathology of *Achatina* (Manna, 1975) ecological studies (Raut, 1981) were some of the important studies pursued under the guidance of Prof. K. C. Ghosh. At present malacological investigations are undertaken by Raut, Sur and their students. Raut and his students are carrying out ecological studies on certain common land and freshwater molluscs.

Physiology of some freshwater molluscs was the subject of special interest to Sherbet and Lakshmi (1964), Saxena (1956, 1965) Raghupathiramireddi and Swami (1954, 1967, 1968) Patnaik (1968, 1971) and Patnaik and Ray (1966–68).

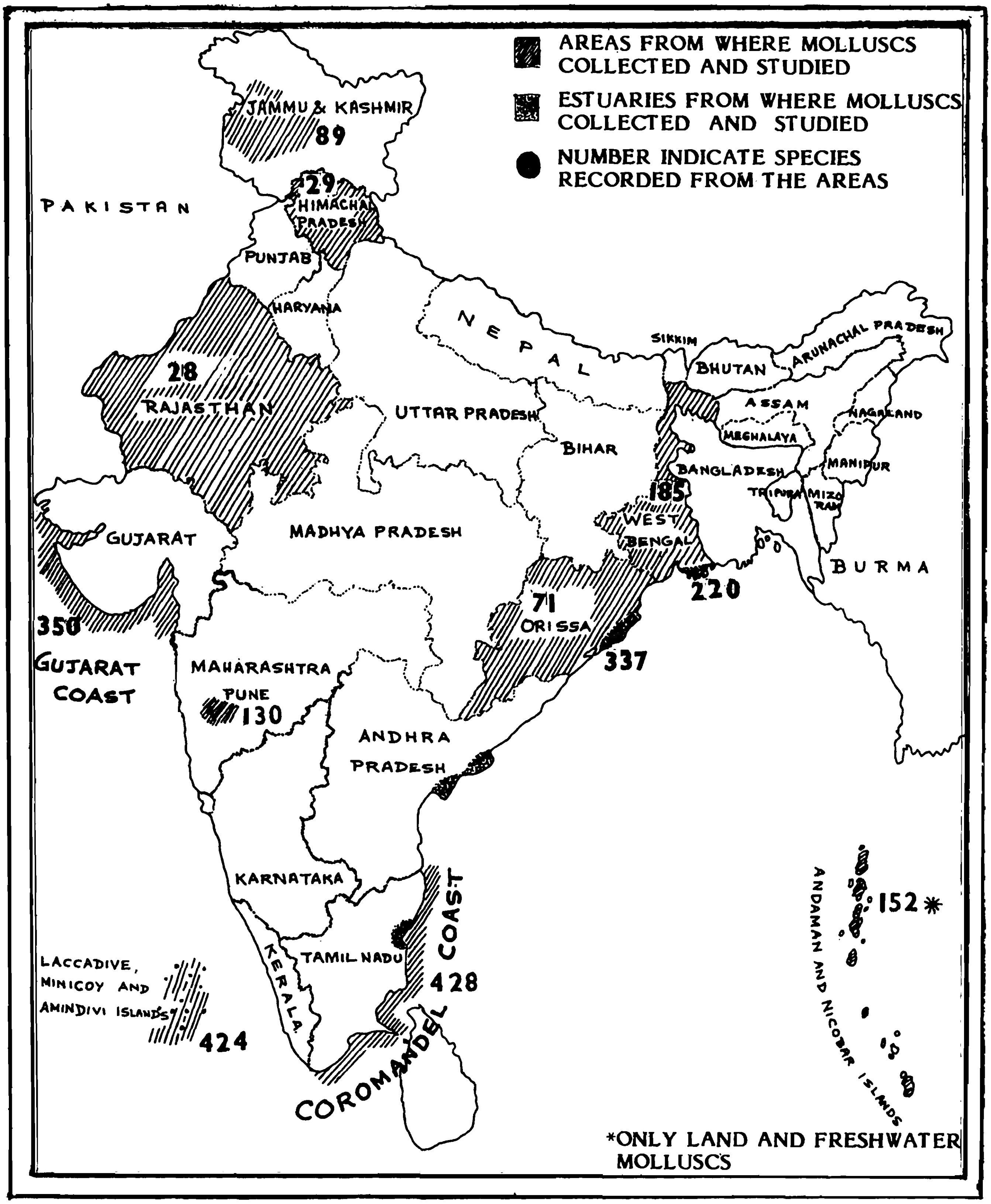
The establishment of Central Marine Fisheries Research Institute in 1947 had brought into focus the importance of marine molluscs in fisheries. Malacological research assumed greater significance and received much momentum. Commercially important molluscs have received more attention. Surveys were conducted and biological investigations were carried out on a number of marine species. Virabhadra Rao (1951, 1953–1955), 1958, 1960) has been the leading malacologist who made significant contributions to shell fish fisheries and opisthobranch molluscs. The studies by Abraham (1953) and Durve (1964) on *Meretrix casta*, by Nayar (1955) and Alagarswami (1966) on the *Donax*, by Narasimham (1969) on the Ark shell, by Silas (1968) on cephalopods have considerably enriched our knowledge on these molluscs. Bulletin no. 25 (eds. R. V. Nair and K. S. Rao) published by the Central Marine Fisheries Research Institute sums up our knowledge on molluscan fisheries. A number of studies have been encouraged on the biology, population density, fishery potential and culture techniques of economically important species of molluscs.

The good work that Durve had stared in CMFRI is being continued by him in the University of Udaipur, but concentrating on productivity in freshwater molluscs.

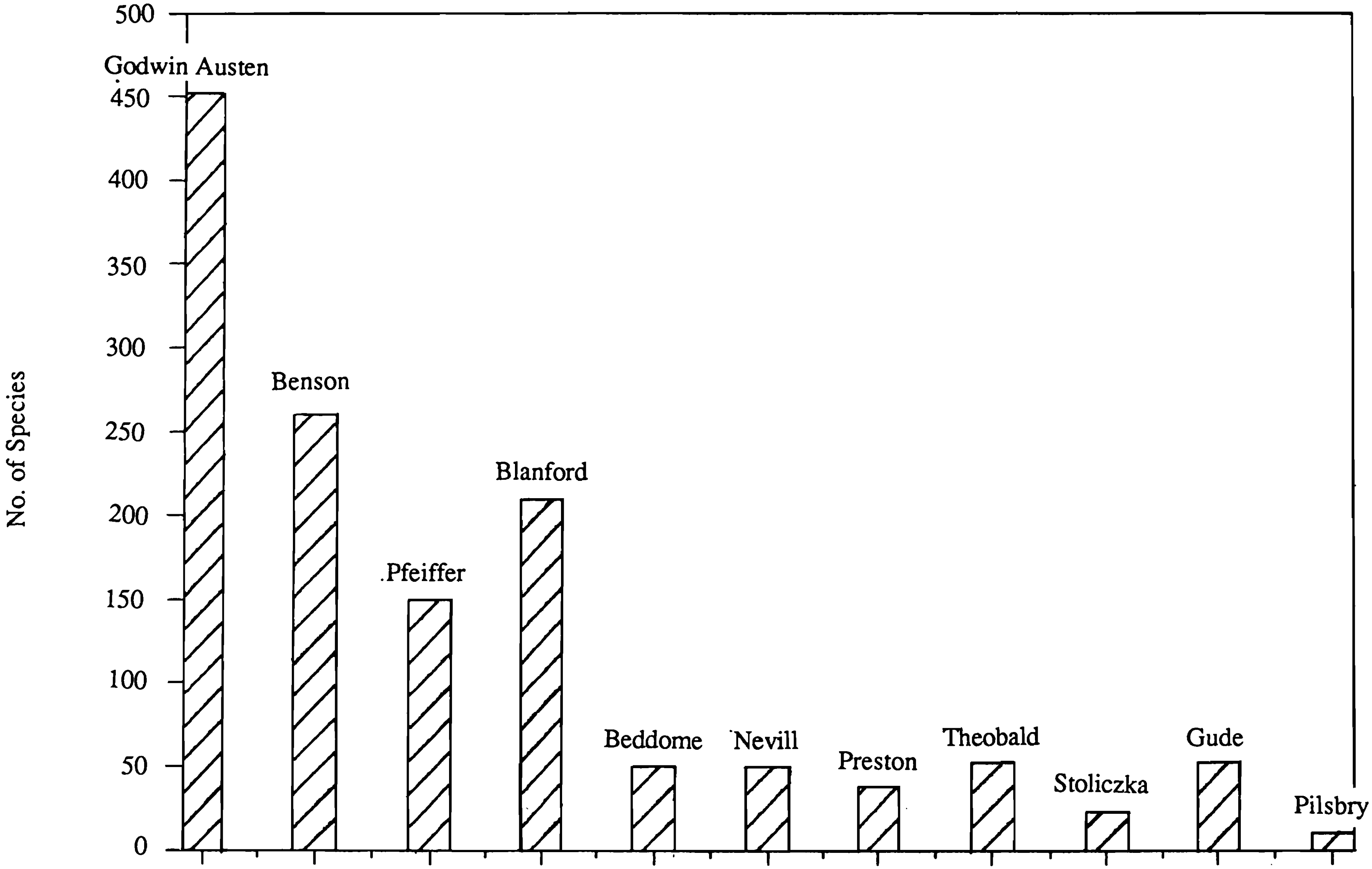
Since certain freshwater snails are important intermediate hosts of trematode parasites, occasionally helminthologists are also attracted to the subject and a few workers like Bali and Dutta (1978), Mohandas (1975), Biswas and Subramanian (1978) had investigated certain aspects of intermediate snail hosts.

Studies from Different Environs

The information on Indian molluscs is scattered in more than 4000 references involving more than 50 scientific and semipopular journals. It is impossible to get a coverage of all those references within such a short review. But in a very general way it can be said that a major part of these references deal with marine molluscs and cover Indian Ocean, which often may fall beyond the exclusive economic zone of India. A total of about 2380 references are cited for Indian ocean (Jones, 1971) which also include areas beyond Indian territory. During the last two decades an average of 25 references every year are estimated, thus making a total of about 3000 references on marine molluscs. About 555 references have been compiled with regard to freshwater molluscs of India and adjacent countries (Subba Rao, 1989). The data on land molluscs is available in about 700 titles.



Survey and identification of Molluscs



Number of Species Described By Various Authors (up to 1920 only)

Malacological studies in India have started with land molluscs. In the beginning, studies on these molluscs were faunistically oriented. Extensive collections were made in the Himalayas starting from the Pir Panjal Range on the west to Dafla, Jaintia Hills etc. in the east. Collections were also made from the Peninsular India, especially in the Western Ghats. All the collections were studied by various malacologists during the pre-independence period. These studies have culminated in the publication of three volumes in the Fauna of India series. References to earlier publications on the subject can be obtained from these volumes (Blanford & Godwin-Austen, 1908; Gude, 1914, 1921). There are very few recent publications on land molluscs of India.

Recent studies on land molluscs include those of Kashmir (Rajagopal & Subba Rao, 1971), Pune district (Subba Rao and Mitra, 1975); Orissa (Subba Rao *et al.*, in press); Andaman and Nicobar Islands (Subba Rao and Mitra, in press).

There had been considerable interest in the study of molluscs of freshwater ecosystem. Preston (1915) published a Fauna volume which is useful as it gives first referrence and original description of several species. Important contributions were made after its publication by Annandale, Prashad, Rao, Nagabhushanam and his students. Up-to-date information and complete bibliography of freshwater molluscs has been provided by Subba Rao (1989).

Molluscs of the marine ecosystem have attracted a large number of workers from India and also abroad. A number of papers have been published on molluscs of different areas in the Arabian sea. One of the recent publication on Bombay molluscs by Subrahmanyam et al (1949-52) records 308 species of different classes of molluscs. Preliminary data on Karwar and Konkan coast molluscs were given (Paul, 1952-54; Joshi 1969). Molluscs of the Cochin harbour area were studied by Cheriyan (1964, 1968) and Desai (1971). Our knowledge on the opisthobranch fauna of Gulf of Kutch is largely due to Narayan (1968, 1981, 1974) and Burn (1970). Molluscs of Arabian Sea in general were studied by Melvill and his associates between the years 1893 and 1905.

On the east coast, molluscs of the Madras coast have received greater attention. A large number of papers have been published on molluscs in general or with reference to some important molluscs of the Madras coast, Tuticorin, Krusadai Islands and Gulf of Mannar. Many of the earlier reference on the molluscs of the area can be found in Satyamurti (1952, 1954). After fifties several papers have appeared, which presented specific problems, like physiology of a particular species, fishery of certain species etc. There are however, some recent comprehensive accounts on molluscs of Coromandal coast (Rajagopal and Mukherjee, 1982; Mukherjee, 1985) and Cephalopods of Madras coast (Jothinayagam, 1987).

Insular ecosystem of Andaman and Nicobar Islands and Lakashdweep Archipelago is not thoroughly explored. We have only a few desultory account on molluscs of inland and offshore areas of these islands. Although not very exhaustive, a recent contribution on molluscs of Lakshadweep Archipelago by Surya Rao and Subba Rao (in press) is an attempt at up-dating our knowledge.

We have several estuaries in our Indian territory. No estuary has been thoroughly explored for its malacofauna, since majority of the papers published deal with only a part of the fauna or with ecology. A satisfactory, to some extent a thorough survey of the Hooghly-Matlah estuary, including Sunderbans, has been conducted by the Zoological Survey of India and the results are being analysed for publication. Some idea of the malacofauna of Mahanadi estuary, Vellar estuary (including Pitchavaram mangroove), and mangroves of Andaman and Nicobar Islands can be drawn from recent works by Subba Rao (1968), Subba Rao and Mukherjee (1974) for Mahanadi; Kasinathan & Shanmugam (1985) for Vellar estuary, Das and Dev Roy (1989) for mangroves of Andamans; molluscs of Krishna estuary, Murty & Rao, 1977). A catalogue with bibliography of estuarine molluscs has been prepared by Subba Rao and Surya Rao (1985).

In general macromolluscan fauna of the easily accessible habitats and ecosystems have been studied. So far Parasitic and pelagic molluscs have received less attention. The latter have been investigated by a few workers such a Sakthivel (1972, 1976). Some studies on interstitial molluscs were conducted by Rao and Ganapati (1968), Salvini-Plawen & Rao (1973). But there is still scope to explore molluscs of deep seas and offshore waters of our seas. We do not have comprehensive data on molluscs of Andaman and Nicobar Islands and molluscs of mainland coasts. Our knowledge of the molluscs of different states is far from complete. We have documents on malacofauna of Manipur (Annandale et al, 1922), Rajasthan (Ray & Mukherjee, 1965), Orissa (Subba Rao et al, 1989, and in press), Kashmir (Rajagopal & Subba Rao, 1968, 1971), Pune (Tonapi & Mulherkar 1963; Tonapi, 1973; Subba Rao and Mitra, 1975), Himachal Pradesh and Madhya Pradesh (Agrawal 1977, 1978) and Lakshadweep (Surya Rao & Subba Rao, in press). Malacologists in the Zoological Survey of India are currently engaged in the study of molluscs of West Bengal, Tripura, Meghalaya and up-dating of the fauna of Chilka and Hooghly-Matla estuary.

Estimation of Taxa

Out of the seven recognised classes of Mollusca only five major classes, namely Polyplacophora, Gastropoda, Scaphopoda, Bivalvia and Cephalopoda are represented in the Indian region. Against an estimated total of about 415 families in the phylum, about 257 families presumably occur in the Indian subcontinent and its territorial waters. The National Zoological collections in the Zoological Survey of India comprises of 255 families and a total of about 11,000 species collected from different localities, not only in India but also from other parts of the world.

Out knowledge of the Indian molluscs is far from complete and hence an accurate assessment of the fauna is bound to be a difficult proposition. However, molluscs of land and freshwater ecosystems have been more thoroughly inventorised than their counterparts in the seas around India. As such the estimation of number of families, genera and species of land and freshwater molluscs is reasonably accurate. But with regard to marine molluscs it is only an assumption based on inferences drawn from the available collections and literature.

The family-wise break up of molluscs of India and adjacent countries is as given below:

Class	No. of families Marine	Freshwater	Land	Total
Polyplacophora	9	—	—	9
Gastropoda	120	12	25	157
Bivalvia	60	9	—	69
Scaphopoda	3	—	—	3
Cephalopoda	28	—	—	28
Total	220	21	25	266

Land molluscs

These include both operculate and non-operculate prosobranch and pulmonate snails and slugs. Winckworth (1950) estimated a total of about 133 genera and approximately 4000 species of operculate land snails of the world. In India and adjacent countries there are 525 species of land operculates falling into 32 genera. Of the total estimated 667 genera and 15,000 species of pulmonate land snails and slugs, India shares about 104 genera with 950 species.

Classified estimates of different categories are given in the following table.

The land operculates of India include a number of zoogeographically significant genera such as *Cyclophorus, Diplommatina* and *Alycaeus* (Order : Mesogastropoda), which have a number of endemic species. Major part of the operculate genera are distributed in South India and Sri Lanka.

The number of land species (India only)

Subclass	Order	Families	Genera	Species
Prosobranchia	Archaeogastropoda	2	3	12
	Mesogastropoda	2	32	524
Pulmonata	Systellommatophora	1	2	11
	Stylommatophora	20	100	940
	Total	25	137	1487

The family Ariophantidae (order Stylommatophora) is represented by the genera like *Macrochlamys, Sitala, Kaliella, Ariophanta, Girasia, Austenia, Sesara, Sophina* and *Durgella* which are endemics of Indian subcontinent. *Glessula*, which shows maximum specialisation among Indian land molluscs is abundant in India but has only a few species in the rest of the oriental region. *Boysia* (Family Vertiginidae), *Lithotes*, and *Camptonyx* (Family Succineidae) are endemic to India; the last mentioned is restricted to Kathiawar in Gujarat. *Hyalimax* is common to the Andaman and Nicobar Islands and Mascarene Islands.

A unique example of land mollusc is *Hemiplecta basileus* (Ariophantidae), the imperial snail of India, which is endemic to the teak forests in Western Ghats. It is the largest snail, which however, is surpassed by the introduced giant African snail, *Achatina fulica*.

Among slugs, *Mariaella* and *Andenus* occur at higher elevations, the former an endemic of Western Ghats and the latter extending upto an altitude of 4000 m. in the Himalayas.

Freshwater molluscs

Out of 8,765 fr freshwater species estimated to exist in the world 284 species (56 genera) are reported from India and adjacent countries.

According to Subba Rao (1989) the following is the break-up of various categories of freshwater molluscs :

The number of freshwater species (India & Adjacent Countries)

Class	Order	Families	genera	species
Gastropoda	Archaeogastropoda	1	4	14
	Mesogastropoda	9	24	110
	Basommatophora	3+1	8+1	46+1
Bivalvia	Arcoida	1	1	3
	Unionoida	4	10	67
	Veneroida	4	8	43
Total		23	56	284

Among freshwater molluscs there are endemic genera such as *Cremnoconchus*, a freshwater littorinid occurring in Western Ghats and *Mainwaringia*, of family Thiaridae, distributed in the Ganges delta. *Mysorella* distributed in South India, is another endemic genus. *Paludomus*, *Fossarulus* and *Tricula* are other important genera.

Among gastropods, families such as Neritidae, Assimineidae and Littorinidae are although marine have a few representatives in freshwater also. Certain families of bivales have contributed single genus or species to freshwater fauna eg. *Scaphula* (Arcidae), *Novaculina* (Solenidae) *Tanysiphon* (Glauconomidae) and *Modiolus* (Mytilidae), all living in the Ganges.

Indian bivalve fauna is remarkable in that it has two families, namely Unionidae and Pisidiidae of great antiquity and also a family of recent origin, Aetheriidae. The last mentioned family has a discontinuous distribution as it occurs in South America, tropical Africa, Madagascar and India.

Marine molluscs

Although numerically abundant as individuals and species, marine molluscs have not received the attention they deserve. Several papers have appeared on the marine molluscs, but not sufficient to present a comprehensive data. For some of the families, especially of micromolluscs, there is no basic data of their, occurrence in India seas, or the number of species but are included in the estimate since the territory falls within the known ranges of their distribution. A rough estimate of families, genera and species is as given below.

Estimated numbers of marine molluscs of India

Class	Family	Genera	Species
Polypacophora	9	13	41
Gastropoda	120	340	1900
Bivalvia	60	150	1100
Scaphopoda	3	3	20
Cephalopoda	28	85	210
Total	220	591	3271

Classified Treatment

Class Polyplacophora

Systematics and distribution of Indian ocean chitons were discussed by Winckworth (1927, 1933) and Leloup (1936, 1937, 1939, 1940, 1952). Recently Rajagopal and Subba Rao (1971) reported 12 species under 7 genera from Andaman and Nicobar Islands. Kaas (1954) reported chitons from Karachi and Arabian Sea. Nagabhushanam and Murti (1968) studied the physiology of reproduction in *Chiton granoradiatus* Leloup. Kaas and Van Belle (1984, 1985) have brought out two modern and up-to-date comprehensive monographs out of the total proposed ten-volume series of living chitons of the world.

Class Gastropoda

Subclass Prosobranchia

Order Archaeogastropoda

The order includes a total of about 18 families, but representatives of 11 families are only reported from Indian waters. Most of the families are marine and only two families have been studied in India. Physiological and ecological studies and structural variations in the shell in relation to distribution of the limpet, *Cellana radiata* on the Waltair coast were dealt (Balaparameswara Rao and Ganapati, 1979, 1971). Systematics, ecology and distribution of Patellidae in the Indo-Pacific region were treated in a monograph (Powell, 1973).

The ecology, systematics and distribution of Indian neritids were exhaustively treated (Subba Rao, 1975). The chromosomes and biology of some Indian species were investigated (Natarajan, 1969, Govindan and Natarajan 1974) thus laying the foundation for an understanding of the evolution of the group. Grüneberg (1976) investigated the polymorphism in *Clithon oualaniensis*.

Two economically important families are Trochidae and Turbiridae. Their species composition and distribution have not been investigated. However, investigations were carried out on fisheries of *Trochus niloticus* and *Turbo marmoratus* (Rao, 1939). Although recent surveys were conducted for *Trochus* and *Turbo* fishery Rao's work is the only source on reproduction and growth of *Trochus*.

Order Mesogastropoda

About 70 families are recognised in the order, of which 45 families are reported from Indian territory. Mostly marine, but a few freshwater and land forms are also known.

Our knowledge of land operculates, namely families Cyclophoridae and Pomatiasidae, is largely due to Godwin-Austen, Benson, W. H. Blanford, Pfeifer and Beddome. The two families have been exhaustively treated in the Fauna of British India III (Gude, 1921). Recent studies were focussed on the chromosomes and biology of four species of *Theobaldius* occurring in the Western Ghats (Kasinathan and Natarajan, 1968).

Freshwater molluscs constitute nine families and all have been investigated with respect to one aspect or other. Data on various aspects of these studies can be obtained in a recent handbook (Subba Rao, 1989). Three of the families, namely Viviparidae, Pilidae and Thiaridae have attracted more attention than others. There were investigations on the distribution, evolution and palaeogeogrphy of recent and fossil viviparidae. The external ornamentation, evolution of shell sculpture and mantle were were also thoroughly studied. The anatomy, including comparative anatomy, ecology and growth rate have also been investigated. Chromosomes and elaboration of enzymes in digestive gland are some other subjects, which have been pursued by Indian malacologists. The family, Pilidae, which include apple snails, is another common freshwater family. In fact, *Pila* can be called as the darling of Indian malacologists since it attracted a number of investigators especially physiologists. After the publication of Indian Zoological Memoirs of *Pila* (Prashad, 1932) a number investigations were carried out on the physiology embryology, ecology and the important phenomenon of aestivation, references to which can be obtained from the Handbook (Subba Rao, 1989).

At the family level the generic limits in Pilidae have been classified by Michelson (1961). The family Thiaridae which includes maximum number of species among mesogastropods has received considerable attention. The relationships of old and new world melanians have been discussed by Morrison (1954). The family is yet to be revised as far as its systematics are concerned. Ray (1947, 1951) enumerated a few species from Andaman and Nicobar Islands and described a new species from Coromondle coast which however turned out to be an already known one (Subba Rao, 1989). Biology and physiology of some common species have received maximum attention. Seshaiya (1929, 1934, 1935, 1936) investigated the stomach and the anatomy of *Paludomus tanschaurica, Melanoides crenulata (Thiara torulosa)* and comparative anatomy of melaniids. Physiology of digestion, brood pouch, embryology and development were also subjects of investigations. Latest contributions on the group include those of Muley (1975–1978) and Muley and Nagabhushanam, (1975, 1977). For further information one may refer to Handbook (Subba Rao, 1989).

One often finds in literature the family name Hydrobiidae, which however is not represented in India. All those genera formerly included in that family are now grouped under three separate families, namely Pomatiopsidae, Iravadiidae and Bithyniidae. The family Pomatiopsidae is represented by one subfamily namely Triculinae in India. Davis (1960–1980) made important contributions to our knowledge on the family. The only recent study on the Indian species of *Tricula* is by Davis *et al.*, (1987). The information on the families, Iravadiidae, Bithyniidae and also Stenothyridae is old and is available in publications dating back to the first quarter of this century (See Subba Rao, 1989).

The family Assimineidae is common in Indian estuaries but not studied recently by any worker.

Abbott (1958) while dealing with the gastropod genus *Assiminea* in the Philippines, added useful catalogue of names connected with *Assiminea*.

Except the above discussed few families all other families include marine forms and as far as India is concerned these families were treated in casual and isolated reports. Excellent monographs were published on the families like Littorinidae (Rosewater, 1970), Strombidae (Abbott 1960, 1961, 1967), Cassididae (Abbott, 1968) and Cerithiidae (Houbrick, 1978, 1985) of the Indo-Pacific region. Anatomy, reproductive biology and phylogeny of the family Planaxidae have been investigated (Houbrick, 1987). The family Cypraeidae has also been well-studied in the Indo-Pacific region. But most of these studies have not taken into account the collections from Indian seas.

Systematics and distribution of Strombidae in the Indian seas have been discussed (Subba Rao, 1971, 1977). Ray (1949, 1951) published notes on cowries.

The genus *Janthina* of the Indian ocean was treated by Laursen (1953) and Ganapati and Subba Rao, (1959).

Pelagic molluscs belonging to the families Atlantidae, Carinariidae and Ptrotrachaeidae have received some attention. Fraver (1869) was perhaps the first to draw the attention to pelagic molluscs. Except for Tesch's works (1906, 1910, 1949) dealing with collections of Siboga and Dana expeditions there are no recent works on Heteropoda. Benson (1835) described two new species of *Carinaria* from the Indian ocean. Ramanujam (1945) recorded *Recluzia* from Bay of Bengal. Sebastian (1963) recorded *Cardiapoda placenta* in the Arabian Sea.

Panikar and Tampi (1949), Natarjan (1957) and Desai (1962) studied egg masses of certain molluscs.

The only work which refers to some parasitic molluscs from the Indian seas was by Koehler & Vaney (1908).

Order Neogastropoda

The order includes 18 families, which are exclusively marine. The families Turridae (Powell, 1964, 1967, 1969), Vasidae (Abbott, 1969), Thaisidae (Emerson and Cernohorsky, 1973), Harpidae (Rehder, 1973) and Mitridae (Cernohorsky, 1976) were monographed in Indo-Pacific Mollusca. Indian mitres were monographed by Ray (1955) and Subba Rao and Dey (1984). Kohn (1967) Kohn and Robertson (1966) published ecological notes on the cones of Trincomalee region, Sri Lanka and systematic list of cones of Maldive and Chagos Archipelagoes. Up-to-date data on cones of India are provided in two recent papers (Kohn, 1976; Subba Rao, 1980).

Muricidae is a large family and several papers have appeared on it. The Muricidae of the world has been reviewed by Radwin & D'Attilio (1976), who have made important contributions to the knowledge of the family. Breeding habits of some common Indian species were observed by Natarajan (1957) and Chari (1968). Subba Rao and Surya Rao (study completed) have thoroughly revised muricids of Indian seas.

Nassariidae of Indo-Pacific region has been thoroughly reviewed by Cernohorsky (1980).

Subclass Opisthobranchia

Order Cephalaspidea

The order includes about 15 families of which 9 are represented in Indian waters. Except for a few references in general faunistic accounts no significant investigations were carried out with special reference to these families.

Order Anaspidea (or Aplysiacea)

The family Aplysiidae, which has a wide distribution in the Indian Ocean is represented in

Indian Seas also. The family and its species have been reviewed by Eales (1944, 1960). Bhargava (1968) studied the heart in *Aplysia fimbriata*. The family is of considerable significance as some of the species have biomedical potentials, which are currently being investigated by NIO and CDRI.

Order Pyramidellacea

Semiparasitic molluscs belonging to this order did not receive much attention.

Order Acochlidiacea

Members of this order are minute interestitial molluscs. Out of the three recognised families two, namely Hedylopsidae and Microhedylidae are known from India. The former is represented by a single species while the latter by two species belonging to two different genera (Rao & Ganapati, 1968).

Order Rhodopacea

It includes a single monotypic genus *Rhodope* a vermiform interstitial gastropod. The only available report did not establish the identify of species (Rao & Ganapati, 1968).

Order Notaspidea

Of the two families Umbraculidae and Pleurobranchidae, the latter only has been dealt, along with other molluscs. A limited number of species were reported by Satyamurti (1952) and Narayanan (1968).

Order Sacoglossa or Ascoglossa

It includes sap sucking sea slugs recognised into seven families of which five families, namely Oxynoidae, Polybranchidae, Stiligeridae, Elysiidae and Juliidae have been hitherto reported from India seas. Excepting the first family a few reports have appeared on other families. A few species of Polybranchidae were reported by O'Donoghue (1932). Virabhadra Rao (1937) reported a new species of *Stiliger* (family Stiligeridae) and gave a description of its structure, habits and early development. Virabhadra Rao and Prabhakara Rao (1963) described another new species from the Gulf of Mannar. A few species of Elysiidae were recorded by Satyamurti (1952) and Narayanan (1968).

Bivalved gastropods of the family Juliidae have been adequately covered. These gastropods were reported from the Gulf of Mannar (Prabhakara Rao 1965), Vishakhaptnam and Andaman Islands. Bivalved gastropods of the Indian seas were reviewed by Ganapati and Sarma (1975) and later Sarma (1976) described three new species from eastern Indian Ocean.

Order Thecosomata and Gymnosomata

Members of these two orders were earlier known under the familiar name Pteropoda. A considerable amount of work was done by earlier malacologists on the group as a whole. Frayer (1869) reported on a collection of pteropods from Bay of Bengal. Stubbings (1938) and Frontier (1963) worked out the material collected during different expeditions in the Indian Ocean. The most recent work, on euthoecosomate pteropods which makes a comprehensive coverage of the Indian Ocean is by Sakthivel (1972, 1973, 1976), Sakthivel and Aravindakshan (1971) and Sakthivel and Haridas (1975).

Order Nudibranchia

The order includes about 47 families, of which about 15 are known from Indian seas. Our knowledge of nudibranchs with special reference to India is very meagre and scanty. However, there are several references, starting from Alder and Hancock (1866, 1884-85) who laid a good foundation of the subject. Later workers have dealt with a selected number of species of a particular locality. Farren (1905), Eliot (1906, 1909, 1910, 1961), O'Donoghue (1931, 1932), Eales (1938, 1944), Virabhadra Rao (1936, 1952, 1961), Virabhadra Rao and Alagarswami (1960), Narayanan (1968) and Prabhakar Rao (1968) have investigated a few of the nudibranchs, which however is insufficient to present comprehensive understanding of the group.

Order Onchidiacea

The order includes a single family Onchidiidae, which hitherto was placed under the subclass Pulmonata. Fretter (1943) showed its relation to opisthobranchs and a separate order was created to accommodate this family. Stoliczka (1969) gave an account of the species occurring in Lower Bengal, while Prashad (1930) described two new species of the genus *Peronina*. A monograph was published on the common species of *Onchidium verruculatum* by Awati and Karandikar (1948).

Subclass Pulmonata

The classification of Pulmonata by Franc (1968), which was adopted by Runham and Hunter (1970) recognises three orders, namely Basommatophora, Systellommatophora and Stylommatophora. All the three orders are represented in India.

Order Basommatophora

The order includes 14 families and of these, only six are reported from India. Three of these, namely Ellobiidae, Amphibolidae and Siphonariidae are marine. Except for occasional inclusion of these families in faunal lists no intensive studies were carried out on these families in India.

Freshwater families, namely Lymnaeidae, Planorbidae and Ancylidae have received considerable attention and a large literature is available on the first two. Their systematics, biology of common species, physiology and anatomy have been studied (For details see Subba Rao, 1989).

Order Stylommatophora

It is the largest order comprising 58 families and several doubtful ones (Taylor and Sohl, 1962). It includes all terrestrial snails and slugs. The Indian land molluscs fall under about 20 families. Systematics ecology and anatomical details of a few species are dealt with in the Fauna volumes (Blanford and Godwin Austen, 1908; Gude, 1914; Godwin Austen, 1921).

Indian succineids were revised and the anatomy and ecology of some species were studied (Rao, 1924, 1925). Recently Patterson (1970) studied the chromosomes and described new genera and species from India. Ghosh (1958, 1959, 1963) made important contributions to our knowledge on the biology, development, mating and oviposition in *Achatina fulica* and a few other land snails. Breeding, feeding and growth rate in the common garden snail, *Opeas gracile* were studied recently (Biswas et al 1976; Mitra et al 1976; Subba Rao et al, 1981). Growth rate in *Glessula gemma*, a common land snail in West Bengal has been studied (Subba Rao *et al.*, 1984).

Pestiferous nature of some ariophantid snails was explored (Subba Rao 1975) and later pestiferous snails of India are dealt in a more comprehensive manner (Raut and Ghosh, 1984). Ecology of *Ariophanta maderaspatana* and biology of *Ariophanta solata* were studied (Masurekar and Bagalkote, 1976; Bhat and Viswanathan, 1972).

Most interesting and valuable study of land molluscs is the development of a technique, for farming of the Giant African snail, *Achatina fulica*, by the Scientists of the Central Inland Capture Fisheries Research Institute, Barrackpore (Vinci *et al.*, 1988).

Order Systellommatophora

The order includes garden slugs which cause damage to vegetable crops (Rao and Ramdoss, 1953). The common and widely distributed species *Laevicaulis alte*, has attracted a number of investigators. Its reproductive biology, ecology, food preference, growth rate, fecundity and egg-nesting behaviour were highlighted (Nagabhushanam and Kulkarni, and Nagabhushanam, 1974; Subba Rao et al, 1989; Raut and Panigrahi, 1988).

Class Scaphopoda

The representatives of the class are exclusively marine and burrow into sand extending from littoral to deep sea zones. Obviously the collection of these forms needs special techniques and there are not many references on Indian scaphopods. Some information on certain species can however, be obtained from collections made by International expeditions. Scaphopoda collected by the John Murray Expedition, 1933–34 in the Western Indian Ocean was reported by Ludbrook (1954). On the basis of dead shells washed ashore twelve species from Madras beach were reported (Gravely, 1941; Satyamurti, 1956). Eight species were recorded from the Kerala coast (Kurian, 1948; Cheriyan, 1968). The only Indian work on the biology of this group deals with the feeding and burrowing mechanisms (Dinamani, 1964).

Class Bivalvia

The classification given by Newell (1968) in Moore's Treatise on Invertebrate Palaeontology is generally accepted. He recognised 10 orders and about 102 families. Of the latter, about 75 families are represented in India. There had been very few attempts to revise individual families of bivalves in India. Information on bivalves is scattered and is found only in general faunistic works. Prior to 1900, bivalves were dealt in some papers by Melvill and his collaborators, E. A. Smith etc. Bivales of Percy Sladen Trust Expedition were reported by Prashad (1923). He (1932) also brought out an excellent monograph on Pelecypoda of Siboga Expedition. Deep sea bivalves of John Murray Expedition were studied by Knudsen (1967). Ray (1952) described some new species from the Indian Ocean. Bivales of Gulf of Mannar and Gulf of Kutch were reported respectively by Satyamurti (1956) and Kundu (1965). Bivalves of water bodies of Nagpur were studied by Krishnamurti et al (1968). Ecology and culturing of a few species of edible bivalves were studied by Parulekar *et al.*, (1984).

Freshwater Bivalves

Freshwater bivalves of India are classified into eight families and of these, three families, namely Unionidae, Amblemidae and Corbiculidae are common and distributed throughout India. These three and another family Pisidiidae are well studied and systematically well-documented (Prashad 1921–1933). Our knowledge on the freshwater bivalves of India is documented in the Handbook (Subba Rao, 1989).

A significant and interesting finding is the occurrence of pearls in the freshwater mussel, *Lamellidens marginalis* (Lamarck) (Janaki Ram, 1989; Raut & Biswas, 1989; Subba Rao, 1989). Fish hosts of the glochidium larva of the freshwater mussel have been studied (Raut & Biswas, 1990).

Marine Bivalves

A large number of bivalves inhabit marine ecosystem. A good number of species are edible and are economically important. The Indian work is mainly concentrated on forms like edible oysters, pearl oysters, cockles, clams, razor shells and ship worms.

Prashad (1933) revised the family Nuculidae.

Biology and fishery of *Anadara qranosa* and taxonomy of blood clams were studied (Narasimhan, 1969, 1988). *Anadara* in Indian and Pacific waters of Australia was reviewed by Gill (1974).

Systematics and distribution of pearl oysters (Family Pteriidae) were discussed by Prashad and

Bhadury (1933) and Virabhadra Rao (19068). Growth rate of pearl oyster was recorded by Gokhale et al (1954). Length–weight relationship of pearl oyster (Alagaraja, 1962) and its breeding (Narayanan 1974) were also investigated. Data on pearl fisheries has been well documented. Eswaran et al (1950) and Gokhale et al (1960) for Gulf of Kutch; history of pearl fishery of Tamil coast (Arunachalam, 1952); perl fisheries of Tuticorin (Hornell, 1972; Awati, 1928; Chacko, 1956, 1963; Aruldoss, 1956; Devadoss et al, 1958) and pearl culture in general (Alagarswami, 1968, 1971). A manual on pearl culture techniques as brought out by CMFRI (1984).

Nomenclature and biology of some edible oysters (Family Ostreidae) of the genus *Crassostrea* were studied by Durve (1960, 1961, 1965, 1967) and Durve and Bal (1961). Spawning, development, sex changes and seasonal gonadal changes and rate of growth in spat were studied by Virabhadra Rao (1951, 1953, 1954) and Virbhadr Rao and Nayar (1956). Shell characteristics of the spat of *Crassostrea madrasensis* and *Crassostrea cucullata* as indicator of metal pollution and bioconcentration in iron and trace metals in it are some recent studies (Rajendran and Kurian, 1986; Senthilnathan *et al.*, 1986; Unnikrishnan and Nair, 1986).

Environmental impact on the body component indices and boring and fouling organisms of *Crassostrea madrasensis* are subjects of latest investigations (Thangavelu and Sanjeevaraj, 1988).

The family Mytilidae includes two species of the genus *Perna* commonly known as green mussel and brown mussel. Techniques have been developed for the culture of these mussels (Qasim *et al.*, 1976). These are also useful in pollution studies. National Seminar on Mussel Watch organised by the School of Marine Science, University of Cochin in 1986 had focussed the attention on mussels as indicators of pollution and bioaccumulation of trace metals and heavy metals. Mussel Farming, Progress and Prospects (CMFRI bulletin 29, 1980) gives an account of important mussel species and details the techniques of their culture.

Veneridae is a large family comprising a number of commercially important molluscs. The taxonomy of the family is up–dated by Fisher–Piette (1970, 1971). Biology, seasonal gonadal changes, spawning and the rate of filtration in *Meretrix casta* were studied (Abraham, 1953; Durve, 1963, 1964). The effect of insulin on carbohydrate metabolism and neurosecretory cells in *M. casta* was studied (Kasinathan, 1962, 1967). The chemical composition of adductor muscle in *Meretrix meretrix* was analysed (Kalyani, 1974). Biology of *Katelysia marmorata* and growth rate in *Katelysia opima* were studied respectively by Joshi (1963) and Virabhadra Rao (1951). Growth and production of *Gafrarium pectinatum* from West Coast of India were studied (Ansari *et al.*, 1986).

Two common Indian species of the family Donacidae have attracted some investigators. The growth and annual reproductive cycles of *Donax cuneatus* were studied respectively by Nayar (1955) and Satyanarayana Rao (1967). Some aspects of the biology of *Donax faba* on the Mandapam shore were studied (Alagarsunmi, 1966). A systematic account of all the Indian species of the family Donacidae has been published recently (Subba Rao and Dey, 1985). Growth of the bean clam *Donax incarnatus* was studied by Nair et al (1978).

Marine timber–boring organisms of the families Teredinidae and Pholadidae have attracted more attention than any other group of bivalves. Systematics of Indian teredinids were studied by several workers starting from Erlanson (1936) to Santha Kumaran (1989). Teredinid borers of Sunderbans were studied by Roonwal (1966) and Rajagopal (1961, 1964, 1966, 1970). Collections of these borers were made from several estuaries along the east and west coast: Mahanadi estuary (Subba Rao, 1968), Visakhapatnam coast (Ganapati and Nagabhushanam, 1953–1958), Godavary estuary (Ganapati and Lakshmana Rao, 1959), Krishna estuary (Rambabu et al, 1987), Tamilnadu coast (Nair, 1954-1958, 1961-63, 1965), Vellar–Coleroon estuary (Nair and Dharmaraj, 1980), south–west coast (Erlanson, 1936), Goa (Santhakumaran, 1983) and Andaman & Nicobar Islands (Das & Devroy, 1989). Work on the wood–borers was summed up in a report prepared by the Forest Research Institute (Purushotam and Satyanarayana Rao, 1971) and in a recent annotated bibliography (Santha Kumaran, 1985). The genera *Martesia* and *Lignopholas* (Pholadidae) in the Indo Pacific were revised recently (Turner & Santha Kumaran, 1989).

Class Cephalopoda

Our knowledge of the systematics of Indian cephalopods is largely due to Goodrich (1896), Hoyle (1904), Massy (1916), Winckworth (1926), Robson (1926, 1924, 1932), Adam (1939), Moses (1948, 1949), Adam & Rees (1966). A recent catalogue of Cephalopods of Indian Ocean by Silas (1968)(up dates our knowledge on the group. Two new species and two new records of octopods were reported from the south-west coast of India (Oomen, 1966, 1976 & 1977). Recently Jothinayagam (1987) reported 27 species from Madras coast.

There is a regular fishery of cephalopods along our coasts. Biology and fishery of the Palk Bay squid, *Sepioteuthis arctipinnis* Gould were investigated (Rao, 1954). Its embryonic development was also studied (Alagarswami, 1966). The squid and cuttle fish resources of India were reviewed recently (Silas *et al.*, 19832). Ten species were recorded from Visakhapatnam coast and the biology of *Sepia aculeata* was studied (Rayudu, 1982).

Current Studies

In Zoological Survey of India systematics and distribution of molluscs of Tripura and Meghalaya are currently under study. These include land and freshwater molluscs.

Our knowledge on marine molluscs is far from satisfactory and hence revision of some families has been taken up. Studies on the family Muricidae have been completed. Mytilidae of Indian seas is currently under revision.

Outside ZSI serious malacologial research is carried out in some centres, namely: Marathwada University, Aurangabad, Centre of Advanced Study in Marine Biology, Porto Novo; Nagarjuna University, Guntur and the University of Calcutta. The studies are mostly aimed at biology, toxicology and ecology. Physiological studies are carried out at Venkateswara and Andhra Universities.

Currently molluscs have attracted attention as sources of biomedical compounds. Several species of molluscs are screened by the scientists in Bose Research Institute, Calcutta; NIO, Goa; CDRI, Lucknow; Andhra University, Waltair and Regional Research Laboratory (CSIR), Bhubaneswar.

Shell fishery is the subject of special investigation at CMFRI.

Culture of freshwater pearls is being attempted at the Central Institute of Freshwater Aquaculture, Bhubaneswar.

The use of molluscs in pollution studies is practised at several centres.

Expertise

INDIA

In ZSI

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R. Kasinathan, Centre for Advanced Studies in Marine Biology, Porto Novo, Tamilnadu, [Mangroove and marine molluscs].

R. Naghabhusanam, and U. H. Mane, Deptt. of Zoology, Marathwada University, Aurangabad 431 004. [Physiology, neurosecretion, marine molluscs, bore and foulers].

S. K. Raut, Deptt. of Zoology, University of Calcutta, Ballygunge Circular Road, Calcutta 19, [Ecology of land and freshwater molluscs].

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ECHIURA

Introduction

The Echiura popularly called as 'spoon-worm' are inhabitants of the shores of polar, temperate and tropical seas. They have also been collected from the floor of oceans at great depths.

The first echiurans described appear to be Thalassema (=Lumbricus) thalassemum (Pallas, 1766) and Echiurus (=Lumbricus) echiurus (Pallas, 1766) where the first described bonellid is Bonellia viridis Rolando, 1821. Sedgwick (1898) raised the Sipunculoidea and Priapuloidea to the rank of the phyla but continued to consider the Echiuroidea as a class of the Annelida. The Echiuroidea was established as a phylum largely as a result of embryological and developmental studies of Newby (1940) who showed that the echiurans and annelids differ considerably in their mode of development and they are not more closely related to annelids than they are to molluscs. The phyletic status of the group is now generally accepted (Hyman. 1940; Fisher, 1946; Stephen, 1965; Stephen and Edmonds, 1972) and common name is echiurans but echiurid for the members of Echiuridae and bonellid for the Bonellidae.

Echiura comprise unsegmented, coelomagte, bilaterally symmetrical and soft-bodied invertebrates. They are cigar or sausage-shaped creatures, with highly muscular sacs filled with fluid in which the long alimentarycanal and other organs freely move. The name 'spoon-worms' is derived from the shape of the contracted proboscis which is muscular, sensory and lies at the anterior end of trunk but cannot be retracted within the body. The mouth is anteriorby place usually at the base of long proboscis used for gathering food and the anus at the posterior extremity of trunk. A pair of setae are usually present on the ventral surface of the body just posterior to mouth and one or two rings of anal setae encircle the posterior region of two genera. One to numerous nephridia, usually present in pairs, are attached to the ventral surface of the body wall. A part of anal vesicles serves as excretory organ. The sexes are separate, fertilisation is usually external and the larve is a trochophore.

According to Dattagupta (1975) the phylum has been divided into two classes. One of the classes is further subdivided into two Orders and five families as follows:

Class	Order	Family
Echiurida	Echiuroinea	Echiuridae
		Thalassematidae
		Ikedaidae
		Bonellidae
	Xenopneusta	Urechidae
Sactosomatida	—	—

In Echiurida body wall consists of innermost circular and oblique layers of muscles; anal vesicles, collateral intestine or siphon, proboscis and anterior setae are present in nearly all species.

In Sactosomatida, proboscis, setae and anal vesicles or siphon are absent and body wall with innermost circular muscles missing or degenerate.

Echiurans inhabit all possible habitats starting from intertidal to the abyssal region of the ocean. Bonellids have been dredged from depths of 6,000-10,000 m. Sometimes echiurans are very

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common in a particular locality. Their size also varies from a few millimeters to 25 centimeters in length. As they are soft-bodied and almost defenceless creatures they always live in protected places and are well adapted for living in burrows. They are found in sand or mud where they sometimes live in U-shaped burrow, under rocks, in debris, amongst root of marine angiosperms, in the discarded shells of echinoids and in cracks and galleries in rocks.

Echiurans are deteritus feeders. With the aid of their highly muscular and sometimes spoon-or scoop-like proboscis they suck sand, mud, coral fragments and finely divided particles from their surroundings into their mouths and extract organic matter from the ingested material. Some species, however, trap bacteria and very fine particles of food in a slime net which is secreted from the surface of the animal.

Historical Resumé

The knowledge of echiurans from the Indian coast is meagre. The earlier work were carried out in a rather stray fashion from different coastal belts of India.

The pioneering work on the Indian echiurans dates back to 1903. Echiurans of the Minicoy Island in the Lakshadweep collected during Gardiner's expedition to the Maldive and Laccadive Archipelagoes, were studied by Shipley (1903) but unfortunately his collection is not traceable in any museum in Great Britain. This was subsequently followed by Annandale and Kemp (1915 - fauna of Chilka and Gangetic delta), Annandale (1922 marine element in the Ganges), Prashad (1919-1935), Awati (1936, 1938), Awati and Deshpande (1933-1936) and Awati and Pradhan (1935-1936).

For nearly two decades after Prashad and others (1936) there appeared no publication on this group in India though the work on this group progressed rapidly in other parts of the globe,. Gideon (1957), Gideon et al. (1956), Jose (1964), etc. recorded some echiurans from the Gulf of Kutch. Menon and Dattagupta (1962, 1964) and Dattagupta and Menon (1961, 1963, 1964, 1965, 1971 and 1975) described and reported several echiurans from the Indian waters., Dattagupta in 1967 dealt with genera of bonellids and in 1975 presented a super in 1974 on Anelassorhynchus, in 1976 on echiuran taxonomy. generic classification in echiurans Mathews (1975) dealt with geographical distribution of Indian echiurans.

Beside the taxonomical aspects, Dattagupta and Surendra Sing (1965) studied histological difference between two closely related bonellids and in 1975 on morphology and histochemistry of segmental organs of a few echiurans. Other wise on echiurans are by Menon (1975) on coelom and coelomic elements, Menon and Dattagupta (1975) on main vessels and sinuses, Menon and Sareen (1975) on female reproductive system and Mathew (1975) on the integument. Subsequently, Dattagupta and Singhal (1978-1982) published several papers on echiuran biology and ecology.

Apart from the Indian forms, Dattagupta studied the deep water echiurans of the world - 'vema' collections (1975), Caribbean deep sea bonellids (1977), Atlantic echiurans (1981), Indian Ocean echiurans (1983), Atlantic echiurans (1981), Indian Ocean echiurans (1983), echiurans from Venezuela basin (1991) and benthic community of the Bay of Biscay.

For more then a decade (1978-1991) taxonomic studies in the Zoological Survey of India have made some progress. Haldar (1978, 1981) studied echiurans from the east coast of India and from the Gulf of Cambay. Haldar (1985) also studied the ecology of a species from Gujarat coast this recent contribution on this group is from the Lakshadweep (in press). Results of studies on estuarine ecosystems of the Hooghly-Matla and Chilka Lagoon have been finalised.

Studies from Different Environs

The habitats of echiurans range from sand, mud to hard substrate extending from intertidal to abyssal depth. They are burrowers in sand or mud, where they fashion more or less permanent tunnels. Sometimes they live under rocks, mud-filled mollusc shells or sand-dollar tests, which afford some protection or the rock galleries excavated by boring clams.

Earlier work except those of Annandale & Kemp (1915) & Prashad (1919-1935) contained only casual references to the nature of the habitat. Later work contained some information on the general nature of the environment from where the fauna have been collected but mainly related to the intertidal and littoral forms. Dattagupta et al. (1962, 1966) studied taxonomy, ecology and zoogeography of some forms from Gujarat, Gulf of Kutch, Kerala and Andamans. Mathew (1975) studied the geographical distribution of the Indian forms. Haldar (1981) discussed in detail the ecology of an echiuran from the Gulf of Cambay.

Our knowledge of deep sea forms is still poor. Work on the Echiuran biology started at the university level in mid-thirties.Work of Prashad and Awati (1935) on reproductive and segmental organ and Awati and Deshpande (1933) on the development of a species, and burrows, food-getting and respiratory movement of the same species in 1935 (a, b & c) deserve mention. After a gap of two decades Gideon (1957), Gideon et al. (1956) and Jose (1964) while working in Marthawada University made some contribution on echiuran taxonomy of Gulf of Kutch. More or less at the same time Dattagupta and his team at Pilani University started work on echiuran taxonomy (1961-1971), histology and histochemistry (1963, 1964, 1966), same aspects of echiuran biology (1976a-e, 1982) and echiuran ecology (1979, 1980). Echiuran ecology is also dealt by Haldar (1981, 1985) at the Zoological Survey of India.

Estuarine ecosystem of this group has attracted still less attention. Earlier work of Annandale & Kemp (1915) reported two species, one each from brackish water near Calcutta and Chilka Lake. Haldar (1985) reported faunal wealth of this group from the Indian estuaries. Recent contributions on this group from estuarine ecosystems of the Hooghly-Matla and Chilka Lagoon are finalised by Haldar.

Estimation of Taxa

Echiura of the world comprise 127 species in 32 genera under 5 families. Of these, only 43 species under 14 genera are on record from the Indian Ocean., In this respect echiuran fauna from the Indian coast is fairly rich in comparison to that of the Indian ocean. i.e. 33 species under 9 genera. The genera represented in the Indian Ocean only are given in the following table.

Genera		No. of species		
		World Ocean	Indian Ocean	Indian coast
Family Bonellidae				
Genus	Acanthobonellia	3	3	4
	Archibonellia	2	2	—
	bonellia	5	2	1
	Chanostomellia	2	1	—
	Ikedella	3	1	1
	Sluiterina	1	1	—
	Pseudobonellia	1	1	—
	Eubonellia	1	1	1
Family Echiuridae				
	Echiurus	4	1	1
Family Thalassematidae				
	Ochetostoma	29	16	14
	Listriolobus	8	1	1
	Thalassema	15	2	1
	Anelassorhynchus	14	10	8
Family Ikedaidae				
	Rubricelatus	1	1	1
		89	43	33

Out of 20 genera under bonellids each of 11 genera is represented by one species and are exclusively deep water forms of either the Pacific or the Atlantic Ocean. Out of 11 echiuroid genera 6 are inhabitants of the Indian Ocean as well as Indian subcontinent.

Distribution Pattern of Echiuran Fauna in India

Region	No. of species
Gujarat including Gulf of Kutch & Gulf of Cambay	14
Maharashtra	1
Karnataka	1
Kerala	5
Lakshadweep	8
Gulf of Mannar	6
Orissa	4
West Bengal	4
Andamans	9
Nicobars	3

As per the information available from the literature as well as from author's field observations it may be inferred that 33 species are known from the intertidal zone of mainland and insular areas of indian subcontinent. Out of 33, 5 species are mud-burrowers, 9 sand-burrowers and the rest dwell under rocks, stones; coral boulders and inside the coral or rock crevices. Truly deep water forms are still unknown in the Indian waters. Like sipunculans, echiurans too are reported from the estuarine areas of India by Annandale and Kemp (1915) Prashad (1919) and Haldar (1978, 1985).

Classified Treatment

In addition to taxonomic studies some other aspects of echiuran biology are available in the literaturel Awati and Deshpande (1933-1936) and Prashad and Awati (1935) studied the reproductive and segmental organ of *Thalassema bombayensis*, Awati (1936, 1938) on proboscis and ciliated apparatus of *T. bombayensis*, Awati and Deshpande (1935-1936) on the food-getting, respiratory movement, alimentary canal of T. bombayensis. Dattagupta et al. (1964) studied the morphology and histology of males of Acanthobonellia, Dattagupta and Singh (1966) on histological difference between two closely related species of Acanthobonellia, Dattagupta and Singh (1976) on morphological and histochemical studies on segmental organs of a few echiurans, Dattagupta and Menon (1976) on main vessals and sinuses in a few species echiurans, Dattagupta and Singhal (1979) on burrowing and feeding behaviour of a few echiurans, in 1980 on ecology of some echiurans, and cytological studies on Achethobonellia maculata, and in 1982 on some aspects of reproduction in Achaetobonellia maculata. Current Studies

In Zoological Survey of India, studies on systematics and distribution of echiurans are at present undertaken with emphasis on state-wise faunal resources. The projects on echiuran fauna of the Chilka lagoon and the Hooghly-Matla estuary have been completed. Elsewhere in India there appears to be no work on this group at present.

Outside India, several scientists, particularly from U.S.A. France, Brazil, U.S.S.R., Australia and Japan are engaged in ecobiological, physiological, histochemical, developmental and evolutionary studies.

Expertise

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OLIGOCHAETA

Introduction

The evolution of the Oligochaeta is obscured due to paucity of fossil records. Nevertheless, their origin has been inferred from studies on the distribution, ecology and comparative anatomy of extant species. On the basis of fossil tracks, Valentine (1980) suggested that vormiform coelomates originated about 700 million years ago. The Annelida were possibly well established at at the junction of the Precambrian and Cambrian periods (570 million years). The differentiation of freshwater oligochaetes from sea annelids probably took place in the early Palaeozoic. Sims (1980) assumed that ancestors of present day terrestrial forms (earthworms) were established in the undivided palaeocontinent of Pangaea which was formed at the end of the Palaeozoic and the beginning of the Mesozoic.

Oligochaetes are cylindrical, bilaterally symmetrical coelomate worms with internal and external metameric segmentation. They lack any appendages and suckers but posses a few hook-like chaetae embedded in the skin with which they gain hold on the substratum. Hence the name Oligochaeta (*oligo*, few; *chaetae*, bristles). They are hermaphrodites and ova are fertilized in cocoons secreted by a clitellum. Development is direct, without a free larval stage in the life cycle. On the basis of size and habitat, oligochaetes are often distinguished into two convenient groups: *Microdrili* (small mainly aquatic worms including the terrestrial family Enchytraeidae) and *Megadrili* (larger, mostly terrestrial worms and their aquatic representatives).

Oligochaetes have close affinities with leeches and to indicate this relationship Michaelsen (1928) combined the orders Oligochaeta and Hirudinea into Class Clitellata. Both the Oligochaeta and Hirudinea have been lately classified as distinct classes of the super-class Clitellata of the phylum Annelida, which also comprises the class Polychaeta. On the basis of phyletic relationships, Sawyer (1986) has proposed to include the Clitellate as a subphylum of the phylum Uniramia; other subphyla being Onchophora (Class Onychophora), Myriapoda (Class Chilopoda and Class Diploda) and Hexapoda (insects; Class Apterygota and Class Pterygota). The subphylum Clitellata included two classes: Oligochaeta and Hirudinea; the polychaetes with certain traits formed a distinct group from Uniramia. However, this report follows the traditional classification of the segmented worms: phylum Annelida, comprising a super-class Clitellata (Class Oligochaeta and Class Hirudinea) and the class Polychaeta. The latest classification of Oligochaeta as proposed by Brinkhurst and Jamieson (1971) and modified by Sims (1980, 1982) is given in the following table.

More than 4200 species of oligochaetes are known in the world. Of these, 280 are Microdrili and the remaining about 3920 belong to Megadrili (earthworms). The number of genera have been estimated between 75 and 80 for Microdrili, and between 235 and 240 for Megadrili.

Oligochaetes are found in all types of aquatic and terrestrial habitats. Aquatic Oligochaeta comprise marine, brackish and fresh-water species. The terrestrial forms (earthworms) cannot tolerate dry conditions and their burrows may be as deep as 3 metres (e.g. *Drawida grandis*) to reach moisture. They are mostly nocturnal and emerge from their burrows at nightfall. The process of soil formation leads to horizontal layers and earthworms inhabiting different layers are usually categorized into three groups: (i) surface of litter dwellers (epiges), (ii) topsoil inhabitants (endoges) which are less pigmented and also less active, and (iii) subsoil dwellers (aneciques) which are unpigmented or light pigmented and slow-moving. Some worms are arboreal and inhabit accumulated detritus in the leaf axils of banana, palm, bamboo trees, etc. Organic materials like compost, manure, forest litter and humus, municipal dumps, soils wetted with effluents and

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kitchen drainage are highly attractive to some species.Some live under snow and can tolerate extreme cold condition on high mountains.

Latest classification of Oligochaeta

Class	Order/suborder	Superfamily
Oligochaeta	Lumbriculida	
	Moniligastraida	
	Haplotaxida	
	Haplotaxina	
	Tubificina :	Enchytraeoidea
		Tubificoidea
	Alluroiina	
	Lumbricina :	Biwadriloidea
		Criodriloidea
		Lumbricoidea
		Glossoscolecoidea
		Megascolecoidea

Earthworms are known to be friends of farmers. They enhance soil fertility by changing its physico-chemical properties. They construct extensive burrows and deposit the ingested material as surface or subsurface casts. In this way, large quantities of soil from deeper layers are brought to the surface and decaying organic matter is taken down into soil. Soils with worms remain loose and have a greater capacity to retain air and water. Earthworms enhance microbial activity by breaking up organic matter during humidification. A large number of worms die during unfavourable period when chemical demand in soil is maximum because of growing vegetation. Microbial decomposition of dead worms releases considerable amount of nitrogen and other nutrients (25% nitrogen in the form of nitrate, 48% ammonia, 3% soluble organic compounds, 27% unaccounted). Addition of oligochaetes in sewage sludge and sludge amended soils hastens in sludge decomposition and stimulates metabolic activity of bacterial population therein. They are also important in redistributing certain toxic heavy metals in polluted waters and soils by their burrowing, feeding and excretory activities. Because of their feeding habits, earthworms have been utilized for the production of vermicompost through vermiculture techniques. Earthworm tissue is rich in proteins , and with suitable processing it could augment or even supplant traditional feeds for livestock and aquaculture. Maoris in New Zealand and the natives of New Guinea considers worms as delicacy.

Earthworms have been used in folk-medicine in treating certain diseases. Some species of aquatic oligochaetes are good bioindicators of polluted waters.

Earthworms have also been reported to cause damage to crops. They seize leaves of growing plants and pull them into burrows, often killing the plants. Intensive burrowing activity of worms sometimes retard germination, growth and root development of vegetable crops. They also act as essential intermediate hosts to protozoan, cestode and nematode parasites of birds and mammals. There are reports of worms causing soil erosion on hill slopes by bringing fine soil to the surface. Castings of some species on drying become cement-like hard clods,which affect normal percolation in soil and productivity of vegetable crops, especially root crops like carrot, turnip, radish, etc.

Historical Resumé

Carlos Linnaeus (1757) listed 2 annelid species in the 10th edition of *Systema Naturae:* an oligochaete (*Lumbricus terresris*) and a polychaete (*Lumbricus marinus*). Otto Friderich Muller and Jean-Baptiste Pierre Antoine Leclercque de Monel Lamarck recognised separate species of aquatic oligochaetes (microdriles) between 1774 and 1816. Diversity in earthworms (megadriles) was brought to light by Savingny in 1826, when he described 20 lumbricid species from the Paris region in France. In the Indian subcontinent, these organisms attracted the attention of individual European naturalists during the fifth decade of nineteenth century. Collections were made from different areas and preserved for future studies. In the meanwhile, Charles Darwin's (1881) work on the formation of vegetable mould through the action of worms had generated global interest on oligochaete studies. Thus individual efforts began much before the establishment of organised institutions like the Zoological Survey of India.

i.) Pre–1900

The significance of earthworms has been recognized in this country since ancient times as preparations made from them were used in the Unani System of Medicine for treating certain diseases.Modern scientific studies on oligochaetes in our subcontinent were initiated sometime during the later half of the last century. Robert Templeton, a British Zoologist, was perhaps the first one to undertake systematic collection and study our oligochaete fauna, when he discovered *Megascolex caeruleus* in 1844 from Sri Lanka. Schmarda (1861) and Vaillant (1867) followed Templeton in describing new species of both aquatic and terrestrial worms from the island. Efforts of Edmond Perrier (1872) resulted in the description of *Moniligastor deshayes* gen. et sp. nov. from Kerala on the Indian mainland. But it was only during the last two decades of the nineteenth century that unexplored fauna of our subcontinent attracted serious attention of famous European Oligochaetologists: Beddard (1882-1905), Bourne (1886-1894), Benham (1893), Michaelsen (1897-1936), Ude (1893) and Fedarb (1898).

Frank Evers Beddard,an expert oligochaete taxonomist from England, characterised several species from the 'British India' between 1883 and 1893. He consolidated the then existing knowledge on world oligochaetes (including India) in his 'Monograph on Oligochaeta' which was published in 1895 and formed basic work on the group until the end of last century. Beddard (1902) revised the genus *Amyntas* (*Amynthas*) and for the first time surveyed earthworms of the Maldive and Laccadive Islands in 1903. He (1905) discovered a tiny enchytraeid oligochaete, *Henlea lefroyi*, which destroyed the eggs of locust *Acridium* sp. Besides taxonomic studies, Beddard (1882) published an account on the anatomy and histology of an Indian earthworm.

Based on a few characters, Alfred Gibbs Bourne (1886) named certain species from the Nilgiri and Sheveroy Hills in southern India. He (1894) brought out slightly detailed descriptions of oligochaetes but these were considered inadequate. Bourne's (1889) other taxonomic contribution was a short paper on earthworms of the western Himalayas and Dehra Dun. Bourne was also interested in anatomical studies and examined the circulatory system in earthworms (1891).

Rosa, an Italian Zoologist who had accomplished notable work on European oligochaetes, concentrated his investigations (1888 and 1890) on Leonardo Fea's collection of Burmese earthworms in the Muso civico di Storia Naturale Giacomo Doria,Genova, Italy. A new species *Megascolex templetonianus* was revealed by him from Sri Lanka in 1892. Contributions of Benham (1893), Ude (1893) and Fedarb (1898a, 1898b) were limited to the discovery of a few new species from various parts of the country.

The knowledge on oligochaetes of India was of a somewhat sporadic nature throughout this period. Oligochaete species were mainly distinguished by external characteristics with little stress on their anatomy. Wilhelm Michaelsen, a German Oligochaetologist and whose work circled the globe, started working on Indian oligochaetes towards the end of last century. His first major contribution (1897) was the publication of a comprehensive account on earthworms of Sri Lanka. Species were better characterized with emphasis on both external and internal diagnostic features.

ii) 1901 to 1947

This period is considered as glorious one in the history of Indian oligochaete taxonomy. It is marked by investigations of world-renowned workers like Wilhelm Michaelsen, Lt. Col. John Stephenson and Gordon Enoch Gates. These luminaries later on formulated basic classifications of Oligochaeta of the world. Another important development was establishment of the Zoological Survey of India in 1916, which led to organized faunistic survey in the country.

Michaelsen's (1900) monograph on Oligochaeta was published in *Das Tierreich*, which dealt with descriptions of all known species of the world. This work, though out-dated, is still considered as a valuable reference guide for oligochaete taxonomy. Initially, Michaelsen (1903, 1904) directed his studies on oligochaetes of Sri Lanka. Gradually, he extended his research activities to other parts in the subcontinent. Michaelsen (1907-1910) reported several new oligochaete taxa primarily based on the material collected by the staff of the Indian Museum and lent by Dr. Nelson Annandale, the Superintendent of the museum at that time. Most of the 'types' of Michaelsen's species were deposited in Zoologisches Institute and Zoologisches Museum, Universitat Hamburg, Germany but some specimens of the 'type series' had also been registered in the collection of the Indian Museum. Michaelsen (1909) published a consolidated account on the Oligochaeta of India and adjacent countries in the Memoirs of the Indian Museum. This work formed the basis for future taxonomic studies on Indian oligchaetes, as it included keys for identification and descriptions of all known species in our subcontinent till that date. From 1910 till his death in 1937, Michaelsen contributed only 2 notable publications on our fauna, since he concentrated his researches on the Ethiopian and Neotropical fauna during this period. He described earthworms, including new species, of Travancore and Coorg regions in 1913 and 1920 respectively.

Thomas Nelson Annandale (1905-1906), the then Superintendent of the Indian Museum, described two species of aquatic microdrile worms of the Naididae as commensal on freshwater sponges, snails and bryozoans.

Lt. Col. John Stephenson of Indian Medical service (IMS) and Professor of Zoology at Government College,Lahore dominated oligochaetological studies for about two decades from 1910 to 1930. He began his initial investigations on aquatic oligochaetes of undivided Punjab (1902-1910) and Travancore (1910). Stephenson (1911-1922) recognized several new taxa of both aquatic and terrestrial oligochaetes from various parts of the country on the material collected by the staff of the Indian Museum, Bombay Natural History Society and himself.Dr. Baini Prashad, a student of Stephenson, also carried out extensive collecting for the latter's studies. Stephenson (1923) published a monograph on the Oligochaeta of this region under *'The Fauna of British India (including adjacent countries)'* series. Besides taxonomic descriptions, this monograph discussed phylogenetic relationships of Indian oligochaetes for the first time. Stephenson (1924) studied cavernicolous oligochaetes collected by Dr. S.W. Kemp from the Siju cave in the Garo Hills, Meghalaya. Between 1924 and 1931, Stephenson contributed a few publications on these organisms in our subcontinent. Majority of Stephenson's papers were published in the Memoirs and Records of the Indian Museum. The 'Types' of Stephenson's species were deposited in the BritishMuseum (Natural History) and the Indian Museum; those in the latter now form a part of the National Zoological Collections in the Zoological Survey of India. The most outstanding work of Stephenson was the publication of another monograph *'The Oligochaeta'* in 1930, which is still an indispensable source for morphological, ecological, biological and taxonomic details of oligochaetes of the world. Luigi Martiis Cognetti (1911) recognized new species of *Megascolex*, *Plutellus* and *Drawida* from Kerala.

Much interest was also generated to work out the morphology of Indian earthworms in 1920's. Dr. Baini Prashad dealt with the anatomy of *Pheretima posthuma* at Government College, Lahore under the supervision of Stephenson. Studies were conducted on the lymph, alimentary and calciferous glands by Thapar (1918, 1932), and Stephenson and Prashad (1919). Bahl concentrated on nephridial studies, while Stephenson and Haru Ram (1919) investigated the morphology and development of prostate glands in the Megascolecidae. Prof. Karm Narain Bahl (1924) of Lucknow University in his presidential address to the Zoology Section of the Indian Science Congress at

Bangalore stressed the need for preparing memoirs on Indian animal types. The onus of writing the first memoir on *Pheretima* fell on Bahl himself. This memoir, published in 1926, is still considered an excellent work on detailed morphology of *Metaphire (=Pheretima) posthuma*. Twenty four years after its first appearance, Bahl's monograph has passed into revised second (1930), third (1943) and fourth (1950) editions, which indicates its popularity as a guide to teachers and students of Indian zoology. Bahl (1922-1947) worked out detailed morpholgy, development and physiology of excretory system in a number of Indian worms. His contributions on oligochaete nephridia formed in part basis of Jamieson's (1971) latest classification of earthworms of the world. Mode of reproduction in aquatic oligochaetes was explained by Mehra (1920, 1927).

Rao (1920-1927) gave an account of anatomy of *Drawida* species and history of *Lampito mauritii*, and discovered new taxa of *Glyphidrilus* from Karnataka in south India. Aiyer (1925-1929) studied taxonomy of aquatic and terrestrial Oligochaeta of Travancore.

Gordon Enoch Gates, an American Zoologist, joined Judson College at Rangoon in Burma in 1924 at a time when Stephenson's *Fauna of British India (Oligochaea)* had just appeared. Gates was fascinated by the existence of great diversity among the Burmese earthworms,and took up studies on oligochaete taxonomy. He dominated in this field for about 55 years (1925-1982) not only in our subcontinent but also all over the world. Between 1925 and 1943, he published a series of papers on earthworms of Burma and recognised new anatomical characteristics of taxonomic importance. The Second World War not only resulted in the destruction of Gates' collections, library, most of his records and manuscripts but also termination of earthworm collecting in Burma. He continued to publish papers on the Burmese earthworms from 1952 to 1962 based on his notes and material that was rescued during the war. Gates' work on earthworms of Burma culminated in the publication of a comprehensive monograph in 1972, which also included descriptions of species from northeast India, and Andaman and Nicobar Islands.

Gates (1934-1940) undertook revisionary studies on Indian genera mainly based on material borrowed from the Zoological Survey of India and British Museum. These studies revealed several new genera: *Scolioscolides, Nellogaster, Barogaster, Lennogaster, Rillogaster, Pellogaster, Priodochaeta, Priodoscolex* and *Travoscolides*. Because of second world war, Gates shifted his activity Burma to India at Allahabad between 1943 and 1951. He thoroughly surveyed earthworms of Allahabad sector in the Gangetic plains,parts of central India, Dehra Dun and some northern hill stations.He discovered new genera, *Bhalia, Calebiella* and *Deccania* during these explorations. Gates (1941-1945) also worked out earthworms of Sri Lanka. Extensive taxonomic studies on oligochaertes in the Indian subcontinent led Gates to formulate a new classification of earthworms based on stable somatic characters.

Cernosvitov (1937) identified a small collection of Indian Lumbricidae. Anatomy of *Glyphidrilus annandalei* was described by Nair (1938-1939). Saksena (1943) determined new types of muscle fibres in *Pheretima posthuma*. Histochemical studies on ova of this species were undertaken by Nath and Bhatia (1944). Enteronephric nephridia and physiology of excretion attracted the attention of Vati (1945, 1947) and Hora (1946) respectively.

iii) 1948-1990

Taxonomic studies Indian earthworms suffered a set back between 1947 and 1970. Gates had left this subcontinent to extend his research activities on north American worms at the University of Maine in U.S.A. But based on his earlier studies, he could revise Indian Lumbricidae in 1958 and Octochaetidae in 1962. Investigations in the Zoological Survey of India were neglected in the beginning of this period in the absence of an oligochaetologist. Scientists and staff of the survey were occupied in rearranging collections which had suffered during the Varuna floods at Varanasi in 1943. Meanwhile, centres of advanced research in different zoological disciplines had been established in the country at various institutions and universities, and oligochaetes being convenient laboratory organisms became targets of investigations.

Jatinder Mohan Julka renewed systematic studies on earthworms in the Zoological Survey of India in 1965. His interest on these organisms was sustained due to Gates' guidance through correspondence. To begin with, Julka and his colleagues published notes on the regional distribution of oligochaetes and their occurrence in various parts of the country (1967-1977, with Halder; 1970-1972, with Soota). Julka participated in two multidisciplinary scientific surveys expeditions to unexplored areas of Arunachal Pradesh: Daphabum region of Lohit district (1969-70) and Subansiri district (1974-75). Several new taxa were recognized from the earlier material (1975) and also from material collected during these expeditions (1976 and 1981). Julka undertook investigations on earthworms of Orissa (1976 and 1978; 1987 the last one with Senapati). For the first time from India, he recorded two peregrine species: *Lumbricus castaneus* from Himachal Pradesh in 1979 and *Nematogenia panamaensis* from Kerala in 1990 (in collaboration with Paliwal). Julka (1982) published a comprehensive account on earthworms of Andaman and Nicobar Islands. He brought to light two new monotypic genera from Karnataka, and new genus with 3 new species from Meghalaya between 1982 and 1988. Earthworm resources of India and their distribution were assessed by Julka and Paliwal (1986). Stephenson's Fauna of British India on Oligochaeta became obsolete with the recognition of new taxonomic characteristics and taxa. Julka took up revision of Indian earthworms and to begin with he produced a monograph on the family Octochaetidae (1988) under the *'Fauna of India'* series. This work dealt with descriptions of 128 species, including 6 new genera and 16 new species. Affinities of Peninsular worms were traced with the Malayan fauna by Jayaram (1949). Rao (1969) recorded a marine species of enchytraeids among interstitial fauna inhabiting beech sands of Orissa. Notes on earthworms of Dehra Dun and the Himalayas were made by Soota (1970), and Soota and Halder (1977-1981) respectively.

Besides taxonomic studies, investigations on other aspects of Oligochaetes have been carried out in the Zoological Survey of India. Mukherjee (1969) found water birds feeding upon aquatic and terrestrial worms. Infestations of protozoan parasites in earthworms has been the subject of study by Biswas and Mukherjee (1974), Mandal and Nair (1975-1976), Mukherjee (1980), and Mukherjee and Chakraborty (1975-1987). At the High Altitude Zoology Field Station of Z.S.I. at Solan, Julka and his colleagues have been contributing substantially to the knowledge on their ecology and biology since 1984: seasonal activity and population dynamics (with Mukherjee and Paliwal), mass migration (with Chandra and Mukherjee) and effect on C/N ratio of soil (with Mukherjee). Mukherjee and Julka (1981-1984) recorded soil Protozoa in the intestine of earthworms.

Role of earthworms in soil fertility attracted the attention of Shrikhande and Pathak (1948) at Bombay University, and Dubash and Ganti (1963) at Institute of Science, Bombay. Dubash and Tembe (1959) published methods of their culture. They in collaboration with Ganti (1961) brought out a comprehensive review on India earthworms. Following research at Bombay, serious studies on these organisms were undertaken at other institutions/universities in Maharashtra. Functional morphology of calciferous glands was studied by Kashyap and Ranade (1952), and Joshi and Kelker (1953) at Pune University. Histochemical investigations were undertaken by Kamat (1955-1962) at Maharashtra Association for Cultivation of Science Research Institute at Pune and by Varute (1970-1972) at Shivaji University, Kolhapur. Hanumante and Nagabushanam (1977-1979) of Marathawada University at Aurangabad contributed significantly on neurosecretion, osmotic behaviour and regeneration in *Perionyx excavatus*. Srinivasulu (1986) investigated association of mycoflora with the digestive tract of an earthworm.

The work of Nijhavan and Kanwar (1952) on physicochemical properties of worm castings at Punjab Agriculture University, Ludhiana is still useful in understanding their effect on soil productivity. Malhotra (1957) and Nath *et al.* (1958) of Punjab University carried out histochemical studies in *Pheretima posthuma*. Menon made significant contributions on various, systems of *Eutyphoeus* (1968, with Sareen and Kaur; 1969, with Singal; 1969, with Singal and Sharma; 1969, with Kaur and Singal; 1973, with Sareen and Mittal). For the first time, cytological studies were initiated on Indian oligochaetes by Handa(1969-1971;1976, with Sharma and Sohi). Sareen and his students (1970-1976) continued cytological observations on their reproductive organs. Vasisht (1977-1981) concentrated his studies on digestive system in north Indian aquatic oligochaetes. Neurohistology in oligochaetes was studied by Satija and Carg in 1973 and 1976. Some information on worms of neighboring areas was available from the works of Das *et al.* (1964) and Sharma and Kaul (1974) in Jammu and Kashmir, and Kapur and Kapil (1986) in Haryana. Sharma and Madan (1983) of Indian Institute of Technology, New Delhi published an excellent review of worms in relation to soil health and pollution control.

Khambata and Bhat (1953-1957) initiated researches on intestinal microflora of earthworms at Kasturba Medical College at Manipal in Karnataka. Bhat and his students (1974-1975) further developed suitable techniques to ascertain their dietary and migratory habits.Saroja (1959-1964) and Rao (1962-1963) of Karnataka University devoted their energies to examine physiology of oxygen consumption and low temperature acclimation in earthworms. Under the supervision of Rao, Kale (1972-1976) continued studies on effect of thermal acclimation on oligochaete metabolism.

Ecological studies on earthworms were undertaken at the University of Agricultural Sciences, Bangalore by Krishnamoorthy, Kale and Bano between 1977 and 1979. Kale and Krishnamoorthy (1978, 1981) studied their distributional pattern in different habitats and their influence on soil fertility. Krishnamoorthy (1976-1989) carried out investigations on behaviour and comparative ecology of earthworms in grassland and woodland sites. Kale and Bano (1986) concentrated their researches on vermicomposting, which resulted in developing organic fertilizers from worm casts (vermicompost named as Vee Comp. E. 83 U.A.S.) and worm tissue as source of protein in the food of poultry and aquaculture.

K. Vanamala Naidu (1961-1967) of Government Arts and Science College, Chittoor in Andhra Pradesh undertook taxonomic studies on aquatic oligochaetes which had remained neglected since the publication of Stephenson's Fauna of British India in 1923. He revised the Aelosomatidae, Naididae and Tubificidae. His painstakingly prepared checklist of freshwater Oligochaeta of the Indian subcontinent and Tibet is still an important reference work.

Physiological studies on earthworms attracted the attention of Tandan (1951) and Gupta (1976-1979) at Lucknow University. Agarwal and Sharma (1977) contributed towards the knowledge on neurosecretory cells of cerebral ganglion of *Pheretima posthuma* at Dehra Dun. Taxonomy and ecology of the Enchytraeidae were studied by Lal (1981) at Benaras Hindu University. Mukherjee (1986, with Janardan Singh) carried out a comparison of different quadrat sizes and extraction methods for estimating earthworm populations. Use of earthworms as a fish feed was advocated by Srivastawa in 1986. Histochemical studies on prostate glands and gizzard were undertaken by Sharan (1971), and Vinayak and Prashad (1975-1978) at Patna University.

Since 1976, Subbarao and his students have been pursuing ecological and physiological studies on a littoral oligochaete at Andhra University. A new protozoan ciliate from brackish water oligochaete was described by Joseph and Hanumantharao (1980). Effects of fire on nutrients of worm casts and fertilizers on population density attracted the attention of Vikram Reddy (1983-1987) at Kakatiya University. Prabhoo (1961-1964) revealed the existence of 5 new enchytraeids from Kerala soils. Taxonomic studies on these worms are still neglected in our country as compared to other regions of the world.

Protein constituents of cuticle in earthworms were analyzed by Rajulu and his colleague (1968-1973) at Madras University. Arunachalam and his co-workers (1978-1988) carried out investigations on the biology, ecology and histochemistry of a peregrine species, *Pontoscolex corethrurus* at Madurai University. Bioluminescence in *Lampito mauritii* was observed by Kaleemurrahman (1981) at National College, Madras. Distribution and population structure of earthworms were surveyed by Ismail (1985, with Murthy; 1990, with Ramakrishnan and Azar). Growth as a factor in harvesting worms was studied by Ismail and Alawdeen in 1986. Other oligochaete researchers in Tamil Nadu during this period were : Radha (1982, taxonomy and bioecology of enchytraeids). Rajaram *et al.* (1986, ecology of aquatic oligochaetes) and Vardaraj

(1986, effect of insecticides on earthworm metabolism).

Physiological and ecological studies on central Indian earthworms were undertaken by Asthana (1968 & 1977) and Chauhan (1978-1980) respectively. Dev and Vyas (1972) analysed alkaline phosphates in the alimentary canal and spermathecae of *Barogaster annandalei*.

Prof. Madhab Chandra Dash initiated researches on oligochaete ecology at Berhampur University in Orissa. His investigations included estimation of worm populations by chemical extraction methods in 1973 (with Patra), ecology and taxonomy of the Enchytraeidae between 1973 and 1978 (with Thambi and Nanda), comparison of primary plant production with secondary production of oligochaetes in 1974 (with Patra and Thambi) and population of oligochaetes in 1974 (with Patra and Thambi) and population dynamics and energy budget of *Lampito mauritii* in 1973-1977 (with Patra). Subsequently, Dash shifted his activites to Sambalpur University where he developed an excellent centre of oligochaete research. Initially, studies were undertaken on various aspects : Histochemical changes during developmental stage of *Lampito mauritii* (1977, with Senapati, Hota and Guru), morphology and production of cocoons and emergence pattern (1979-1980, with Senapati), fungal and nematode feeding (1979-1980, with Behera, Mishra, Nanda and Senapati), respiration (1979-1984, with Mishra,and process of decomposition and soil turnover (1980-1986, with Senapati,Rana, Panda, H.K. Dash and Behura). Different types of digestive enzymes in the Enchytraeidae were studied by Dash and his students in 1981. Dash and his co-workers (Senapati, H.K. Dash, Patra and Nanda in particular) also contributed substantially to the knowledge on wormcast production, population dynamics and energetics in different habitats between 1979 and 1983. Dash (1983) published a monograph on the biology of Enchytraeidae.

Bikram Keseri Senapati and his students have conducted research on population biology,reproductive strategy and secondary production of earthworms. Another aspect of Senapati's investigations has been effect of insecticides and organic matter accumulation on earthworm activity between 1986 and 1987 (with Pani,Sahu and Mishra). Studies of Senapati and Dash (1982, 1986) on earthworms in relation to decomposition and waste utilization would be useful in developing vermitechnology in the country. Mishra, another student of Dash, has been concentrating studies on effects of insecticides and starvation on earthworm metabolism since 1986.

Reddy (1978, with Alfred), and Ramakrishnan (1988, with Mishra; 1989, with Bhaduria) undertook investigations on population dynamics of earthworms in different habitats at Northeast Hill University, Shillong.

Studies from Different Environs

Microdrile Oligochaeta

Aquatic oligochaetes usually do not have any habitat preference in relation to physico-chemical parameters of environment or specific plant association or any other readily recognizable ecological criteria (Brinkhurst and Jamieson, 1971). Studies on aquatic worms of different environs (family Tubificidae) in our region are very few most of these deal with the taxonomy of littoral forms. Researches on benthic species have remained more or less neglected. Stephenson (1903-1920) recorded several species from small fresh water bodies like ponds, tanks, pools, ditches, etc. from northwest and central India, Western Ghats and Sri Lanka, primarily based on the material collected by Annandale of the Indian Museum. Oligochaetes of a tank within the Indian Museum compound at Calcutta were extensively explored by Annandale (1905-1906), Michaelsen (1909) and Stephenson (1911-1912). The other notable contributions on worms of these habitats were those of Aiyer (1929) in Kerala and Naidu (1961-1963) in Andhra Pradesh respectively. The lacustrine fauna attracted the -attention of Oligochaetologists only on a few occasions : Bhimtal and Nainital lakes (Michaelsen, 1909; Stephenson, 1916), Villayami lake in Kerala (Aiyer, 1929), Lok Tak lake in Manipur (Stephension, 1907) and Inle lake in Burma (Stephenson, 1918).

Among freshwater streams, the Bagga stream at Cuddapah in Andhra Pradesh was thoroughly explored for oligochaeotological studies by Naidu (1961-1963). Sporadic records of one or two species had been made from other habitats : sewage canal (Naidu 1961), Ravi, Gaumati and Handri rivers (Stephenson, 1914, 1920, Naidu, 1961) and brackish water Chilka lake (Stephenson, 1917, 1921). Stephenson (1923) compiled a list of several aquatic oligochaetes as commensals on sponges, snails and bryozoans of standing waters.

Another group of Microdrile oligochaetes, the Enchytraeidae (pot worms), occurs in terrestrial littoral and marine habitats. They are abundant in acidic soils with high organic matter. The work on Indian Enchytraeidae is limited to a few research papers. Dash (1978-1980, with Thambi and Nanda) carried out studies on the taxonomy and ecology of these worms in grasslands and deciduous forests of Orissa. Prabhoo (1961-1964) and Radha (1982, unpublished) studied their systematics in South Indian soils. Ecological investigations on pot worms of a tropical grassland were undertaken by Lal (1981, unpublished). A salt-tolerant species, *Stephensoniella* (=*Enchutraeus*) *barkudensis* had been recorded from the bracksih water Chilka lake and Ennur estuary. A couple of species were encountered among interstitial fauna on sea beaches by Aiyer (1929) and Rao (1969).

Megadrile Oligochaeta

Most of Indian Oligochaete publications are on earthworms. Certain areas of the country have been surveyed extensively. Evergreen forests, with considerable rainfall and large amount of organic matter in the soil in eastern Himalayas harbour rich earthworm fauna. Several new species were described from these forests in Meghalaya (Stephenson,1920 Julka, 1988), Arunachal Pradesh Stephenson, 1914; Julka, 1976, 1981) and Darjeeling district of West Bengal (Michaelsen, 1909; Stephenson,1920, Julka, 1975). Mass migration of worms in hill soils of Nagaland and Himalchal Pradesh was observed by Reddy (1980) and Julka *et al.* (1984) respectively. Studies on earthworms had been conducted on different types of forests : subtropical pine forest in Meghalaya (Reddy and Alfred, 1977), mixed broad-leaf and pine forest in Himachal Pradesh (Julka and Mukherjee, 1984), subtropical woodland in Orissa (Mishra and Dash, 1984) and peninsular woodlands in Karnataka (Krishnamoorthy, 1985, 1988). Aiyer (1929) and Julka (1986, with Chandra) examined earthworms of tropical rain forests in Kerala. New megadrile taxa were revealed from the deciduous forests and pastures in the western Ghats by Stephenson (1920), Gates (1945) and Julka (1982, with Rao; 1983). Earthworms of eastern Ghat soils were studied by Senapati and Dash (1982), while whose of broad-leaf subtropical forests in Doon Valley were surveyed by Gates (1945) and Soota (1970). Earthworm fauna of pasture, arable and deciduous forest soils were explored by Julka (1975-1978), and Julka and Senapati (1987). Anthropochorous lumbricids from high altitudes of the Lahaul valley and other parts of Himachal Pradesh were reported by Julka (1979, 1981) and Soota and Halder (1980).

Earthworms of aluvial soils in the Gangetic plains attracted the attention of Gates (1945-1947). Comprehensive accounts on northern peninsular soils were published by Gates in 1945 and 1956. Stephenson (1923), Gates (1960) and Julka (1988) studied the megadrile fauna of laterite soils in Maharashtra.

Investigations on the activities, biomass and energy budget of earthworms in pastures were undertaken by Roy (1957) and Desh *et al.* (1977-1983). Studies on these organisms in agroecosystems were carried out by Senapati *et al.* (1986-1988), and Reddy and Goudnarayan (1987). Recently, Julka and Paliwal (1990) have investigated seasonal changes in the population of worms in an orchard. Earthworms of shifting cultivation (Jhum) in northeast India were studied by Mishra and Ramakrishnan (1988) and Bhaduria and Ramakrishnan (1989). Stephenson (1924) described cavernicolous oligochaetes from the Siju cave in the Garo Hills in Meghalaya.

Oligochaetological studies on peninsular soils were carried out to some extent by Michaelsen (1909), Gates (1945), Kale and Krishnamoorthy (1978), and Julka (1988). Earthworms of acidic soils in Palni Hills attracted the attention of Michaelsen (1909), Jamieson (1977) and Julka

(1988).

Several species from the insular ecosystem of Andaman and Nicobar Islands have also been reported (Julka, 1982). Bionomics and salinity tolerance of a littoral oligochaete on Andhra coast were investigated by Subbarao and Ganapati (1972-1978). Earthworms of diverse ecosystems were thoroughly explored by Gates in a series of papers published between 1925 and 1972. He also studied worms from the plains and hills of Sri Lanka in 1941 and 1945.

Estimation of Taxa

Oligochaete fauna in our region is represented by two orders : Moniligastrida and Haplotaxida. Out of twenty seven recognized families, fourteen families comprising 91 genera and 585 species occur in the Indian subcontinent. The National Zoological Collections in the Zoological Survey of India comprise about 362 species belonging to 64 genera and 11 families.

The family-wise break-up of oligochaetes in the Indian Subcontinent is as follows :

Order	No. of Suborders	No. of Super-Families	No. of Families
Moniligastrida	—	—	1
Haplotaxida	2	6	13
	2	6	14

Microdrile oligochaetes

These comprise aquatic forms and tiny terrestrial pot worms of the Enchytraeidae belonging to suborder Tubificina of Haplotaxida. Microdriles in our subcontinent are represented by three families of aquatic oligochaetes namely Naididae,Tubificidae and Phraeodrilidae, and terrestrial pot worms of the Enchytraeidae. An approximate estimate of different categories of microdriles in the Indian subcontinent and world (figures in parenthesis) is given below :

Family	Genera	Species
Echyteaeidae	8 (21)	21 (500)
Naididae	11 (20)	46 (100)
Tubificidae	6 (25)	10 (147)
Phraeodrilidae	1 (1)	1 (24)
	26(67)*	78(771)*

* Excluding 13 genera and 109 species belonging to those families not found in India.

Although aquatic oligochaetes of southern hemisphere are poorly known,there appears to be a greater diversity in northern hemisphere. Most Indian species of aquatic oligochaetes are cosmopolitan. Among these are : naidid species of *Chaetogaster, Nais, Slavina, Stylaria, Haemonais, Dero* and *Pristina*, and tubificid species of *Tubifex, Limnodrilus* and *Aulodrilus*. However, a few species of the Naididae (*Chaetogaster limnaei gengalensis, Dero indica, D. plumosa, Aulophorus humanae* and *A. indicus*) seem to be endemic and show close affinities with the fauna of southern hemisphere. Distributional range of certain species like *Allonais inaequalis, A. pectinata, A. gwaliorensis* and *A. paraquayensis* extends to Africa, south America and other parts of Asia. Cultures of *Limnodrilus hoffmeisteri*, a cosmopolitan tubificid, are commonly used as feed for aquarium fishes in several parts of the country, especially in West Bengal and Orissa.

The Phraeodrilidae is restricted to southern hemisphere. Only one species, *Phraeodrilus zeylanicus*, has been recorded from Sri Lanka in this subcontinent. Studies on tropical Enchytraeidae are fairly sparse. Until 1961, twelve species belonging to five genera, *Enchytraeus, Achaeta, Fridericia, Stephensoniella* and *Hemienchytraeus*, were known from Indian soils. With the record of three more genera, *Marionina, Propappus* and *Hemifridericia*, a few more species were added to our knowledge of enchytraeids.As a result, a total of 21 species are known from India as compared to about 500 in the world. Almost all Indian enchytraeid genera have world-wide distribution, but with endemic species in this region. The true picture of endemicity of Indian species could be inferred only by further extensive exploration of enchytaeids in the subcontinent.

Megadrile Oligochaeta (Earthworms)

Like elsewhere, earthworms form bulk of oligochaete fauna in India and adjacent countries. They belong to order Moniligastrida and suborder Tubificina of Haplotaxida. They are represented by 508 species and 67 genera in the Indian subcontinent as compared to about 3320 species and 240 genera in the world. Details of different taxa in our region are as follows (figures in parenthesis denote world fauna) :

Family	Genera	Species
Moniligastridae	4(5)	97(113)
Criodrilidae	1(1)	1(1)
Lumbricidae	8(21)	16(302)
Glossoscolecidae	1(25)	1(200)
Almidae	1(5)	4(40)
Ocnerodrilidae	8(21)	16(108)
Acanthodrilidae	3(27)	34(482)
Octochactidae	26(45)	145(430)
Megascolecidae	14(25)	195(1000)
Eudrilidae	1(45)	1(500)
	67(220)*	508(3176)*

* Excluding 20 genera and 144 species belonging to those families not found in the Indian region.

Majority of megadriles are endemic in our subcontinent. A few peregrine species have been introduced presumably in soil around roots of exotic plants. Generic distribution of peregrine species among 8 families is : Lumbricidae (8), Ocnerodrilidae (4), Megascolecidae (2), Acanthodrilidae (2), Eudrilidae (1), Glossoscolecidae (1), Criodrilidae (1) and Octochaetidae (1).

Among the Moniligastridae, *drawida* contains the maximum number of 79 species with endemicity in South and northeast India and Burma. Some of the longest Indian worms (over one metre in length) belong to this genus e.g. *Drawida nilamburensis* and *D. grandis*. Other genera of this family found in our region are : *Moniligaster* (8 spp) in southern portion of peninsular India, *Desmogaster* (8 spp) and *Hastirogaster* (2 spp) in Burma.

The Ocnerodrilidae comprises two subfamilies : Ocnerodrilinae and Malabariinae. All southeast Asian genera of the Ocnerodrilinae came originally from south America or Africa (Gates, 1972). These are *Gordiodrilus, Ocnerodrilus, Eukerria* and *Nematogenia*, each being represented by one or two circummundane species.Monospecific *Curgiona* is known to occur only in south India. Gates (1972) believed its home range to be in Africa. The Malabariinae genera, *Malabaria* (4 spp), *Deccania* (1 sp) and *Thatonia* (5 spp.), are endemic and probably evolved in the Indian peninsula.

Indian acanthodrilids are represented by a peregrine species, each of *Microscolex* and *Pontodrilus*, and several endemics of *Plutellus* (32 spp).

The Octochaetidae has largest number of genera (26) in the Indian region. The number of known octochaetid species is 145 which are numerically second to megascolecids in this region. Excepting *Dichogaster* (represented by 5 anthropochorous species), all Indian octochaetid genera have endemic species. Most of these genera have endemic species. Most of these genera are found only in the indian subcontinent, and can be referred to two distinct groups : north, northeast and Burmese group of *Eutyphoeus* (45 spp.) *Bahlia* (1 sp), *Calebiella* (1 sp), and *Scolioscolides* (1 sp), and a second group of peninsular India comprising 22 genera with majority of species belonging to *Hoplochaetella, Octochaetona, Celeriella, Wahoscolex, Lennogaster* and *Ramiella*.

The Megascolecidae contains 14 genera represented by the largest number of 193 species. The pheretimoid group comprising *Amynthas* (33 spp.) and *Metaphire* (26 spp.) is endemic in Burma and Andaman and Nicobar Islands; the other group being represented by one or two peregrine species of *Pithemera* and *Polypheretima*. *Tonoscolex* (16 spp.), and *Nelloscolex* (2 spp.) are endemic in Burma and northeast India. Recently, another endemic genus *Kanchuria* with 4 species has been discovered from the Garo and Khasi Hills in Meghalaya.*Perionyx* with 53 species has discontinuous distribution in western and eastern Himalayas, Burma and peninsular India, but majority of species are found in the Darjeeling district of West Bengal in the eastern Himalayas. Other megascolecid genera, *Megascolex* (33 spp.), *Notoscolex* (11 spp.), *Lampito* (8 spp.), *Lannoscolex* (1 sp.) and *Troyia* (1 sp.) belong to the Indian peninsula.

The ethiopian Eudrilidae is represented by one or two records of a circummundane species, *Eudrilus eugenae*.

Classified Treatment

Order Moniligastrida

Family Moiligastridae

Stephenson (1923) and Gates (1934, 1945, 1965, 1972) described several species of *Drawida* from various parts of the country. Recently, Julka (1976, 1978) revealed three new species of this genus from Arunachal Pradesh. Senapati *et al.* (1979) studied seasonal dynamics and emergence pattern of *D. calebi*. Effects of insecticides on population and reproductive biology were estimated by Pani and Senapati in 1986. Revised descriptions of all known species of *Moniligaster* were published by Gates (1940). An up-to-date key for the identification of all moniligastrid genera, and descriptions of moniligastrid species from Burma and northeast India can be found in the monographic work of Gates (1972).

Order Haplotasida

Suborder Tubificina

Superfamily Enchytraeoidea

Family Enchytraeidae

About 21 genera comprising 500 species are known in the world, but only 7 genera and 21 species are reported from Indian soils. Stephenson (1923) gave descriptions of a few species in the Fauna of British India.Prabhoo (1961, 1964) described 5 new species of *Achaeta* from Kerala. A few new species of different genera were also discovered by Thambi *et al.* (1978) and Lal *et al.* (1981). Ecological studies on enchytraeids of grasslands were carried out by Thambi *et al.* (1978) and Dash *et al.* (1978). Dash's studies on enchytraeids culminated in the publication of a comprehensive monograph "Biology of Enchytraeidae" dealing with their morpholgy, taxonomy, biology, physiology and ecology.

Superfamily Tubificoidea

Family Naididae

Stephenson (1923) consolidated information on naidids known from India and adjacent countries. Aiyer (1929) discovered a new genus *Stephensoniella* from aquatic habitats in Kerala. He also gave detailed descriptions of certain species of *Aulophorus, Dero, Nais, Pristina* and *Slavina.* Detailed descriptions of south Indian species are available in the works of Naidu (1961-1963). Sharma *et al.* (1976) brought to light the chromosome number in Dero *indica* and *Aulophorus furcatus*. Revised descriptions of the world species and keys for their identification have been provided by Brinkhurst and Jamieson (1971).

Family Tubificidae

Taxonomy of Indian tubificids has been dealt with by Stephenson (1923) and Naidu (1965). An up-to-date account on their morphology, ecology, biology and taxonomy has been presented by Brinkhurst and Jameison (1971) in a monograph, "Aquatic Oligochaeta of the world" Chromosomal patterns in two species, *Limnodrilus hoffmeisteri* and *Branchiura sowerbyi,* were studied by Sharma *et al.* (1976). Ecology of *Tubifex tubifex* in the Veli lake on southwest Indian coast has been worked out by Shobana and Nair (1983).

Family Phraeodrilidae

This family is restricted to southern hemisphere with only one species, *Phraeodrilius zeylanicus,* known from our region (Sri Lanka).

Superfamily Criodriloidea

Family Criodrilidae

The family is endemic in the palaearctic region. Immature specimens of circummundane *Criodrilus lacuum* collected from different Indian localities possibly belong to *Glyphidrilus.*

Superfamily Lumbricoidea

Family Lumbricidae

Endemics of this family are restricted to temperate ones of North America and Eurasia. However, several species have been transported to almost all continents presumably in soil around roots of plants carried by man. Successful colonization of these has taken place in southeast Asia only at elevations with temperate-like climate. They are now widely distributed in the western Himalayas and Darjeeling Hills. Cernosvitov (1973) and Gates (1939) redescribed lumbricid species in the collection of the Zoological Survey of India. Gates (1958) further published revised descriptions of species known from the Indian mainland. A comprehensive account of all known species in the Indian subcontinent is available in Gates' (1972) monograph on Burmese earthworms. Julka (1981) reported anthropochorous lumbricids from Lahaul & Spiti in Himachal Pradesh with an average elevation of 3000 m.

Superfamily Glossoscleccoidea

Family Glossoscolecidae

This family is represented by a single neotropicalperegrine species, *Pontoscolex corethrurus,* from various localities in Burma, Andaman and Nicobar Islands and Indian lowlands. At places, particularly in rubber plantations of lower Burma and Kerala, it has become numerically dominant species. Its biology has been worked out by Arunachalam (1978) in the Palni Hills of south India.

Family Almidae

A single genus, *Glyphidrilus*, with four endemic species occurs in India and adjacent countries. All these species are limicolous and have discontinuous distribution. Revised descriptions of Indian species have been given in the works of Brinkhurst and Jamieson (1971) and Gates (1972). Naie (1938) published a detailed account on the anatomy of *Glyphidrilus anandalei.*

Superfamily Megascolecoidea

Family Ocnerodrilidae

About 21 genera comprising 108 species are known in the world. Of these, seven genera with 15 species occur in India. Taxonomic descriptions and distributions of these are available in the works of Gates (1949, 1956, 1972) and Julka (1976; 1990, with Paliwal). Indian Ocnerodrilids are represented by neotrpical *Eukerria*, ethiopian *Gordiodrilus* and *Nematogenia*,and neotropical and ethipian *Ocnerodrilus* circummundane pergrine species. Monospecific *Curgiona* known only from southern tip of western Ghats may also be of ethiopian origin. Other ocnerodrilid genera belonging to the subfamily Malabariinae are definitely endemic in this subcontinent and presumably evolved in the peninsular India. These genera are *Malabaria* in the Gangetic plains, western Ghats, peninsular plateaus and Burma; *Deccania* in northern and southern portions of western Ghats; *Thatonia* in north and east plateaus of the peninsula.

Family Acanthodrilidae

This family comprises about 27 genera and 480 species in the world. Indian acanthodrilids are represented by three genera and 18 species. Gates (1972) published the latest key for identification of oriental genera and species but deals with detailed descriptions of Burmese species only. Descriptions of *Plutellus* species from the Indian mainland and Sri Lanka are available in the works of Stephenson (1923) and Julka (1975, 1976, 1981). Two genera, *Pontodrilus* and *Microscolex* are represented by circummundane species *P. bermudensis* and *M. phosphorous*. Subbarao and his colleagues (1972-1978) have provided information on salinity tolerance and bionomics of *P. bermudensis* in the coastal region of Andhra Pradesh.

Family Octochaetidae

Taxonomy of Indian octochaetids has been worked out in detail. Stephenson (1923) distinguished genera of this family (as defined now) among three subfamilies of the Megascolecidae. Gates was not convinced with this classification and undertook revisionary studies on octochaetid genera. Between 1937 and 1940 he recognized several new octochaetid genera *Scolioscolides, Barogaster, Lennogaster, Rillogaster, Pellogaster, Priodochaeta, Priodoscolex, Travoscolides* and *Celeriella*. Gates (1962) transferred most species of *Octochaetoides* to his new geneus *Octochaetona*. Julka (1988) published a comprehensive monograph on the Octochaetidae under Fauna of India series. In this work, he designed Indian species of *Howascolex* to a distinct genus *Wahoscolex*, and also recognised another five new genera from various parts of the country. Descriptions of Burmese species have been provided by Gates (1972) in his monograph. Jamieson (1977) described two new species of *Celeriella* from Palni hills.

Family Megascolecidae.

This family is the largest one in having 1000 known species in the world. In our subcontinent it is represented by 25 genera and 127 species. Descriptions of all known species from Burma, northeast India and Andaman and Nicobar Island have been dealt with by Gates in 1972. He revised the Indian species of *Pheretima* in 1937 and *Lampito* in 1938. He discovered two new genera : *Nellogaster* in 1938 and *Nelloscolex* in 1939. Sims and Easton (1972) revised the world species of *Pheretima* and recognised new genera of Pheretimoid complex: *Pithemera, Metapheretima* and *Metaphire*. Easton (1976) studied atonomy and distribution of *Metapheretima elongata* species complex of Indo-Australian region. Jamieson (1977) discovered a new genus, *Troyia*, from Palni Hills. A new genus *Kanchuria* and its three new species were brought to light by Julka (1988) from the Garo and Khasi hills in Meghalaya. Since Bahl's work, *Pheretima posthuma* has attracted the attention of several histochemists and physiologists in the country. Various aspects of another common species *Lampito mauritii* have also been worked out.

Family Eudrilidae

The family is restricted to the ethiopian region. But one species *Eudrilus eugenae* has acquired worldwide distribution in the tropical regions presumably through the agency of man. In India this species has been collected on one or two occasions. Recently, culture of this species have been utilized for the production of vermicompost at University of Agricultural Sciences at Bangalore.

Current Studies

Taxonomy and ecological studies on earthworms of fragile western Himalayan ecosystem are being vigorously pursued at the High Altitude Zoology Field Station of the Zoological Survey of India at Solan in Himachal Pradesh. In connection with the writing up of the second volume on megadrile oligochaetes under Fauna of India series, topotypes of several species from various parts of the country are under study.

Ecological studies at HAZFS ZSI, Solan include investigations on population dynamics, biomass and habitat preference of earthworms in Himachal Pradesh. Protozoan parasites of these organisms are also being studies.

Studies on ecology and energy budget of earthworms are being carried out at Sambalpur University in Orissa. Agriculture Scientists at the University of Agricultural Sciences at Bangalore are conducting investigations on their basic ecology and vermicomposting techniques. Some ecological researches on earthworm ecology are in progress at Kakatiya University in Andhara Pradesh and G.B. Pant Institute of Himalayan Ecology at Almora.

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POLYCHAETA

Introduction

Polychaetes are a group of worms well known since the early periods of man's interest to study natural history. Majority of these worms are benthic, only a few are pelagic. Benthic polychaetes are most commonly encountered on sandy or muddy bottoms extending from the sea shore to the greatest depths of the hadal zone. Basically being inhabitants of marine environments, the polychaetes are also common in the estuaries enjoying an everchanging brackish water environment, and a few tolerant species may even extend up to the freshwater zone.

Polychaete worms, commonly known as bristle worms, belong to the Class Polychaeta under the Phylum Annelida, with more than 8,000 global species, including approximately 400 species from India. The body from of this group of worms varies, depending on whether they are free moving, sedentary or pelagic. This is such a varied class that almost any modification could be found, if searched for. To mention some of the special adaptations, of this group are : nest building with sea grass, tube building with various material (hard calcium tubes, leathery mucous tubes, delicate sand tubes), fitter feeding nests and strong jaws to catch prey. Polychaetes are traditionally separated into two large orders, Errantia and Sedentaria, on the basis of development of the anterior end and the life habits of the species. Several attempts were made to subdivide the polychaetes and the various systems proposed differed considerably in structure and in the number of families incorporated. Fauchald (1977) proposed a scheme of classification based on phylogenetic relationships and recognised 17 orders and seven suborders to include 71 families. Major anatomical as well as morphological features were used to define the orders. But the system is still incomplete, because Fauchald could not accommodate 5 families in any of the established orders, and another 5 families in suborder. In spite of the great volume of literature on the polychaete taxonomy there is no general agreement on the problems of grouping families into orders.

Among all the marine benthic organisms, polychaetes constitute the most important component of the macro-invertebrates. The extensive use of polychaetaus annelids as indicators of various degrees of marine pollution is a recent development, though Wilheloni (1916) made the first reference to the polychaete, *Capitella capitata* (Fabricius), as an indicator species. The variety and abundance of species present can often be used as an indication of the cleanliness of the environment in which they live (Jones 1969, Moore 1972).

Historical Resumé

i) Pre–1900

Previous to the year 1900 practically nothing was known concerning the polychaetes of India, apart from the report of a tubicolous polychaete (unidentified) on the beach of Kelvi, Mahim, 80 km. north of Bombay, by Keswal (1892). The earliest record of polychaetes from India dates back to 1908 when Stephenson described a capitellid worm, *Matla bengalensis* wrongly designating it as an oligochaete worm, from Port Canning, Gangetic delta. But later, in 1910, he himself recognised that as a polychaete. From the same locality, Willey (1908) described a spionid worm, *Spio bengalensis*. However, the first comprehensive account of the brackishwater polychaetes of India was published by Southern (1921). In all he recorded 30 species of polychaetes from the Gangetic delta, Chilka Lake and Cochin backwater. A total of three new genera and 27 new species were described from the above mentioned areas. Gravely (1927, 1930) documented the polychaete fauna of Krusadi Island in the Gulf of Mannar. Subsequently, a series of papers were published on the taxonomy, anatomy, development and breeding habits of brackish water polychaetes (Aiyar 1931,

A. Misra, Zoological Survey of India, Calcutta.

1933b, 1933c, 1939, Aiyar and Panikkar 1937). Polychaetes of interstitial habitats had received considerable attention (Aiyar and Alikunhi 1940, 1943, Alikunhi 1941a, 1941b, 1942, 1943, 1947). Panikkar and Aiyar (1937) gave an account of the brackishwater fauna of Madras, where 19 species of polychaetes were included.

ii) 1901–1947

During this period the collections of th Zoological Survey of India and of the Indian Museum, Calcutta, were extensively studied by Fauvel (1928, 1929, 1930, 1932, 1940), which included polychaetes not only from the coasts of India, but also from those of the neighbouring countries. Three hundred species were recorded in Fauvel's report (1932). Subsequently, Krishnan (1936) described the development of a brackish water polychaete *Diopatra Variabilis* and later in 1946 (unpublished thesis) made an extensive study on the polychaetes from Madras. Ranganathan (1943) reviewed the mode of breeding and development in brackish and freshwater polychaetes. While studying the growth and breeding of certain sedentary organisms in the Madras harbour, Paul (1942) included certain polychaete species of the area.

The circulatory system of *Nereis cultrifera* was described by Karandikar & Thakur (1946).

The archiannelids belonging to the genera *Polygordius*, *Protodritus* and *Saccocirrus* were taxonomically investigated by Aiyar (1930). Aiyar and Alikunli (1940, 1944), Alikunli (1943, 1946, 1948).

i) 1948 – 1990

During the period under consideration it has been observed that gradual emphasis was paid towards the investigation of the polychaetous worms from diversified habitats of different areas of India. But taxonomic literature on this group of annelids from India is poor. However, recent ecological and distributional studies relating to the benthos of the different marine and brackishwater areas of India, indicate that the Polychaeta is one of the dominant and diversified groups of organisms inhabiting particular habitat.

The most important work on the taxonomy of polychaetes pertaining to Indian water is that of Fauvel (1953). In his monumental work, Fauvel (1953) reviewed all the earlier works of Polychaeta from India and adjacent areas wherein he recorded 450 species of which 283 belong to the Indian territory, including 47 brackish water forms. He, however, believed that this number represented only about one half of the expected total.Other significant contributions are those of Hartman (1975 & 1976) who studied the polychaete's collected during the International Indian ocean Expeditions (1963-64), and prepared a catalogue and a bibliography of the species from India. Most of the other investigations dealing with polychaetes from coastal and brackish water habitats are regional in nature. The polychaete fauna of Digha beach in West Bengal was dealt with by Rao & Misra (1988). Misra, Chakraborty and Soota (1987) prepared a list of species and studied the polychaete fauna of Orissa coast. Earlier works dealing with polychaetes from Orissa are those of Nagabhushanam Rao (1969), Soota & Rao (1977), Ganapati & Lakshman Rao (1962) and Sarma (1977), who included polychaetes in their generalised ecological investigations in Visakhapatnam coast. Rao & Soota (1977) prepared a short list of species from Tamil Nadu coast. Srikrishnadhas, Ramamoorthi & Balasubramanyan (1987) reported the polychaetes from Porto Novo waters. The polychaetes of the southeast coast of India in general and of the Gulf of Mannar in particular, received attention of several workers (Bause, 1959; Ghosh, 1963; Rangarajan, 1963a, 1963, 1964, Rangarajan & Mahadevan, 1962 and Rajarajan & Sankarankutty, 1962).

While investigating the benthos of the Bay of Bengal, Ansari, Harkantra & Nair (1977) reported polychaetes as one of the major constituents of the fauna. The polychaetes of Andaman and Nicobar Islands were investigated and the results published in a series of papers (Tampi & Rangarajan, 1963 & 1964; Daniel & Ghosh, 1964; Soota & Rao, 1977; Rao & Soota, 1977; Soota, Misra & Chakraborty, 1980; and Parulekar & Ansari, 1981).

The ecology of the intertidal fauna of the sandy beaches of southwest coast of India was investigated by Trevallion, Ansell and Sivadas (1970) and Philip (1972). The taxonomy of the polychaete fauna of Ratnagiri, south of Bombay, was dealt with by Day (1973), Pettibone (1977), Gaikwad & Ranade (1979), Parale & Gaikwad (1989) and Wadker & Gaikwar (1989). An account of the polychaetes of Bombay waters is available in Bhatt & Bal (1964). The occurrence of Arenicola in Indian waters was first reported by Ranade (1952) and subsequently described by Kewalramani, Wagh & Ranade (1959). The studies on the polychaete fauna of Maharashtra and Goa by Parulekar (1971) and of Malvan by Parulekar (1981) deserve special mention. The marine fauna of Karwar coast and neighbouring Islands were investigated by Patil (1951). Attempt was made to investigate the polychaete fauna of the Gujarat coast by Dalal & Dubale (1975) and Dalal, Dubale & Shah (1978). Dalal (1982) made some ecological investigations on the polychaetes of Okhawandal region. More studies n the polychaetes of the coastal region of Gujarat are available in Rao & Soota (1981), Soota, Misra & Chakraborty (1981), and Misra & Chakraborty (1983).

Works on the brackish water polychaete fauna of India has been systematically taken up in recent years. But such works throw little light on the distributional patterns of these worms. This is largely due to the fact that many of these areas were not adequately surveyed and studied. Hitherto, a limited number of brackish water areas viz. Hugli-Matla, Godavari, Vellar, Chilka and Pulicat on the east coast and Mandovi - Zuary and Vembanad on the west coast of India, have fairly been surveyed. A total of 171 species spreading over 97 genera and 38 families have so far been reported from the brackish water bodies of India. Informations about the polychaete fauna of Hugli - Matla estuarine complex is available from Southern (1921), Fauvel (1932) and Misra *et al.* (1984). Most of the recent ecological investigation in this estuarine complex (Datta & Sarangi, 1980; Bhuniya & Choudhury, 1981; Nandi & Choudhury, 1983; Choudhury *et al.*, 1984a, b) indicate that this group of worms is one of the most important components of the benthic fauna. While reporting on the polychaete fauna of Orissa, Misra *et al.* (1988) observed that 46 species were available in the brackish water habitats of Orissa. The polychaetes of Chilka Lake were studied by Southern (1921), Rajan (1965) and Patnaik (1972); of Mahanadi estuary by Julka & Rao (1976); of Baitarani and Burhabalang estuary by Soota & Rao (1977) and Rao (1981).

Detailed benthic faunal investigations in the Gautami - Godavari estuary were conducted by Radhakrishna (1963) and Radhakrishna & Ganapati (1968). An eco-biological investigation of these worms from the Vashista - Godavari estuary was undertaken by Srinivasa Rao & Rama Sarma (1978a & b, 1979, 1980, 1981, 1983a & b). Ganapati & Raman (1976) recorded *Capitella capitata* as an indicator of pollution in the Vishakhapatnam harbour. While surveying the effects of pollution on the eco-biology of benthic organisms in Vishakhapatnam Harbour, Raman & Ganapati (1983) reported that polychaetes were not only the most diverse, but in terms of population density, they often formed an incredibly high percentage of organisms collected at any station.

The polychaetes of Adyar estuary and other brackish-water bodies around Madras were dealt with by Panikkar & Aiyar (1937). Krishnamoorthy (1973) observed the distribution of six species of polychaetes in the Adyar estuary. While the lenthic fauna of Valler estuary on the east coast of India has been thoroughly investigated by Balasubrahmanyan (1960a & b, 1964), McIntyre (1968); Ajmal Khan *et al.* (1979), Srikrishnadhar *et al.* (1981) and Chandral *et al.* (1982). The polychaete fauna of the Pulicat Lake was merely listed by Chacko *er al.* (1953) and taxonomically investigated by Sunder Raj & Sanjeeva Raj (1987).

The occurrence of polychaetes in the Cochin Harbour area was first reported by Cheriyan (1966) and subsequently investigated by Desai & Krishna Kutty (1967) and Gopalakrishna Pillai (Thesis, 1978).

The ecology of benthos in relation to salinity and substratum in the Mandovi estuary in Goa was studied by Parulakar & Dwivedi (975). Biomass and faunal composition of the Zuary estuary was studied by Parulekar *et al.* (1975). They found the polyhaline condition and sandy substratum accounted for high biomass, while higher population density was noted at euryhaline zone. Polychaetes were found to be the dominant group in silty bottoms while bivalves in the sandy bottoms. Parulekar *et. al.* (1980) prepared a list of polychaetes occurring in Mandovi–Cumbarjua canal–zuary estuarine system. while studying the intertidal benthic community structure of sand-dwelling macrofauna of an estuarine beach (Siridao) in Goa, Harakantra & Parulekar (1984, 1985) observed that the number of polychaete species was the highest, though quantitatively they formed the co–dominant group.

Polychaetes are also common in the intertidal habitats of the beaches along the Indian coast. Significant contribution on the intertidal polychaetes of India are those of Rao & Ganapati (1966, 1967, 1968), Rao (1969a, 1969b, 1970a, 1970b, 1972, 1975, 1978, 1980), Rao & Misra (1983a, 1983b, 1988) and Westheide & Rao (1977).

Apart from the larval and post-larval stages, some of the polychaete species are truly planktonic in nature. Chacko (1950) investigated the marine plankton in general from the waters around the Krusadai Island. Bal & Pradhan (1952) recorded the zooplankton in Bombay waters. Thomas (1963) dealt with the taxonomy of a palagic polychaete species of the genus *Loandalia*.. In a series of papers Peters (1967, 1973a, 1973b, 1974 & 1977) dealt with the taxonomy, distribution and abundance of pelagic polychaetes of Indian waters. Seasonal variation in the plankton of Porto–Novo waters was studied by Krishnamoorthi & Daniel (1967). Ganapati & Radhakrishna (1958) studied the polychaete larvae in the plankton off Waltair coast. The ecology of polychaete larvae of Porto Novo waters was studied by Srikrishnadhas & Ramamoorthi (1982).

Several species of polychaetes live in class association with other invertebrates and often termed as commensals. Krishnamoorthi & Daniel (1950) described a rare case of commensalism between *Amphinome aralifera*, and Sankolli & Sheno (1965) described a case of commensalism between *Loimia medusa* and a porcellanid crab. Ganapati and Radhakrishnan (1962) reported a case of inquilimism between a hesionid worm and a holothurian species. Kirkegaard & Santhakumaran (1967) described a new species of cirraculid worm occurring in association with marine wood borer. Kumaraswamy Achari (1971) dealt with three species of sabellarid worms occurring in close association with sponges and corals. Rao & Sowbhagyavathi (1972) made detailed observation on the associates of crinoids at Waltair coast with special reference to Myzostomes.

Studies from Different Environs

Most of the species of polychaetous worms are basically inhabitants of marine habitats. However, these are also common in the brackishwater environment and only a few of them may extend up to the freshwater zone. The majority of the species are benthic, only a few are pelagic. Most of the benthic polychaetes prefer sandy or muddy substrata extending from the sea shore to the greatest depths of the hadal zone; some are found to be comfortable in the crevices of rocks or coral reefs. Availability of polychaetes in diverse ecological niches is due to their high degree of adaptibility to a wide range of environmental factors.

Fauvel provided a comprehensive account of the polychaetes of Indian waters and its adjacent areas. He has published a series of papers (*vide* Historical Resume) of which the 'Fauna of India : Annelida, Polychaeta', appeared in 1953 is most significant. Hartman (1975, 1976) dealt with the polychaetes of the Indian ocean collected during the International Indian ocean Expedition (1963–1964). However, Southern (1921) is the pioneer in providing a comprehensive account of the brackish water polychaetes of India. The studies relating to the marine and estuarine benthic as well as pelagic forms are dealt with separately in the Historical Resume. So far, only a limited number of bracksihwater bodies, viz., Hugli–Matla, Godavari, Vellar, Chilka and Pulical on the east coast and Mandovi–Zuary and Vembenad on the west coast of India, have fairly been surveyed. India has a vast coastline of about 6000 km which has not been adequately surveyed for the collection and study of the polychaetous worms.

Estimation of Taxa

Several attempts were made to subdivided the polychaetes, and the various systems proposed differed considerably in structure and in the number of families incorporated. Hartman (1959) included 33 families of Errantia, 28 families of Sedantaria, 3 families of parasitic polychaetes and 3 families of aberrant groups in her system but did not group them into orders. Fauchald's (1977) scheme of classification includes 81 families of which 76 families are grouped under 17 different orders and 5 families are of uncertain affinities. In recent literature, polychaetes are treated under families without specifying any order.

The knowledge of the Indian polychaetes is far from complete and scattered in nature. Therefore, an accurate assessment of the fauna is very difficult to propose. Out of the 81 recognised families, nearly 950 genera and 8000 species of polychaeta, 61 families and more than 200 genera and 400 species are represented in Indian waters.

Most important work on the taxonomy of polychaetes pertaining to Indian waters are those of Fauvel (1932, 1953), which include 283 species belonging to the Indian waters, of which 47 species were recorded from the brackish-water habitat. Taxonomic literature on the brackishwater polychaete fauna of India is poor in comparison to that of its marine component. A careful, review of literature reveals that 171 species of polychaetes under 38 families are recorded from the brackishwater habitats of India.

Current Studies

In Zoological Survey of India taxonomy and distribution of polychaetes of marine (Andamans & Gujarat) and brackish-water habitats (Chilka Lake and Hugli-Matla estuary) of India are currently under study.

Outside ZSI, no serious attempt has been made for taxonomic investigation on this group of annelid. However, the eco-biological investigations are done in : Marine Science Department, Calcutta University; Department of Zoology, Andhra University, Waltair; Centre for Advance studies in Marine Biology, Porto Novo; National Institute of Oceanography, Goa; Department of Fish Hydrography, College of Fisheries, Ratnagiri.

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HIRUDINEA

Introduction

Leeches are widely distributed in the temperate and warmer areas of the world and they are such familiar organisms that it is not surprising to find their description both in the ancient and modern literature of the leading nations of the world. Leeches are segmented worms devoid of chaetae or parapodia, and with two suckers for attachment. They feed on blood. Leeches belong to the Class Hirudinea, which consists of two orders comprising five families and twenty five genera. So far fifty nine species including eight subspecies are known from the mainland of India.

In the order Rhynchobdellae, the leeches are mainly freshwater and marine forms. Their size is generally from 6 mm to 20 mm in length and thus may escape the attention of the ordinary observer. These leeches have protrusible proboscis for sucking the blood and juices of their prey.

The leeches of the Order Arhynchobdellae do not have protrusible proboscis. They are also called jawed leeches and the specialization has reached its maximum in this order. They are adapted to sanguivorous or predaceous habit. They are mainly freshwater and terrestrial. The length of the body varies from 10 cm to 40 cm.

Leeches are of two types, i.e. venomous and non-venomous. Venomous leeches are a menace to human beings and cattles. The non-venomous leeches have been used throughout the world as remedies for the throat and inflammatory swelling in human beings on account of their property of sucking blood in excess. Medicinal leeches have also been used for releasing the blood pressure in human beings. The species mostly used for this purpose is mainly *Hirudo medicinalis*. Beautifully coloured and ornamented leeches are also used as decorative pieces.

Historical Resumé

(i) Pre–1900

The term Hirudinea was first established by Lamarck in 1818. Although the reference to leeches have been found in the ancient and modern literature as back as 500 B.C. in the literature of Mahabharata, studies on Indian leeches has been almost negligible, but outside India work has been carried out regularly. The earliest record is that of Linnaeus (1758). Between the years 1758 and 1900 the important works include those by Blanchard (1887-1917), Whitman (1884-1892) and Moquin Tandon (1826). The contributions in general included faunal list, taxonomy - often with anatomical details, distribution and field ecology. There were however, no exclusive studies on Indian leeches.

(ii) 1901 to 1947

It is the most productive and significant period in the study of Indian Leeches. The important works on the Indian leech fauna were by Harding and Moore (1898-1927), Oka (1895-1925) and Chelladurai (1934). The only comprehensive work has been the Fauna of British India - Leeches by Harding & Moore (1927). In addition, Bhatia (1930-1940) has also contributed significantly on various aspects of leeches.

(iii) 1948 – 1990

During the period between 1940 and 1950 there has been no work on this group. Later, Sanjeeva Raj (1951-1981), Baugh (1960) and Chandra (1967-1990) published accounts on the

Mahesh Chandra, Zoological Survey of India, Solan

systematics, ecology and distribution of Indian leeches. There were some occasional papers by Soota also.

Studies from Different Environs

Leeches occur in three types of ecosystems, marine, freshwater and terrestrial. The marine leeches were mainly studied by Sanjeeva Raj and the freshwater and terrestrial leeches have been thoroughly studied by Bhatia, Chandra, Soota and Baugh.

Leeches from Kashmir to Arunachal Pradesh, Rajasthan, Maharashtra, Himachal Pradesh and Northeast India were studied. Occasional records also exist from certain other states of India. The freshwater leeches have been studied from tanks, pools, lakes, hill streams and rivers. The terrestrial ones from tropical forests and deep forests of the Himalayas upto an altitude of 3000 mts. The leech fauna of Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu and Orissa are poorly studied and needs a thorough survey.

Estimation of Taxa

Out of the seven recognised families of leeches, only five families viz. Piscicolidae, Glossiphonidae, Erpobdellidae, Hirudidae and Haemadipsidae are represented in India. The National Zoological Collections in the Zoological Survey of India comprise 59 species belonging to the above mentioned families.

The family-wise breakup of Indian species of leeches are given below :

	Marine	Freshwater	Land	Total
Piscicolidae	10	—	—	10
Glossiphonidae	—	24	—	24
Erpobdellidae	—	5	—	5
Hirudidae	—	11	—	11
Haemadipsidae	—	—	9	9
Total	10	40	9	59*

* Out of 59 species, 32 species are endemic.

Classified Treatment

Sanjeeva Raj gave comprehensive treatment of the Family Piscicolidae. Baugh and Bhatia have studied primarily the Family Glossiphonidae. Soota and Chandra have carried out researches on the whole group in respect of field ecology and extension of distributional records.

Current Studies

In the Zoological Survey of India, systematics and distribution of leeches of Himachal Pradesh of the Western Himalayan Ecosystem are currently under study.

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ARCHIANNELIDA

Introduction

Archiannelids comprise a heterogeneous group of small segmented marine worms, usually without parapodia or setae, by which they are readily differentiated from their closest relatives, the polychaetes. These worms are aberrant annelids well adapted for interestitial life. Their length is highly variable between 0.25 mm and 80 mm, with the somatic segments ranging from 5 to 250. The body is dorso-ventrally flattened and pale-white or transparent, with the cuticle often supporting hypodermal glands. Head is distinct and bears two tentacles and in some cases statocysts, nuchal organs and ciliary bands. Eyes are absent in the majority. Hind end or pygidium bears anal cirri or lobes or papillae, which are mostly adhesive in nature. Anal segment and its lobes are richly supplied with adhesive hypodermal glands. Sexes are separate. Gonads are paired and produced distinct ova and sperm.

All the archiannelids are free-living, harmless and occur in marine sediments, with the exception of the sole freshwater genus *Troglochaetus*. These worms generally prefer coarse sands with sufficient interstitial spaces near low water level, although some occur in sublittoral and subsoil habitats. Few archiannelids also live in littoral muds or algae. The smaller specimens are interstitial in their habit, while the larger ones are burrowing in the substratum. They are highly thigmotactic and adhere to substratum firmly during any commotion in the habitat. Their mode of locomotion is mostly by creeping, although the larger worms burrow in sand with remarkable ease. The archiannelids are largely omnivorous feeding on fine organic detritus, bacteria, diatoms and other smaller metazoans. They are gregarious, the phenomenon being closely related to tidal rhythm in some cases. Being intertidal animals, they are largely eurythermic and euryhaline, tolerating a wide range of temperature and salinity in the habitat. Higher temperature and salinity of coastal waters during summer months act as a stimulus for these worms to breed and reproduce more during March to August. Quantitatively, their densities in marine sediments are known to range from a few individuals to a few hundreds of specimens per 10 cm^2 of the sediment. Besides forming food for larger animals in the littoral ecosystem, archiannelids also proved quite sensitive to ecological stress resulting from organic pollution in the habitat, thereby serving as indicators of pollution. They also form suitable material for experimental studies on ecology.

Historical Resumé

Interest in the study of archiannelids inhabiting the intertidal marine sediments and littoral algae dates back to the middle of the 19th century when the earliest worms were discovered and described on the European coasts, as *Nerilla antannata* Schmidt (1948), *Dinophilus gyrociliatus* Schmidt (1857), *Polygoridus lacteus* Schneider (1868), *Saccocirrus papillocerus* Bobretzky (1872) and *Protodrilus leuckarti* hatschek (1882). Since then, a good number of species, genera and families of the archiannelids from different parts of the world were described by several authors as new to science. However, nothing was known of this group of worms from Indian coasts until the pioneering contribution on archiannelids was made by Aiyar and Alikunhi (1944) and Alikunhi (1964, 1948) from intertidal sands on the Coromandel coast. These authors described with much anatomical detail two species of Polygordius (*P. madrasensis, P. uroviridis*), two species of *Protodrilus* (*P. pierantonii, P. indicus*) and four species of *Saccocirrus* (*S. minor, S. cirratus,, S. orientalis, S. krusadensis*) as new to science. Subsequently, while studying the interstitial meiofauna from the beach sands on Waltair coast, Rao & Ganapati (1968) reported the occurrence of 12 species of archiannelids, including those known from the European coasts (*Nerilla antennata*

G. C. Rao, Zoological Survey of India, Calcutta.

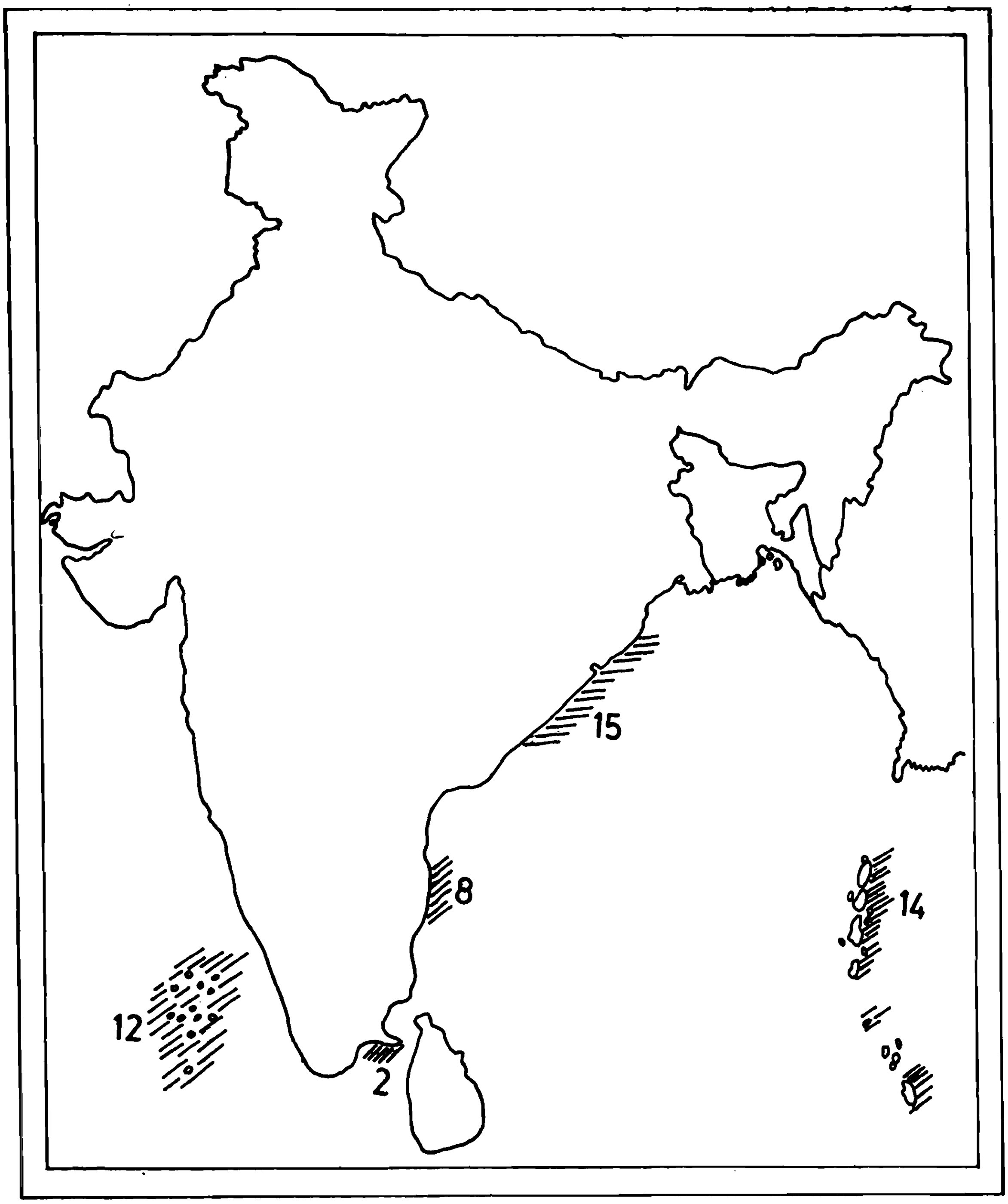
Schmidt, *Nerillidium mediterraneum* Remane, *Diurodrilus minimus* Remane, *D. benazzii* Gerlach, *Trilobodrilus nipponicus* Uchida and Okuda, *Dinophilus gyrociliatus* Schmidt) as well as those from the Coromandel coast. Further investigations of the Waltair beach sands have led to the description of a new species, *Trilobodrilus indicus* (Rao, 1973). A good number of archiannelids were also reported from intertidal sediments on the Orissa coast (Rao, 1969, 1989). Outside the Indian mainland, several known and unknown species of these worms were commonly reported in littoral sediments on the coasts of Andaman and Nicobar Islands (Rao, 1975, 1980, 1987, 1988) in the Bay of Bengal and Lakshadweep (Rao, 1983, 1990) in the Arabian Sea. More Recently, Jouin and Rao (1987) made detailed morphological investigations employing SEM on archiannelids of the Indian Ocean including those from the Indian subcontinent, Lakshadweep and Andamans, resulting in the description of a new subspecies *Polygordius eschaturus brevipapillosus*. All the above taxonomic studies threw considerable light on the wide geographical distribution of these interesting worms in the seas around India. Yet, many areas of Indian coast, particularly on the west, remain unexplored or underexplored for this group of annelids. Hence, detailed exploration of the littoral habitats are like to reveal the existence of more species in this region.

Estimation of Taxa

Taxonomic features generally utilised in the identification of genera and species of Archiannelida are : their body size, number of somatic segments, shape of pygidium and its adhesive papillae, structure of tentacles, palps, eyes, nuchal organs, ciliary bands, etc. on head, disposition of salivary glands, pharyngeal bulb, structure and position of circulatory apparatus, excretory and reproductive organs, sperms and the number and structure of parapodial setae when present.

The archiannelids were earlier considered as a class of primitive annelids, but according to the recent opinion of some zoologists, they are polychaetes secondarily adapted for interstitial mode of existence by the loss of lateral parapodia and hence are to be considered as an order of the Polychaets (Hermans, 1969). However, the archiannelids hitherto known comprise six families representing 21 genera and over 120 species as given below: Polygordiidae (*Polygordius* - 15 species), Protodrilidae (*Protodrilus* - 32 species, *Astomus* - 1 species), Protodriloidae (*Protodriloides* - 2 species), Saccocirridae (Saccocirrus - 18 species), Nerillidae (*Nerilla* - 10 species, *Nerillidium* - 8 species, *Mesonerilla* - 10 species, *Meganerilla* - 2 species, *Nerillidopsis* - 1 species, *Paranerilla* - 1 species, *Bathynerilla* 1 species, *Afronerilla* - 1 species, *Troglochaetus* - 1 species, *Bathychaetus* - 1 species, *Thallassochaetus* - 1 species, *Psammoriedlia* - 1 species), Dinophilidae (*Dinophilus* - 8 species, *Trilobodrilus* - 4 species, *Apharyngtus* - 1 species) and Diurodrilidae (*Diurodrilus* - 6 species). But, the archiannelids known within the Indian region represent all the 5 families (except Protodriloidae), 8 genera and 21 species as given below.

Genus	No. of species	Endemic
Polygordius	4	1
Protodrilus	4	2
Saccocirrus	5	1
Nerilla	1	-
Nerillidium	1	-
Dinophilus	2	
Trilobodrilus	2	1
Diurodrilus	2	
Total	21	5



Map showing the areas on Indian Coast where archiannelids were collected, studied and reported. Numbers indicate the species recorded.

Out of the 21 species known in this region, 16 species are eurytopic occurring in widely distributed areas of the Atlantic, Pacific and Indian Oceans, while about 5 (25%) are endemic. The eurytopic species, such as *Protodrilus indicus* Aiyar and Alikunhi, *Nerilla antenneta* Schmidt and *Dinophilus gyrociliatus* Schmidt are most widely distributed, while the endemic species *Saccocirrus cirratus* Aiyar and Alikunhi, *S. orientalis* Alikunhi and *Trilobodrilus indicus* Rao are restricted to a few pockets in this region.

Current Studies

Currently, studies on the systematics and distribution of Archiannelida along the Indian coast are being pursued by G. C. Rao in the Zoological Survey of India. Material of these worms was being collected during general faunistic surveys of the coastal areas. No attempts are being made outside ZSI to carry out any kind of study on these annelids. Outside India, Mme Claude Jouin is an active worker and authority on this group, having made a remarkable contribution to the knowledge of these worms from different parts of the world. However, the natural habitats of these animals are under constant and serious threat due to effects of pollution, disturbance, removal of beach sands for construction purposes, etc., resulting in the elimination of many of these sensitive species on our coasts.

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ONYCHOPHORA

Introduction

We are often able to arrange existing organisms in progressive series, of which the extremes are connected by intermediate forms. Not only are all the *connecting links* found between closely related species, but sometimes between the larger groups of the animal kingdom also.

The Onychophora (*Peripatus* and its allies) are in some respects annectent between the Annelida and Arthropoda but the reason for their inclusion in the latter phylum is not evident from superficial examination. They perhaps evolved from Polychaete ancestors which had forsaken a marine habitat and became terrestrial. Parapodia are consequently no longer present as swimming organs, but have become modified for locomotion on land without having acquired the jointed arthropod character. The integument is soft, though it contains chitin and the excretory organs take the form of metamerically repeated coelomoducts. Arthropodan features are exhibited in the possession of tracheae, salivary glands and the terminal claws to the appendages. The presence of jaws of an appendicular nature, the paired ostia to the heart, the pericardium, the heamocoelic body cavity and the reduced coelom are further important characters, allying them with that phylum.

Historical Resumé

The discovery of a species of *Onychophora* from the north-east frontier of India at the foot of the Eastern Himalaya, must be reckoned as one of the most interesting zoological results of the Abor expedition (1911-1912). The single species found was highly peculiar in many respects. Though it showed traces of alliance with *Eoperipatus*, which occurs in Sumatra and the Malay Peninsula, differed sufficiently in regard to the characters employed by Bouvier, Evans and other workers to entitle it to a separate genus. In the absence of any external trace of eyes it appeared to be unique.

For the Abor species the name *Typhloperipatus williamsoni* was suggested by Kemp in 1913. It was given in honour of the late Mr. Noel Williamson, one time Assistant Political Officer at Sadiya, who was treacherously murdered by Minyong Abors on March 30th, 1911, at Komsing, a village not many miles distant from the spot where the specimens were obtained.

The specimens were all found under stones, and this is a point of some interest seeing that all the Malayan species were found in dead wood. The majority of the specimens were found in chinks and crannies under comparatively large stones among the roots of jungle plants. Solitary individuals were occasionally met with, but more usually two to four adults accompanied by a number of young (one time as many as six) were collected together. Some of these specimens are preserved and kept in the National collection of the Zoological Survey of India.

The area in which the great majority of the specimens was obtained was very limited in extent, being about 200 yds. in length by 100 yds. in breadth. Subsequently a close search in a somewhat similar locality, situated in the N.E. near the mouth of the Sireng stream, resulted in the discovery of a few more individuals.

When touched, the specimens, as is usual in the Onychophora, ejected a semi-transparent viscous fluid from the oral papillae. The viscous fluid rapidly solidified and formed long strings of rubber-like consistency which adhered to everything with which they came in contact. That they never stuck to the animal itself was doubtless due to the special skin processes which, in life gives it such a deep velvety appearance.

J. R. B. Alfred, Zoological Survey of India, Calcutta. Adapted from Kemp (1914).

When moving the antennae diverged and were held in the same horizontal plane as the body with the tips flexed a little outwards. The first four or five pairs of limbs are rather irregular in their motions. That of the first pair are frequently held clear of the ground and this is generally the case with those of the last two pairs.

Affinities

The principal characters of the genus *Typhloperipatus* may be thus summarized :

Number of legs, 19 or 20, variable in the same species; Inner jaw with a diastema and saw of denticles; Legs with four complete spinous pads; Nephridial openings of the fourth and fifth legs situated on the third pad; Feet with two distal papillae, one anterior, one posterior; Genital opening between the legs of the penultimate pair; Receptacula seminis present, with two ducts opening into the oviducts; Receptacula ovorum present; Ovaries completely fused, with a single cavity. They lie closely pressed against but not directly attached to the floor of the pericardium, to which, however, they are connected posteriorly by means of a funiculus; The ovary is exogenous, i.e. it is studded with follicles in which the maturing ova lie; The ova are large and heavily charged with food-yolk: they measure about 1.5 mm in their longest diameter; Embryo without a trophic vesicle; Uterine embryos of about the same age; Unpaired part of vas diferens of very great length; Spermatophores long, with horny coat and cap; Skin-pigment brown, disappearing in course of time in alcohol; Legs with well-developed coxal glands; A single crural gland in the male in each of the two pre-genital pairs of legs; The accessory glands of the male open separately on the ventral surface between the genital opening and the anus. To these it must be added that there is no external trace of eyes and that there is a patch of highly modified scales, probably sensory in function, on the lower surface of each antenna. The absence of eyes and the curious modifications in the antennae are doubtless to be regarded as evidence of specialization. They are not shared by any other genus of Onychophora.

It is clear that the affinities of *Typhloperipatus* are primarily with its nearest geographical neighbour, *Eoperipatus*, with which, except for the unique characters mentioned above, it agrees in all important structural details but four *viz.* (i) the position of the renal openings of the fourth and fifth legs which, as in most genera of Onychophora, are situated on the third pad, (ii) the presence of a horny coat, as well as a cap, on the spermatophore, (iii) the separation of the openings of the male accessory glands, and (iv) the similarity in age between the embryos found in a single female. It may also be noted that in *Typhloperipatus* the oviducts are united for a long distance in front of the ovary and that in the male there is only a single crural gland in each of the two pre-genital pairs of limbs in place of the two found in *Eoperipatus*. In the number and position of the leg papillae and in the complete fusion of the ovaries, the Abor genus agrees with *Eoperipatus* and differs from all other known forms. It can scarcely be doubted that *Typhloperipatus* is an off-shoot from the original Malaysian stock and that it is, on the whole much more highly specialized than its allies in the Malay Archipelago and in Sumatra.

As the question stands at present the evidence for a neotropical connection seems to outweigh that for a migration from the Australasian region, and if we accept the view that the former has occurred, some support is given by what is known of the structure of the tropical African *Mesoperipatus*, which both Evans and Bouvier associate with *Peripatus* and *Eoperipatus*. A further study of the tropical African species may be expected to prove of considerable interest from this point of view and if any Onychophore should be discovered in S. India or Ceylon results of great importance may be anticipated.

In spite of further surveys this species has not been encountered till now. It is to be hoped that interested persons can be found to carry on the search.

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Animal Resources of India : 189–202 : 1991

CRUSTACEA

Introduction

Crustacea embraces forms commonly called prawns, crabs, hermit crabs, shrimps, woodlice, fish-lice, barnacles, lobsters, etc. Majority of these are aquatic, breathing by gills or by the general surface of the body. These creatures are in many ways important to man, not only since some of them are valued as food, but also their vast numbers, in many cases virtually myriads, form food in turn for other valued animals, and thus largely contribute to the maintenance of certain fisheries. The crustaceans are known for their remarkable adaptations. Some occur in freshwater, while others resort to estuaries and some to brine pools. Records of forms found in estuaries adapting to purely freshwater are not uncommon. Some of the Indian forms living in the sea are littoral, others pelagic and some are abyssal descending down to great depths of the sea covering hundreds of fathoms; some adapt to live on land and a few survive in deep caves also. Besides, some members occur as parasites on a large variety of animals, including the crustaceans themselves.

Crustaceans live solitarily as in the case of rock lobsters and in gregarious form as in shrimps. Another remarkable feature of these organisms is their size, from the microscopic forms such as *Daphnia, Cyclops*, etc., to crab and lobsters which grow fairly large sizes. Most of them are brilliantly coloured and some present instance of protective coloration. Mimicry and modification of form, etc. are also common among the crustaceans. Many of these carry sponges, alcyonarians, ascidians, etc., on the carapace. Hermit crabs are found to live together with other animals such as sea-anemone and gastropod mollouscs, the sea-anemone and hermit crabs acting as commensals. Some crabs and prawns live inside the mantle cavity of oysters and echinoderms, respectively.

Among the commercially important crustaceans of India, prawn undoubtedly occupies a dominant place by virtue of the magnitude and the value of the fishery they support. Practically all the species of prawns and crabs are edible and a very large number of these are consumed all over the world. Majority of the commercially important species live in the sea and in estuaries of our great rivers. Penaeid prawns are the commonest among them and four species viz., *Peneus monodon, Peneus indicus, Metapeneus monoceros* and *M. brevicornis* are found fairly common in large numbers in the Gangetic delta and other parts of the country along both the coasts. Apart from prawns, lobsters too play an important role in this direction. While tiny mysids fill the pot of the poorer sections of the people, the lobsters adorn the table of the rich. The spiny lobsters or the crayfish, *Panulirus polyphagus* or *P. ornatus* occurs in several localities along both the coasts of India, though it is quite common along the west coast and prefers rocky or stony bottom a little farther away from the low tide zone. The common species of the Bombay coast is *Panulirus ornatus* which hardly grows to a foot in length and is found in fairly large numbers on rocky beds generally in waters somewhat shallower than that in which the other species referred to lives. In addition to prawns and lobsters, many varieties of crabs (both freshwaters and marine) are also utilised as part of food. Majority of swimming crabs belonging to the family Portunidae contribute the largest portion in this direction. *Scylla serrata* is the most common food crab of India and is extensively fished all along the Indian coasts. In addition to this, there are a few other species viz., *Neptunus pelagicus*, *Neptunus sanguinolentus* and *Varuna literata* among the brackish water forms and *Paratelphusa (Barytelphusa) jacqucmontii, Paratelphusa (Paratelphusa) spinigera* and *Paratelphusa (Oziotelphusa) hydrodromus* among the freshwater forms known for their value as food.

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Zoo-plankton constitute crustaceans which act as food of fishes and according to Venkataraman (1960)), crustaceans form the larges group viz. 59.9% among the food of fishes.

In addition to the medicinal purpose for which some of the crustaceans are used, there are some among them, whose activities are detrimental to man in the transmission of diseases. In tropical countries, they play an important role in the life cycle of some parasites..

Some crustaceans directly cause economic loss to man. The fouling of ship barnacles may, at first sight seem to be trivial matter, but a heavy layer of fouling can increase by about 50% of the fuel needed to maintain a given speed. Such increased costs of transport will be directly responsible for the increased price of goods carried by them. There are as many as 20 species cirripedes suspected to be causing fouling of ships and other naval crafts in India. As a rule, the tropics are the worst areas for fouling of ships. The temperate region is no exception to this but the incidence is comparatively less. Damage caused by marine boring organisms is also of great economic importance and of all creatures responsible for such damages two are well known. One is the mollusc *Teredo*, the ship worm and the other being the isopod crustaceans of the genera *Limnoria* and *Sphaeroma*. Piles supporting wharfs and piers seem to be specially the targets by these borers and the damage caused is very considerable.

Historical Resumé

Carcinological research in India dates back to 1869, when James Wood-Manson commenced serious study of the group. Immediately after joining the Indian Museum, Calcutta, he carried out a survey of the Indian marine and freshwater crustaceans, which constituted the beginning of a long and brilliant series of papers and monographs dealing with the group. His copious notes on the crabs and Stomatopoda which he left behind proved to be of immense help to his successors, namely, Alcock and Kemp in their work.

Wood-Mason was also the first specialist to carry out the deep sea biological investigations in the Indian Ocean, where in 1872, he was deputed by the Trustees of the Indian Museum to proceed to Andaman Islands for study and collection of the marine fauna of the area. Apart from his own effort in the collection of marine and freshwater crustaceans, he spared no energies in persuading others from different parts of the country in the enrichment of the Crustacea collections.

Prior to the establishment of the Indian Museum, some work on the Crustacea was done and collections of this group were accumulated in the Museum of the Asiatic Society of Bengal, which formed the nucleus around which the present National Zoological Collections of India have been built up.

Alcock made earnest efforts in the collection and study of the crustaceans from deeper parts of the Indian Ocean. His outstanding contributions viz. Catalogues of the Indian Crustacea and his series of Memoirs on the Crustacea collected by R.I.M.S.S. *Investigator* are too well known to all the carcinologists of the world.

As a result of the studies undertaken in the Indian Museum and subsequently in the Zoological Survey of India for the past seventy five years, the Crustacea Division possesses one of the richest collections of these animals.

As Alcock took greater interest in the study of crabs, the Zoological Survey of India possesses a very fine collection of these animals, probably, the best available in any museum of the world, so far as the Indian region is concerned. Likewise, Kemp who made a special study of the Stomatopoda was instrumental in bringing together an excellent collection of the group. Further, owing to Kemp's interest in the Crustacea as a whole, the Survey is in the possession of vast collections, authentically identified and classified into prawns and shrimps.

Subclass Ostracoda

Orders Myodocopa

Cladocopa

Podocopa

Platycopa

Similar to Branchiopoda, Subclass Ostracoda includes four orders as above. The members of this group are divided chiefly based on the nature of shell, the number of post oral appendage and the nature of caudal furca. Ostraod shells were described from the Upper Cambrian, *i.e.*, about 400 million years ago and over 3,000 species have been described from the Palaeozojc rocks. They are abundant, today in both freshwater and the sea.

Sars (1924, 1925), Muller (1912), Brady (1885) and Daday (1908) have contributed mostly to our knowledge of the group. Order Myodocopa are purely marine forms and comprises two families *viz.* Cypridinidae and Conchoeciidae. Together these families include about 300 valid species of which about eleven species are known from the Indian coast. Merrylal James (1972, 1973) and Pculsen (1965, 1969) have contributed mostly on Indian forms. Sars monograph (1925) on the Crustacea of Norway is the basic reference on Ostracoda, which even to-day is the key work on the group.

The second order *viz.* Podocopa are exclusively freshwater ostracods, except for a few marine forms. The group comprises four families *viz.* Nesidaidae, Darwinulidae, Cytheridae and Cyprididae of which the former two families are not represented from the Indian region. Of the other two families, which comprise both freshwater and marine forms, Cytheridae is represented by very few species from India, while the family Cyprididac has 105 species, so far, recorded from India.

The earlier contribution on Indian forms are by Brady (1857) Gurney (1907), Klie (1927) and Arora (1931). In recent years, Hartman (1964), Deb (1972-1976), Michael and Victor (1975), Victor (1973, 1975), Victor and Fernandes (1976) have contributed vastly to our knowledge of the freshwater ostracods of India.

The two other orders *viz.* Cladocopa and Platycopa are not represented from India.

Subclass Branchiura

Our knowledge of the group from the Indian region is confined to very few workers and is rather scanty. Southwell (1915) gave an account of *Argulus foliacecus* (Linn.) an European species occurring in India. It is not until 1951, when Ramakrishna contributed to our knowledge of the Indian species of arguulids found parasitic on fishes, that the group received adequate attention. He described five species of the genus *Argulus* of which three were described as new to science. He (1962) described yet another taxa from Kerala. Thomas (1961) published a detailed account on the observations on the habit and post–embryonic development of parasitic branchiuran *Argulus puthenvaliensis* Ramakrishna.

Outside the Indian region, Meehan (1940) in his contributions dealt with world species of the genus *Argulus* and Wilson (1926, 1944) dealt with argulids from Thailand and North America. Max Weber (1892) established *Argulus indicus* to accommodate some female specimens collected from the east coast of Java.

Subclass Cirripedia

Orders Thoracica

Acrothoracica

Rhizocephala

Ascothoracica

Annandale who succeeded Alcock as the Superintendent in 1907 and who later became the first Director of the Zoological Survey of India in the year 1916, had interest in the study of Cirripedia (1905-1906). His monographic work (1909) was confined to Pedunculate Cirripedes, specially the family Lepadidae. The material at his disposal was collected from India, including Andaman Islands and Ceylon.

For about two decades since Annandale's work nothing worth mentioning was published. It was only in 1938, when Nileson Cantell dealt with in great detail the cirripeds from the Bay of Bengal, Arabian Sea and the Indian Ocean accumulated in the collections of the Indian Museum that our knowledge on the group was enriched.

Daniel (1952-1971) in a series of contributions enriched our knowledge on the cirripedes of India and the fouling crustaceans. Besides his monograph (1956) on the Cirripedes of Madras coast, he has many other contributions on the group including other crustaceans.

Hoek's (1907) account of Cirripedea Pedunculata from the Malay Archipelago collected by Siboga Expedition and of several important papers dealing with Pacific species by Pilsobry (1907) and Gruvel's (1905) monograph on cirripeds are the only important contributions to our knowledge outside the Indian region.

Subclass Malacostraca

Of all the subclass of Crustacea, Malacostracans specially the Order Decapods, has received adequate attention of carcinological workers and this is evidenced by copious publications on the group from the Indian region. This fact is also reflected by the excellent collections in our holdings.

Order Mysidacea

Mysidaceans, popularly known as Opossum-shrimps, have received attention in the early part of the twentieth century by Tattersall (1906, 1908, 1914, 1915, 1922, 1931). His series of contributions dealt with mysids collected from various parts of the country. In recent years, Pillai (1957, 1961, 1963, 1964) contributed to our knowledge on the mysids of the Kerala and erstwhile Travancore State. During 1967, he contributed a monograph on the shallow water Mysidacea of the Indian waters. The total number of species known from the Indian water is about 75.

Contributions from outside Indian region are mainly by Tattersall (1952-1962) on the South African material and (1951) on British Mysidacea; Sars (1888) on mysids collected by the H.M.S. Challenger Expedition during the years 1873-1876.

Order Cumacea

Very little is known about the crustacean fauna of Indian region pertaining to this group. The first record being by Calman, in 1904 from the Gulf of Mannar, and he described ten species. Subsequently, Kemp (1916) dealt with the Crustacea of Chilka Lake, Kurian in a series of papers (1951, 1954, 1961, 1967) contributed to our knowledge of the Cumacea from the lakes of Kerala and on the collections received from the Zoological Survey of India collected from the Indian coasts and stations around Andaman Islands. Altogether 23 species of Bodotriidae, 3 species of Diastylidae, 4 species of Nannastaeidae and the lonely species of Campylaspididae, are known from the Indian region.

Outside the Indian region, Stebbing (1910-1913) Jones (1955, 1956) contributed on the material from African coasts, Claman (1905, 1907) on the Gulf of Thailand, Hale (1928-1943) from Australia. However, much more remains to be done about these small crustaceans from the deep water regions of India. A comparative study of the Indian Cumacea show that they have close affinity with those of the Australia, Africa and the Gulf of Thailand.

Order Tanaidacea

Our knowledge of Tanaidacea is rather poor from the Indian region. Chilton (1904) contributed a paper dealing with a taxa of the group from the Chilka Lake. Barnard (1935) gave an account of the Tanaidacea collected from erstwhile Travancore and Cochin States.

Order Isopoda

It was Stebbing (1907) who initiated the study on Indian Isopods by publishing an account of the genus *Tachaea* and described a new species of the genus from Calcutta. He later (1921) gave a detailed account of Indian Isopod and dealt with two genera of the Tribe Flabellifera, and five genera of the Tribe Oniscoidea. It was, however, not until Collinge entered the field and made several contributions that the work received adequate attention. Collinge (1914) published an account of three species pertaining to three genera viz., *Philoscia, Parapericyphis* and *Cuboris*, collected from the Port Blair, Andamans and from the Annanmalai Hills in South India. He again (1912–22) contributed two paprs on the terrestrial Isopods obtained from the Abor Expedition. His next contribution to our knowledge of terrestrial Isopods of India dates to 1914, when he worked out the collection received from Madras Province. Of the ten species dealt with, nine species were new to science. *Ennurensis hispidus* and *Hemiporcellio carinatus* stand significant among the collection. Collinge (1916) published another article on the same subject and described species, all of them being new to science pertaining to the genera *Parapericyphis, Cubaris* and *Burmoniscus*. *Burmoniscus kempi* was collected from Maosmai cave near Cherra Punji at an altitude of 4000 ft. This was the second species of the genus *Burmoniscus* found in a cave, the other being *B. moulmeinus*. He (1917) described another new species of the genus *Synidotea* from the Gulf of Mannar.

Subsequently, Chopra (1923) contributed a monumental monograph of the Bopyrid Isopods of India Decapod Macrura. Till then, nothing was known on the Bopyrid Isopod Parasites of India and also of the neighbouring countries. These, were however, common in Indian waters since almost all the species of Caridean prawns generally available in Calcutta markets were infested with them. The fauna of Bopyrids is rich in number of species and also in the number of some individuals. 33 species pertaining to 13 genera were described by him, collected mostly from the Andaman Islands, delta of Ganges, Madras and other areas. Later, he (1924) worked out the fauna of Suju cave and described four species of terrestrial Isopods belonging to three genera and two families *viz.*, Oniscidae and Armadillidae. The cave fauna between 300 to 500 ft. from the entrance of the cave had the richest fauna and this was true of Isopods too. Two myrmecophilous Isopods collected from Barkuda Islands, Chilka Lake were then described by Chopra (1924) brought by Annandale. Of the two, *Cubaris granulatus* was not known to be associated with ants earlier. Chopra (1930) further contributed another interesting paper on the Bopyrid Isopods on Indian Decapod Macrura. The collection included 12 species pertaining to 7 genera collected mostly from the Andaman and Nicobar Islands, delta of Ganges, Gulf of Mannar and Bombay.

Chilton (1926) described several species of Isopods based on the collection obtained from a tour in the Far East. Barnard (1935, 1936) reported on some Isopods, Tanaidacea and Amphipoda based on the collection obtained by the R.I.M.S. *'Investigator'* The collection contained littoral, shallow-water and deep water species from the Mergui Archipelago in the east to the Arabian Sea and mouth of Persian Gulf in the West. The collections contain 34 species of which seven were described as new to science, one of which is littoral wood lice. Verhoeff (1936) also dealt with several species of terrestrial Isopods collected from Madras and other parts of Southern India. He further described a new species of the genus *Protracheoniscus* from Ladakh.

Chopra (1947) gave an account of the first occurrence in India of the ancient suborder Phreatoicoides, based on material received from Dr. Sharif of the Haffkin Institute in 1946 collected in a pucca well at Lohagara railway station, 18 mils from Allahabad. Later, several specimens pertaining to this group were collected from the wells of Banaras (U.P.). This suborder is known to have a very interesting distribution, being somewhat plentiful in Australia, Tasmania and New Zealand and having been found outside this region only in Cape Province of South Africa. its occurrence in South Asia, was therefore considered to be of particular significance. Chopra and Tiwari (1950) described the *Nichollsia kashiense* from the material collected from the well in the outer lawns of the Kaiser castle, Banaras Cantt. Subsequently Tiwari (1952) dealt with in detail the morphology of the same species. He (1953) described a new species of he rate Cymothoid genus *Agarna*, prasitic on the Clupeid fish *Nematolosa nasus* in the Bay of Bengal. Later, Tiwari (1955) contributed another article erecting a new family Nicholisidae to accommodate the genus *Nichollsia*. He (1955) described another species *Nichollsia* from an abandoned well at Monghyr (Bihar).

In recent years Ramakrishna contributed a series of papers on the terrestrial Isopods collected from different parts of the country. His contribution (1970) dealt with Isopod material from the Kameng Division of Arunachal Pradesh. Subsequently Ramakrishna (1969) described a new species of *Philoscia* based on material collected from the Lodna Colliery, 13 kms. from Dhanbad, Bihar, Ramakrishna (1975) described yet another species new to science of the genus *Porcellio* collected from different parts of Rajasthan. He (1975) reviewed the work done on Indian Isopods.

Among the contributors on the marine wood-borers Pillai (1955, 1958 and 1971), John (1968), George (1963), Palekar and Bal (1957), Ganapati and Lakshman Rao (1960), Lakshman Rao and Ganapati (1969), Lakshman Rao (1969), Cheriyar (1968) stand significant. So far, six species of the genus *Sphaeroma* and nine species of *Limnoria* are recorded from the Indian waters. The damage caused by these borers exceeds considerably than that of all other crustaceans.

Among the important monographic contributions from outside Indian region, are by Richardson (1905) dealing with Isopods of North America, Vandei (1960, 1962) dealing with terrestrial Isopods of France, Van Name (1936) on the American land and freshwater Isopod Crustacea, George, A. Schultz (1975) on the marine Isopod Crustaceans Sars (1899) on Isopoda of Norway and Buddle Lund's (1879-1912) series of contribution on the world fauna of Isopods.

Order Amphipoda

Study of Indian Amphipoda has received considerable interest since Giles (1885-1890) gave an account of them collected from the Bay of Bengal by R.M.I.S.S. *Investigator*. Since then Chilton (1920, 1921, 1923 and 1925) and Tattersall (1912, 1914, 1922 and 1925) contributed a series of papers on the group. While Chilton dealt with Amphipods of the river Ganges, Chilka lake and Bengal,.Tattersall accounted for those collected from Tale Sap and freshwater Amphipods from Andaman Island. Barnard (1935) reported on the Amphipods collections made from different parts of India pertaining to the families Ampeliscidae, Oedicerotidae, Calliopidae, Gammaridae, Talitridae, Aoridae, Photidae, Amphithoidae, Corophiidae and Podiceridae.

In recent years, Sivaprakasm (1966-1970) in a series of contributions enriched our knowledge on the Amphipods of east coast of India and listed 61 species. Nayar (1959, 1966) dealt with the amphipods of the Madras coast and Gulf of Mannar. In his monographs on the Gammaridean Amphipoda of the Gulf of Mannar (1967) he dealt with 78 species, of 26 families. Pillai (1967) contributed to our knowledge in two parts on the Amphipod collections of the Central Marine Fisheries Research Institute, mostly made from the Arabian Sea. Surya Rao (1972) enumerated a detailed account of the intertidal Gammarid amphipods from the Indian coasts and listed 132 species pertaining to 54 genera.

Rabindranath (1969) contributed to our knowledge on the amphipods of Kerala. Tembe and Deshpanda (1964) dealt with amphipoda of Bombay shores.

Order Euphausiacea

The importance of Euphausids in the dietary of oceanic fish and baleen whales of Antarctic waters is too well known. But to-date we have very little precise information on their significance to the fisheries of the tropics, specially from the Indian waters. The earliest account on Indian

Euphausiids is known through the work of Wood-Mason and Alcock (1891), Alcock and Anderson (1894), Anderson (1893) on the benthic forms of the Bay of Bengal and Laccadive sea. Tattersall (1911, 1939) gave an account of them from the Indian Ocean.

After a long gap of about two decades, Pillai (1957) described some taxa from Travancore. Panomerava (1964) worked on the Euphausids of Arabian Sea and the Bay of Bengal. Sebastian (1966) dealt with taxonomic account of 23 species of Euphausids from the Laccadive, Maldive and adjoining regions of the Indian Ocean. Gopalakrishnan and Barinton (1969) reported 31 species from the samples of the International Indian Ocean Expedition and Mathew (1971) described two species from southwest coast of India.

Order Stomatopoda

The history of collection and studies on Stomatopoda in the Zoological Survey of India dates from the last quarter of the 19th century when late Wood-Mason devoted himself to the task of acquisition of a representative series of Indo-Pacific species to the nucleus collection then existing in the collection of the Indian Museum.

Since 1895, when Wood-Mason's descriptions were published, considerable additions were made owing to the painstaking efforts of Alcock on the "R.M.I.S.S., *Investigator*" based on this and more representative collections acquired from other world museums, Kemp (1913) published a monograph on Indo-Pacific Stomatopods comprising 139 species and varieties known till then. This monumental work has remained the principal work of reference till date on the Indo-Pacific forms.

Kemp and Chopra (1921) published a note which included descriptions of two more new species and entended distribution and structural peculiarities of twenty others. Chopra (1934) gave an account of collection made by the Bengal Pilot Service at Sandheads, off the mouth of river Hooghly together with notes on other forms. This was followed by Another interesting publication (1939) on the Stomatopod collection of the John Murry Expedition 1933-34 made by Sewell.

Tiwari and Biswas (1952) published a paper based on material accumulated since Chopra's work. After a gap of two decades Ghosh (1973, 1975 and 1976) and Tiwari and Ghosh (1975) have contributed a series of papers highlighting the present knowledge of Stomatopoda in the Indian waters.

Outside the department, noteworthy contributions were made by Alikunhi and Aiyar (1942, 1943), Alikunhi (1944, 1950 and 1951) on growth stages of stomatopods. Contribution son adult form were made by Kurian (1954), Chapgar & Sane (1967) and Shanubogue (1969, 1970). Outside India, Holthuis and Manning have contributed a lot on the group.

Suborder Decapoda

Decapoda is the most highly developed and largest order of Crustacea with about 8500 species. As the name indicates, all members of this group have five pairs of walking legs. They have invaded almost all depths and levels of the sea and some are semiterrestrial to terrestrial. They range in size from tiny pelagic shrimp to large benthic spider crabs. They play an important role in the aquatic ecosystem by recycling dead organic matter. Next to fish, prawns and crabs form major sources of quality protein to man. There are about 350 species of prawns and shrimps, and 20 species of crabs consumed all over the world.

The history of the study of decapods can be traced back to the early recorded history; crab is one of the two invertebrates in Zodaic as the sign of the constellation cancer which is the Latin word for crab. Fabricius was the first scientist to lay the foundation for the classification of Decapod. He divided the Linnean genus *Cancer* into a number of genera. Later, this group broadly divided into long-tailed Macrura and short-tailed Brachyura by Latreille in 1906, and the intermediate group of

Anomura was created by Milne–Edwards in 1834. However, the first major classification was proposed by Boas in 1888. He separated Decapoda into two groups, the Natantia or swimming decapods and the Reptantia or crawling decapods. Boradaile (1907) published a scheme of classification which was widely accepted. The term "tribe" was first introduced in the classification of this group by him. The classification proposed by Beurlen and Glaessner (1930) included more information on fossil Decapoda and altered the traditional classification. Glaessner (1969) gave another classification including only such taxonomic characters which are necessary for coherent presentation of our present knowledge on Decapod phylogeny. This and Boradaile's classification are being followed by many present–day workers.

Suborder Macrura

Research on Macrura of Indian waters was initiated by de Man (1887-1908), who published a series of papers on the collection from the brackish water ponds of Lower Bengal. Alcock (1901, 1906) contributed a comprehensive catalogue on the penaeid prawns of India with keys for identification of species. However the pioneering contribution of this group was made by Kemp (1910) who published in 24 parts in the *Records of the Indian Museum*. He dealt with systematic account of various marine and brackish water forms belonging to several families collected from varied habitats. Chopra (1936-1956), in addition to his systematic studies on this group, published a series of articles on prawn and crab fisheries of India. Later Tiwari (1947-1974) made exhaustive studies on different groups of Macrura. His series of contributions on *Caridea* published in 15 parts was based on the material collected from different parts of India, including Burma, Philippines and China. Pillai (1961-1974) contributed several papers on the fresh water carideans of Andaman & Nicobar Islands.

Jalihal, Shakunthala Shenoy and Sankolli (1975-1984) have made significant contribution on the systematics, ecology and development of inland fresh water prawns of Karnataka. They described eight new species belonging to the Genus *Caridiana* and *Macrobranchium*. Khan (1980) described a new species of palaemon, *Kara fulienses* from Bangladesh. Rabindranath (1980) contributed to the study of eulittoral palaemonid shrimps off Visakhapatnam coast. He also studied the shrimps of the genus *Acetes* from the Krishna estuary. Jayachandran and Joseph (1986) described a new species of *Macrobrachium* from the southwest coast of India. Anantha Raman (1980) reported the occurrence and distribution of freshwater prawns in an around Bangalore.

Culture of prawns and crabs in India have gained much importance in recent years, in the wake of increasing demand, both for domestic consumption as well as for export to foreign countries. Prawns belonging to the family Penaeidae, Sergestidae Palaemonidae and crabs of the family Portunidae constitute major fisheries in India. Chopra (1939-1943), and Panikhar (1937-1950) in a series of papers enriched over knowledge on the prawn fisheries of India. George and Vedavyasa Rao (1967) published an annotated bibliography on the biology and fishery of commercially important prawn of India. The publication on prawns and prawn fisheries of India by Kurian and Sebastian (1976) is one of the noteworthy publication in this field.

Rajyalakshmi (1985) in her review paper on Estuarine Macrura (Penaiae) of India reviewed the current State of our knowledge and literature in this filed. Recently, Muthu *et al.*, contributed a paper on the research and technological progress made in the field of culture of prawns in the *Proceedings of the Symposium on Coastal Aquaculture*.

Suborder Anomura

Sankolli (1963-1966) studied the porcellanid crabs from the intertidal region of Ratnagiri along the west coast of India. Later, Sankolli (1967), Shakuntala Shenoy, (1967) and S. Shenoy and Sankolli (1967) enriched our knowledge on the larval development of Anomuran crabs. Sarojini and Nagabhushanam gave a detailed systematic account of the porcellanids of Waltair Coast.

Reddy and Ramakrishna (1972) listed twenty species of pagurid crabs belonging to families

Paguridae and Coenobitidae. Ajmal Khan and Natarajan (1981) gave a detailed systematic account of the hermit crabes of Vellar estuary with keys for identification of families, genera and species. They also studied the larval development of Pagurid crabs under laboratory conditions.

Recently, Baba Keiji described two new species of anomuren crustaceans, *Gastroptychus chacei* (family Chirostylidae) and *Munida sentai* (family Galatheidae) from Andaman Sea.

Suborder Brachyura

The study of the Brachyuran fauna of the Indian seas started with the study of the deep sea forms by Milne Edwards, de Man (1887) and Handersen (1888). However, the first monumental work on the Indian Brachyura is by Alcock (1895-1911) which is still considered to be invaluable for the study of crabs of the Indo-Pacific region. The work incorporates six tribes, with more than 600 species with detailed descriptions. Laurie (1906) recorded 208 species of brachyuran crabs from the Gulf of Mannar. Kemp (1915-1923) enhanced our knowledge of the brachyuran fauna of the Indian waters. His (1917-1919) revision of the crabs belonging to families Hymenosomatidae and Scopimenrinae are valuable additions to our knowledge on this group. Gravely (1927) studied the crabs from the Gulf of Manner.

Ramakrishna (1951) contributed to our knowledge on the Potamonid crabs available in the collections of the Zoological Survey of India. Pillai (1951) reported on the Brachyura from the Travancore coast. Chapgar (1957) in his book on Marine crabs of Bombay State described 81 species of crabs, giving full systematic descriptions and illustrations. Sankaran Kutty (1961) reported 43 species and two varieties of crabs belonging to 22 genera with the genus *Johnesius* as new to science, from Andaman and Laccadive Archipelago. He (1965) also reported 88 species belonging to 23 families of Brachyura from the Gulf of Mannar with *Aelasius indicus* as new to science.

Wasima (1982) reported a new species *Ixa holthusia* from North Arabian sea. Holthuis (1984) described two new species of *Dorippe* from the Andaman Islands. Deb, (1985-1989) in a series of papers enriched our knowledge on the Brachyunan fauna of Indian waters. She described a new genus of *portunid* crab and 10 new species from Indian waters. In her occasional paper on *Actinae* she dealt with forty four species from Andaman coast. She also revised the genus *Demania*. Deb and Badra recorded *Portunus pubescens* (Dana) from India. Deb, *et al.* (1988) have contributed to the knowledge of Brachyuran fauna of Mangrooves of Sunderbans and Andaman Islands. Dutta, (1989) dealt with freshwater crabs of North-Eastern region of India.

Estimation of Taxa

Name of sub-classes orders	No. of families	No. of genera
Branchiopoda		
Anostraca	5	16
Notostraca	1	2
Conchostraca	5	12
Cladocera*	—	—
Ostracoda	3	24
Copepoda*	63	193
Branchiura	1	1
Cirripedia	9	48

* dealt separately

Name of sub-classes orders	No. of families	No. of genera
Malacostraca		
Schizopoda	5	70
Isopoda	22	155
Amphipoda	44	128
Decapoda	61	614
Stomatopoda	4	36

Area and Groupwise Surveys

Prior to the establishment of the Zoological Survey of India, couple of field explorations were undertaken by scientists attached to the Indian Museum for study and collection of Crustacea material. Wood Mason was the first to carry out deep-sea biological investigations in the Indian Ocean, when in 1872, he was deputed by the Indian Museum authorities to proceed to Andaman Islands for collection of marine fauna including crustaceans. Anderson's efforts on an expedition to Mergui Archipelago was responsible for excellent collection of Crustacea, which were later worked out by the Dutch Carcinologist Dr. J. G. de Man and results published in the *Journal of Linnean Society*.

In subsequent years, Alcock, Annandale and Sewell did a great deal of field studies and enriched museum collections, specially Alcock from the deeper parts of the Indian seas. Of the various military and political expeditions the one which went to the north western parts of India, the Pamir Boundary Commission (1896) brought a very interesting collection from the Russian frontier of the Pamirs. Among the expeditions that went to the eastern parts of the Himalayas, the 'Dafla' (1874, 1875) and the 'Abor' expedition (1911, 1912)) on which Dr. Kemp accompanied the collections, which were extensive and at the same time of exceptional interest, the results of which were published in a special volume of the *Records of the Indian Museum.*

One of the most important field explorations undertaken during the second decade of the twentieth century with special reference to crustaceans was by Kemp and Chopra to the Siju Cave in the Garo Hills, Mcghalaya. Couple of field surveys undertaken subsequently during the next two decades by Dr. Chopra and other scientist attached to the Survey enriched the crustacea collections from Andaman and Nicobar Islands, Chilka Lake, Salt Range, Punjab, Kashmir and Simla hills.

Year	Area
1952-53	Andaman Islands
1953-54	Gujarat (Okhamandal coast)
1954-55	Kashmir Valley
1954-55	Bihar (Monghyr Dist.)
1960-61	Andaman Islands (Little Andaman Is.)
1961-62	Rajasthan, Uttar Pradesh (Varanasi)
1961-62	West Bengal (Calcutta Dist, Sunderban area)
1962-63	Andhra Pradesh (Waltair, Kakinada Vizagapatanam Dist.)

Year	Area
1963-64	Andaman Islands (South Andaman)
1964-65	Tamil Nadu, Karnataka and Kerala coast, West Bengal (Digha coast)
1965-66	Great Nicobar, West Bengal (Digha coast) Karnataka, Orissa
1967-68	Sagar Island
1968-69	Andaman & Nicobar Islands, Gujarat
1968-69	Maharashtra (Bombay & Suburbs)
1969-70	Karnataka (Hassan, Chikmagalur & Shimoga Dists.)
1969-70	Andaman & Nicobar Islands
1970-71	Andaman
1971-72	Assam, Orissa (Balasore, Cuttack, Puri & Ganjam Dists.)
1971-72	Andaman & Nicobar Islands, Gujarat
1972-73	Andaman & Nicobar Islands
1972-73	Orissa, Coorg
1973-74	Andaman islands
1974-75	Manipur, Orissa, Tamil Nadu & Kerala
1975-76	Andaman & Nicobar Islands

Though almost every state in the Indian Union has been covered partially for study and collection of some groups of crustaceans, practically much remains to be explored, specially of such groups of lower crustaceans which have not received adequate attention. Apart from this, there ar certain areas which have, hitherto, not been explored at all viz. Tripura, North Bengal, Sikkim, parts of Bihar, Uttar Pradesh and Gujarat, Telengana area in Andhra Pradesh, Bastar and adjacent areas in Madhya Pradesh, parts of Maharashtra, interior districts of Tamil Nadu and the eastern portion of Karnataka.

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CONCHOSTRACA

Introduction

The members of the order Conchostraca look like miniature bivalves in general appearance. Hence, they are popularly referred to as 'clam shrimps' The conchostracans are seldom found in marine and brackish water environments. They are known to be distributed only in freshwaters.

Conchostracans are widely distributed in ephemeral water bodies. They occur in rain water puddles, rocky pools, seasonal ponds and also abundantly in fish culture ponds in South India. The clam shrimps rarely occur in bigger waterbodies and flowing water bodies with only a few exceptions like the genera *Cyclestheria* and *Lynceus*.

Some of the conchostracans are widely distributed and known to occur both in temperate and tropical regions. They are however, not known from the Antarctica region. The genera such as *Leptestheria, Leptestheriella, Eocyzicus, Caenestheria, Caenestheriella,* are predominantly distributed in tropical regions.

The conchostracan, *Cyclestheria hislopi* appear in the gut contents of carnivorus fish. As such, they form food for them. At the outlets of the fish ponds, the appearance of the conchostracans in abundance may form a menace to the fish farmers.

Historical Resumé

There are about 200 species of conchostracans known all over the world (Belk, 1982). These species can be categorised into five families, *viz.*, Lynceidae (Lynceus), Limnadiidae (*Eulimnadia, Imnadia, Limnadia, Limnadiopsis, Limnadiopsium,* and *Metalimnadia*), Cyclestheriidae (*Cyclestheria*), Leptestheriidae (*Eoleptestheria, Leptestheria, Leptestheriella, Sewellestheria*) and Cyzicidae (*Caenestheria, Caenestheriella, Cyzicus, Eocyzicus*). Most of the species are described based on intraspecific variations. Species level taxonomy in Conhostraca is in need of clarification (Belk, 1982).

Studies from Different Environs

There are about 33 species of conchostracans known from India. These species belong to nine genera; *viz. Cyclestheria* (1), *Lynceus* (2), *Eulimnadia* (5), *Leptestheria* (5), *Leptestheriella* (5), *Sewellestheria* (1), *Caenestheria* (3), *Caenestheriella* (5), and *Eocyzicus* (6). Baird (1849, 1859, 1860) recorded five species viz., *Estheria polita, Caenestheriella boysi, Caenestheriella similis, Cyclestheria hislopi* (from Nagpur), and *Eulimnadia compressa* from several places in India. Sars (1900) recorded *Cyclestheria hislopi, Eulimnadia gibba, E. similis, Leptestheriella nobilis* and *L. hendersoni* from India. *Caenestheriella indica* is reported from Mandapam by Gurney (1906). He also reported *Lynceus brachyura* (O. F. Muller) and *Estheria davidi* Simon from Indian subcontinent. In his monograph on the World Conchostraca, Daday (1913, 15, 23 & 26) redescribed several species recorded from India and added two more species : *Caenestheriella annandalei* and *Leptestheriella sarsi* to the then existing list. Gurney (1930) recorded a species, *Lynceus dendiculatus* from South India. Bond (1934), in his detailed report on the phyllopod fauna of the Indian empire, recorded *Eulimnadia margaretae, Eocygicus hutchinsoni* and *Eocyzicus deterrana.* Karande and Inamdar (1960) recorded *Leptestheriella gigas* and subsequently they (1965) reported an unidentified *Eocyzicus* sp. from Panchagani, Bombay. Tiwari (1959 & 66) recorded *Leptestheria jaisalmerensis, Eocyzicus pellucidus, Caenestheria misrai, Caenestheriella roonwali, Leptestheria biswasi* and *Sewellestheria sambharensis* from North India. Nayar (1965) described

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Eulimnadia ovata and *Leptestheria longispina* and Nayar and Nair (1968) recorded *Eulimnadia michaeli* and *Leptestheriella maduraensis* from South India. Royan and Alfred (1971) described *Lynceus serratus* from Madurai region. Subsequently, Royan and Sumitra (1971) reported *Eocyzicus plumosus* from Madurai, South India. Das and Akhtar (1971) described *Eocyzicus wulari* from Kashmir. Radhakrishna and Durga Prasad (1976) reported *Eulimnadia gunturensis* from Guntur, South India. Durga Prasad (Thesis unpubl., 1981) recorded *Leptestheriella nobilis*, *Caenestheriella indica*, and *Cyclestheria hislopi* from Guntur district and its environs. Recently, Battish (1981) recorded *Lynceus vasishti*, *Leptestheria* sp. indet., *Eulimnadia ovata inversa*, *Eulimnadia* sp. indet., *Caenestheriella ludhianata* and *Eocyzicus dhilloni* from Punjab. Durga Prasad (1982) redescribed *Caenestheriella indica* collected from various localities in India.

Curiously many Indian conchostracans described by the earlier authors are based on very stray collections. Further, some species were erected on the basis of characters which may vary with age. The species, *Lynceus serrata* (Royan & Alfred, 1971) is described without consulting the descriptions of the closely allied nominal species *Lynceus denticulatus* (Gurney, 1930). Hence, the description of *L. serrata* appears to be more or less identical to *denticulatus*. Further, for several conchostracan species, the type material is not easily available. Similarly, the type locality is not mentioned in the descriptions of some conchostracans. These points make it difficult to study the Indian conchostracans. Hence, a serious attention has to be paid by the future workers to these points while studying the conchostracan taxonomy.

Expertise

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CLADOCERA

Introduction

The Cladocera, commonly termed as the 'Water Fleas,' are small, mostly microscopic animals and their body size generally ranges between 0.2 mm to 3.0 mm. They comprise one of the primitive group of lower Crustacea and represent an order of the sub-class Branchiopoda to which the general name of Entomostraca was formerly applied. The other orders included in this sub-class are the Anostraca, Notostraca and Conchostraca and these are often grouped as Phyllopoda. Among these, the cladocerans are more nearly related to the bivalved Conchostraca. However, their relationship with other groups of the microcrustaceans i.e., Copepoda, Ostracoda and Cirripedia is somewhat remote.

Cladocera are characterised by their two-branched antennae which function as the main swimming organs. The members of this group exhibit considerable variations in their general structural plan and behaviour. There is no single genus so generalised as to serve typical of this order although a broader information about their morphological details is provided by the genus *Daphnia*. In view of notable structural differences, the cladocerans are often grouped, by some authors, into two contrasting subdivisions i.e., the Calyptomera and Gymnomera. In the former, the body and limbs (thoracic legs) are enclosed in a bivalved carapace while the head projects; these primarily feed on microscopic algae and fine detritus either by filtering the water or by rasping the surface of plants etc. On the contrary, in all the Gymnomera only brood sac is covered by carapace; these are predacious and feed on other entomostraceous crustaceans and rotifers.

These organisms exhibit an interesting life cycle. Natural cladoceran populations are mostly predominated by occurrence of parthenogenetic females or amictic females. Individual brood-size reflects considerable variations in different families and embryogenesis is accomplished within brood-sac of the primarous females. Sexual or mictic females are noticed only during certain parts of the year and often coincide with appearance of the males. The males are known for many species; these are generally smaller than females and can be differentiated by their antennules, shape of postabdomen and modified first leg. Sexual fertilization results in the production of mictic eggs which are covered over by thick chitinous cases or ephippia. These are also called 'resting eggs' as they normally undergo a period of dormancy before hatching into juveniles.

The members of this group are primarily found in almost all sorts of freshwater ecosystems while species of only three genera i.e., *Podon, Evadne* and *Penilia* are known to be truly marine. Lentic environments harbour wider diversity and abundance of the cladocerans than the lotic biotopes. However, the significance of their occurrence and associations in streams is recently emphasized by Vila (1989). A large number of species particularly belonging to the families Macrothricidae and Chydoridae inhabit littoral weedy margins of lakes and ponds. A few taxa (*Alona quadrangularis* and *Drepanothrix*) live near the mud, although not specially adapted to this mode of life. The genera *Ilyocryptus* and *Monospilus* are structurally adjusted to the benthic zone; these forms may also swim but more often scramble on the bottom pulling with their antennae and pushing with the postabdomen. The species of *Moina* are commonly found in muddy pools though not exclusively confined to these habitats and some species of this genujs are reported to occur in saline lakes. *Dephnia* species are invariably noticed in ephemeral pools, small ponds and lakes. Limnetic cladoceran communities of inland lakes are generally comprised of species of *Daphnia, Diaphanosoma, Ceriodaphnia, Bosmina* and *Moina. Chydorus sphaericus* is commonly encountered in planktonic as well as littoral samples. Certain cladocerans i.e., *Sida crystallina* and

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Ophryoxus gracilis exhibit intermediate character between the littoral and limnetic forms. Planktonic taxa of this group are usually transparent and nearly colourless while those found in the ponds, ditches or in the weedy margins of larger water bodies are often coloured yellowish, brownish or reddish. In addition, the members of this order are known to inhabit subterranean ground waters, dampened mosses and even the wet tree trunks covered by the Bryophytes.

The studies on taxonomy and distribution of these organisms have drawn notable attention since they were first described in the 18th century. Even though, several species reflect cosmopolitan distribution, one of the current problems in this group is to establish their equivalence and to ascertain the occurrence of such cognate species reported from distant geographical localities often transgressing continents. Attempts made to sort out equivalence to non-equivalence of species reported from different parts of the world led to a strong debate for rethinking on 'cosmopolitan' distribution of various taxa and their biogeographical significance. Investigations on ecology and production of these microcrustaceans draw attention in light of changes in their community structure coupled with seasonal and long-term environmental changes, vertical distributional patterns, phenotypic changes associated with cyclomorphosis and effect of predation, prey-avoidance mechanisms, microaggregations, species associations and interesting life cycle strategies involving alternation of parthenogenesis and gamogenesis and production and hatching of resting eggs.

Importance

The cladocerans form an integral link in an aquatic food-chain. They contribute significantly to biological productivity and energy flow in aquatic ecosystems partly because of their rapid turnover rates, metabolism and capability to build up substantial populations within short time-intervals and partly because a large number of species (filter-feeders) are dependent on detritus and autotrophic producers. They invariably comprise an important fraction of Zooplankton in lentic environments and coastal waters. Their frequent abundance in the littoral microinvertebrate communities in lakes and ponds imparts them greater ecological importance. The significance of these organisms as food for both fry and adult fish was first indicated by Forbes (1883) and since then, this role has been emphasized by innumerable aquatic biologists. Analysis of gut contents of commercially important and culturable species of fishes has indicated their contribution upto 90-95% by volume and this lead to their intensive culture as supplementary food in various aquaculture practices.

Various species of the cladocerans are regarded as valuable bio-indicators of water quality. These organisms have also been increasingly used in environmental toxicological studies and bioassay experiments. In addition, they have been utilised as experimental models in ecological, ecophysiological, embryological and population genetics investigations. The Cladocera in general and members of the family Chydoridae in particular are well known to be 'guide-forms' in establishing the trophic and developmental history of ancient lakes and reservoirs especially in the Quarternary epoch as their exoskeletal remains are well preserved in the sediments. In such endeavoures, the knowledge of composition and distribution of extant species is useful to resurrect palaeolimnological conditions.

Classification

Various schemes depicting classification and relationships of Cladocera were proposed earlier by Sars (1865), Gerstaecker (1866), Calman (1909) and Eriksson (1934). these were briefly reviewed by Brooks (1959) who recognised only eight families, to which three more families have been added. These are, Sididae Baird, 1850; Daphniidae Straus, 1820; Moinidae Goulden, 1968; Macrothricidae Norman and Brady, 1867; Chydoridae Stebbing, 1902; Bosminidae Sars, 1865; Polyphemidae Baird, 1845; Leptodoridae Lilljeborg, 1861; Podonidae Mordukhai-Boltovskoi, 1968; Holopedidae Sars, 1865; Cercopagidae Mordukhai-Boltovskoi, 1968.

Historical Resumé

The cladocerans were studied and described by amateur and professional biologists from different continents of the world since the 18th century. However, studies on these microcrustaceans from India date back to the later half of the 19th century and various works relating to taxonomy distribution, ecology and biology from this country are detailed.

i) Pre-1900

This period merely marked the beginning of faunistic study on freshwater Cladocera. Baird (1860) dealt with the description of *Daphnia newporti* based on the material collected by Rev. Hislop from Nagpur city in Maharashtra State.

ii) 1901-1947

During this pre-independence period, Gurney (1906, 1907) reported 22 species on the basis of samples collected by Dr. Annandale from Calcutta and its environs (deposited in the Indian Museum holdings) and also from Lower Bengal and Chakradharpur in Chotanagpur region of Bihar State. Following this, Daday (1911) described one new species from Bangalore from the material sent by Dr. Annandale. However, first study on this group in Zoological Survey of India was undertaken by Dr. R.B.S. Sewell (former Director, ZSI) in 1934 who reported eight species of cladocerans in his publication on 'The Fauna of Salt Lakes, Calcutta' Subsequently, Sewell (1935) gave an account of eleven species from the Indian Museum tank, Calcutta. Important earlier taxonomic information resulted from the collections by the Yale North India Expedition, from various localities in Punjab (parts now in Pakistan), Ladakh, Kashmir and Nilgiri Hills in south India. This material was examined by Brehm (1936) and Brehm and Worterek (1937), who dealt with 35 species and two unidentified species.

As mentioned above, the contributions during this period were relatively few and primarily referred to taxonomy of freshwater cladocerans. Even the study from brackish ecosystem of the Salt Lakes (Sewell, 1934) resulted in taxa which usually occurred in freshwater environs.

iii) 1948-1990

Earlier phase of this period i.e., from 1948-1970 reflected only marginal increase in taxonomic contributions which originated from widely scattered localities. Brehm (1950) examined collections from Naga Hills (Nagaland), Bihar, Simla Hills (Himachal Pradesh), Madhya Pradesh and West Bengal and reported only nine cladoceran species. In another paper, Brehm (1952) described a new species of the genus *Diaphanosoma* from Bombay. Brehm (1953), subsequently, presented an account of 23 species based on his widespread samples from Nepal, Sikkim, West Bengal, Maharashtra, Andhra Pradesh, Uttar Pradesh, Karnataka, Tamil Nadu and Pondicherry. He also dealt with two species of marine cladocerans i.e., *Evadne tergestina* and *Penilia avirostris* from Cochin and Malabar coasts. In addition, Brehm (1963) examined two species from the river Yamuna at Delhi (material sent by Dr. V. Ganapati).

Biswas (1964a, 1966) described one new species each of the genus *Latona* and *Chydorus* respectively from Rajasthan. Further, Biswas (1964b) studied ZSI collections (obtained between 1907-1916) from Simla Hills and samples collected by the Swiss Entomological Expedition (1916) from NEFA (Kameng Division). Petkovski (1966) examined Dr. Ganapati's collections from Ajwa reservoir and Nimeta Water works, Baroda city (Gujarat State) and documented eleven species including the description of *Indialona ganapati*. This was followed by the contribution to the cladoceran fauna of Kashmir by Das and Akhtar (1970).

Information about the occurrence and ecology of cladocerans from the east coast was presented by Prasad (1954), Muthu (1956), Krishnamurthy (1967) and Rajagopal (1967) while similar studies from the western coast were undertaken by George (1958), Mukundan (1967) and Alfred

(1970). These contributions referred to only two marine species as documented earlier by Brehm (1953).

Ecological investigations of freshwater ecosystem were initiated after 1960. Michael (1962) made observations on seasonal events in a natural population of *Ceriodaphnia cornuta* in a fish-pond at Barrackpore (West Bengal). Krishnamurthy (1967) and Parabrahman *et al.*, (1967) dealt with population ecology of *Moina dubia* from sewage oxidation and stabilization ponds. Vijayaragavan (1967) commented on some ecological relationships of cladocerans while Vijayaragavan (1970) analysed seasonal events in a natural population of *Daphnia carinata* in relation to ecological factors. In addition, studies on comparative ecology of fish-ponds as Delhi (George, 1966), zooplankton ecology in a fish-pond at Barrackpore, West Bengal (Michael, 1969), limnology of Sukhna Lake, Chandigarh (Vasisht, 1968) and observations on plankton ecology in fish-ponds at Chandigarh (Vasisht and Dhir, 1970) contributed information to cladoceran ecology from freshwater biotopes.

Systematic contributions during 1971-1980 nearly doubled than the preceding decade and resulted in important information relating to species composition of freshwater Cladocera in this country. Biswas (1971) examined 41 species from Rajasthan. The contemporary publication of Nayar (1971) resulted in only 18 species from this state. Michael (1973) gave an account of species occurring in and around Madurai (Tamil Nadu). Yousuf and Qadir (1975) dealt with seven species from Malpur Sar and Qadir and Yousuf (1977) recorded four species from Beehama spring in the Kashmir valley. Referring to North-Eastern India, Patil (1976) gave a list of 17 species from Meghalaya and Manipur while Biswas (1980) studied 24 species from the states of Assam and Meghalaya. The cladocerans found in water bodies in and around Bhagalpur (Bihar) were studied by Nasar (1977). Sharma (1978) listed 34 species from lower Bengal region of West Bengal. Michael and Hann (1979) while dealing with resurrection of *Chydorus reticulatus* and its relationship with *C. ventricosus* referred to collections of Prof. D.G. Frey (Indiana University, USA) from Trivandrum (Kerala) and commented on the Indian synonyms of this chydorid. Rane and Harshey (1979) reported *Latonopsis fasciculata* from Madhya Pradesh. In addition, Michael and Sharma (1980) dealt with the first report of *Dunhevedia serrata* from India based on Prof. Frey's material from Madras and Ooty lake in Tamil Nadu.

Taxonomic information from backwaters was restricted to the description of *Alona taraporevalae* by Shirgur and Naik (1977) from Back Bay opposite Taraporevala Aquarium, Bombay. However, a number of investigations dealt with ecology of marine cladocerans. Similar contributions from the east coast were made by Kaliyamurthy (1975), Santhanam *et al.*, (1975) and Sundarraj and Krishnamurthy (1975); the studies from the west coast were those of Dellacroce and Venugopal (1972), Nair and Trainer (1972), Menon *et al.*, (1972), Pillai and Pillai (1975) and Goswami *et al.*, (1977).

A good number of studies related to ecology of freshwater cladocerans during 1971-1980. Mitra and Thakurtha (1973) conducted toxicological experiments involving the control of *Daphnia* sp. by copper sulphate treatment. Santharam *et al.*, (1977) studied micro aggregation of *Daphnia carinata* under laboratory conditions and commented on important causative on polymorphism of *Daphnia carinata* in a pond near Madurai (Tamil Nadu). Qadri and Yousuf (1968) analysed the influence of physico-chemical factors on the seasonality of cladocerans in Lake Manasbal (Kashmir). Additional synecological information on this group resulted from various general limnological investigations from the states of Orissa (Saha *et. al.*, 1971), West Bengal (Moitra and Mukherjee, 1972; Jana, 1973, 1976, 1979; Mandal, 1976, 1980), Bihar (Nasar and Dutta-Munshi, 1974; Nasar, 1977), Haryana (Vasisht and Sharma, 1975), Madhya Pradesh (Mathew, 1977), Karnataka (Prasadam, 1977), Tamil Nadu (Prabhavathy and Sreenivasan, 1977) and Kashmir (Zutshi *et al.*, 1980).

The period between 1971-1980 included only nine publications relating to various aspects of biology of freshwater cladocerans i.e., longevity, instar durations, egg production, growth and embryonic development etc. Majority of these studies dealt with tropical species from Tamil Nadu.

The mentioned aspects were examined in *Dephnia carinata* (Navaneethakrishnan and Michael, 1971), *Simocephalus acutirostratus* (Murugan and Sivaramakrishnan, 1973), *Moina micrura* (Murugan, 1975a), *Ceriodaphnia cornuta* (Murugan, 1975b) and *Scapholeberis kingi* (Murugan and Sivaramakrishnan, 1976). In addition, Murugan (1977) deal with hatchability of parthenogenetic eggs of *Simpcephalus acutirostratus* cultured in artificial media. In-virto development of *Daphnia carinata* was examined by Murugan and Venkataraman (1977) while Job and Venkataraman (1989) studied the effect of temperature on development, growth and egg production in this species. Besides, observations on the biology of a subtopical population of the male of *Daphnia lumholtzi* were made by Das *et al.*, (1980) while only two publications i.e., Bhannot and Vass (1976) and Nandy *et al.*, (1977) referred to mass culture of *Daphnia carinata* and *D. lumholtzi* respectively during this period.

The last decade (1981-1990) covered under this resume reflected significant increase in systematic contributions; the number of publications increased nearly four times than the preceding decade. In the beginning of this period, Battish (1981) dealt with species of the families Chydoridae and Macrothricidae from Panjab State. First account of head pore morphology of 20 chydorid species from West Bengal was provided by Sharma and Tiwari (1981). The works of Patil and Gouder (1982, 1988) and Raghunathan (1988b) dealt with the fauna of Karnataka. Taxonomic information from Tamil Nadu was supplemented by the studies undertaken by Raghunathan (1983), Venkataraman and Krishnamurthy (1984a, 1984b, 1984c, 1984d) and Judec (1977) while a couple of other publications from this state (Venkataraman and Krishnamurthy, 1989; Venkataraman, 1990a, 1990b) related to ultrastructure (SEM studies) of various taxa from this region. Ohrer systematic studies referred to the states of Madhya Pradesh (Saini and Singh, 1984; Rane, 1983a, 83b, 83c, 83d, 84a, 84b, 84c, 84d, 85a, 85b, 85c, 86a, 86b, 87; Rane and Jafri, 1990), Kashmir (Yousuf *et. al.*, 1983), Andhra Pradesh (Durga Pradesh *et. al.*, 1985), West Bengal (Sharma and Sharma, 1985), Bihar (Ahmed and Singh, 1988) and Kerala (Raghunathan, 1989). Sharma and Sharma (1990) commented on taxonomic status and distribution of 12 new species and one new subspecies, described earlier by rane in a series of papers during 1983-1987, from Central India. The redescription of the chydorid *Alona taraporevalae* was provided by Sharma and Michael (1983). Other important contributions during this period referred to latitudinal distribution of Cladocera in the Indian subcontinent (Fernando and Kanduru, 1984); review of taxonomic studies on Indian freshwater cladocera and remarks on their biogeography (Sharma and Michael, 1987) and synopsis of different studies on Indian Cladocera (Raghunathan, 1990). Recently, a monograph on the cladoceran taxa documented from this country was published by Michael and Sharma (1988) under Fauna of India Series. In addition, three extra-Indian publications also included samples from this country was published by Michael and Sharma (1988) under Fauna of India Series. In addition, three extra-Indian publications also included samples from this country. Of these, Rajapaksa and Fernando (1986) while dealing with tropical species of the genus *Kurzia* commented on specimens from Calcutta (West Bengal) and Cochin. A note on the distribution of *Alona macronyx* by Rajapaksa and Fernando (1987a) dealt with the material from Jabalpur (Madhya Pradesh) while Rajapaksa and Fernando (1987b) examined specimens of *Notalona globulosa* (= *Indialona globulosa*) from some localities in Orissa, Madhya Pradesh and Tamil Nadu.

A fewer studies dealt with ecology of brackishwater or marine cladocerans during tis decade. Raghunathan and Srinivasan (1983a) analysed cladocerans of the plankton community in ennore estuary, Madras and also made observations (Raghunathan and Srinivasan , 1983b) on Zooplankton dynamics and hydrographic features in this estuarine system. Balakrishnan Nair *et. al.*, (1984) studied their ecology off Kadinamkulum backwaters while Dutta *ét al.*, (1984) studied their ecology off Kadinamkulum backwaters while Dutta *et al.*, (1986) made observations on effect of some physico-chemical parameter on the abundance of cladocerans in a brackish impoundment in West Bengal.

During 1981-1990, relatively more number of papers have dealt with ecology of these organisms from freshwater environs. Yousuf and Qadri (1981a, 81b, 83) made synecological observations in Lake Manasbal; Yousuf *et. al.*, (1983) studied composition and associations of crustacean communities of 17 water bodies in the Kashmir valley and Yousuf *et al.*, (1984) analysed summer and winter cladoceran communities of Lake Anchar, Kashmir. Venkataraman (1981) studied seasonal variations in natural population of *Daphnia carinata* in relation to physico-chemical and biological factors in a tropical temporary pond at Madurai.

Investigations on population dynamics, biology and production ecology of the chydorid, *Chydorus sphaericus* were made by Khan (1983a). Khangarot and Battish (1984) made observations on acute toxicity of copper to *Daphnia lumholtzi*. Sharma and Dutta Gupta (1984) commented on the effect of water temperature on cyclomorphosis in *Daphnia lumholtzi*. Energy budget of *Simpcephalus vetulus* was worked out by Sharma and Pant (1984) while Sharma and Pant (1985a) referred to seasonal variations in species composition of Zooplankton (including 15 species of Cladocera) in two Kumaun Himalayan lakes.. In addition, Sharma and Pant (1985b) estimated oxygen consumption in *Simocephalus vetulus* in relation to size, density and temperature; seasonal and population variations in this daphniid were studied separately by Sharma and Pant (1985c). Manimegalai *et. al.*, (1986) made observations on helmet development in *Daphnia cephalata* in relation to predation under laboratory conditions. Venkataraman and Krishnaswamy (1986) made laboratory studies on *Anisops bouvieri* predation and advantages of cephalic expansion in *Daphnia cephalata* and impact of predation on *D. similis*. Population dynamics of *Moina micrura* and *Ceriodaphnia cornuta* was studied by Murugan (1989, 1990) respectively. Additional ecological information relating to this group was provided in various routine limnological investigations from the states of Jammu and Kashmir (Vass and Zutshi, 1983; Balkhi *et. al.*, 1987; Vass *et. al.*, 1988, 1989), Maharashtra (Rao *et. al.*, 1981), Karnataka (Patil and Gouder, 1985), Uttar Pradesh (Khan *et al.*, 1986) and Tripura (Bhattacharya and Saha, 1986, 1990).

So far only two publications from India referred to physiological studies in this group. Tonapi *et al.*, (1984) made preliminary observations on cardiophysiolog of the moinid, *Moinodaphnia macleayi*. In addition, Tonapi and Verghese (1987) studied cardio-physiological responses of some cladocerans to three common pollutants.

The studies on cladoceran biology registered considerable impetus during 1981-1990. Different observations on various biological parameters related to *Daphnia carinata* (Venkataraman, 1981), *Leydigia acanthocercoides* (Murugan and Job, 1982), *Daphnia lumholtzi* (Kanaujia, 1983; Sharma *et. al.*, 1984b), *Ceriodaphnia cornuta* (Khan, 1983a), *Diaphonosoma excisum* (Jana and Pal, 1984a), *Moina micrura* (Jana and Pal, 1985c), *Simocephalus vetulus* (Sharma and Pant, 1985b; Kanaujia, 1987), *Diaphanosoma senegal* (Venkataraman and Krishnaswamy, 1985), *Daphnia similis* (Venkataraman and Krishnaswamy, 1986; Venkataraman *et. al.*, 1986), *Daphnia cephalata* (Venkataraman and Krishmaswamy, 1986; Murugan and Moorthy, 1988); *Daphnia pulex* (Vass and Raina, 1988), *Simocephalus exspinosus* (Sharma and Sharma, 1989) and *Moina weismanni* (Venkataraman, 1990c). Hatchability of parthenogenetic eggs of *Daphnia lumholtzi* in artificial media was examined by Sharma and Sharma (1982) while Sharma *et al.*, (1984a) studied in-vitro development in this daphniid. Dutta Gupta and Maibam (1983) dealt with reproduction of *Daphnia magna* in relation to influence of density and different concentrations of culture medium (Baker's yeast). Jana and Pal (1983, 1984b,1985a) made observations on effect of inoculum densities on population growth of *Daphnia carinata*, *Diaphanosoma excisum* and *Moina micrura* respectively while Jana and Pal (1985b) studied relative growth and egg production in *Daphnia carinata* under different culture media.

Studies from Different Environs

The studies on Indian cladocera commenced in 1860 but remained neglected till the end of the last century. Subsequent progress till the first half of this century culminated in few taxonomic contributions. An increased attention, however, was focussed in the following decades while considerable proliferation and intensification of research activities was noticed between 1971-1990.

The literature on different aspects so far studied from India is scattered over about 175 references as outlined in the historical resume. Although the present review attempted to incorporate all the relevant information, non-inclusion of unpublished works or else some general ecological publications providing very little information on this group was unaviodable. Even taking all such contributions into a broader consideratiion, only about 190 references could be compiled.

The cladoceran studies in this country began with researches on freshwater representatives and also subsequently received more attention than their counterparts from other aquatic ecosystems. A majority of the Indian publications, therefore, referred to the observations on various aspects of freshwater taxa from the mainland.

In the beginning, most studies on these microcrustaceans were faunistically oriented and this trend even continued to predominate till the more recent decades. As a result, about 75 references dealt with their sytematics from freshwater biotopes and these involved widespread collections ranging from distant temperate localities from the northern boundaries of this country to those from tropical environs of the southern region. Although most investigations were based on scattered collections obtained by individual workers, some institutional surveys were undertaken by the Swiss Entomological Expedition (1916) from NEFA (Kameng division); the Yale North India Expedition (1932) from Ladakh, Kashmir, Punjab and Nilgiri Hills, and by Zoological Survey of India from Simla Hills (1907-1916) and Rajasthan (1957-1960) respectively. The number of publications from different parts of India, however, did not correspond with overall taxonomic information available because a notable fraction of these papers exclusively dealt with new taxa (most of them already synonymised) or new records of limited local distributional interest. Besides, frequent atempts by various workers from this country to pigeon-hole their speciemens into already known taxa without recourse to the study of original descriptions or the reference collections aggrvated the magnitude of nomenclatural anomalies in our literature. Various existing ambiguties (till 1980) were, to a larger extent, resolved in a 'Fauna' volume on Indian Cladocera (Michael and Sharma, 1988) while a number of doubtful reports requiring gurther confirmation were treated as 'Incertae Sedis' This monograph significantly augmented our knowledge regarding composition and distribution of freshwater cladocerans and provided suitable illustrations, keys and systematic notes on the examined taxa to serve as ready reference for future workers. The continued indiscriminate descriptions of several new taxa from central India by Rane (1983-1987) aroused serious concern and their status was examined recently by Sharma and Sharma (1990).

Some general comments on the current status of Indian freshwater Cladocera (Sharma and Michael, 1987; Michael and Sharma, 1988; Raghunathan, 1990) emphasized lacunae relating to State-wise or regional faunistic surveys. An unbalanced picture of the number of species so far documented from various parts of this country (Map) conclusively corraborated with the above generalisation. The cladoceran faunas of only six States i.e., Jammu and Kashmir, Rajasthan, West Bengal, Andhra Pradesh and Karnataka were apparently well explored. The lower number of species reported from many other areas was attributed to insufficient exploration and underline the need for the examination of additional collections in general and the detailed analysis of the littoral communities in particular. The species inventories so far compiled from different regions of India required a critical review in light of questionable status of various reports. Further, most systematic contributions from the mainland were based on the collections from lentic freshwater habitats, only a couple of papers casually referred to the taxa from lotic environs while no information was available on species inhabiting subterranean waters or on those occurring in association with different moss types. The general faunistic nature of many earlier studies and lack of details of the ecosystems sampled or their macrophytic associations (if any) was the main handicap to present a synthesis of cladoceran diversity in various habitats. Comparative morphotaxonomic studies on populations from different parts of this country were altogether lacking. The SEM studies comprised a valuable adjunct to classical cladoceran taxonomy but such obeservations on the Indian taxa were confined to some recent publications by Venkataraman and Krishnaswamy (1989) and Venkataraman (1990a, 1990b). Although earlier publications routinely commented on the occurrence of reported species in different states, only a few papers (Fernando and Kanduru, 1984; Sharma and Michael, 1987) analysed biogergraphical patterns in relation to the latitudinal distribution of freshwater cladocera from this country. In addition, studies on karyotaxonomy and those involving application of biochemical methods to seggregate sibling species complexes presented a challenging task for future workers on this group.

The brackishwater ecosystems remained very poorly surveyed faunistically except for few reports by Sewell (1934), Shirgur and Naik (1977) and Sharma and Michael (1983). The information on the cladoceran ecology from these environs was confined to the observations in the Hughli–Malta Estuary (Shetty *et al.*, 1961), Ennore estuary (Raghunathan and Srinivasan, 1983b) and in a brackishwater impoundment in West Bengal (Dutta *et al.*, 1986). In addition, only one paper (Shirgur and Naik, *loc. cit.*) referred to the biology of *Alona taraporevalae* which was described by these authors from a Back bay at Bombay.

Referring to marine cladocerans, the sole taxonomic report was that of Brehm (1953) although various ecological investigations undertaken at different places along the eastern and western coasts reported on the occurrence and seasonal abundance of marine taxa. However, so far only three species of these organisms i.e., *Penilia avirostris, Evadne tergestina* and *Podon* sp. were documented from the Indian coastal waters. Even though, the cladocerans were reported to comprise only a sub–ordinate group of marine Zooplanktonic communities (Goswami *et al.*, 1977), many workers from this country noticed frequent swarms of the former two species from the Gulf of Mannar, Madras coast, Porto Novo waters, Cochin backwaters and Kadinamkulam backwaters. The significance of these swarms in relation to the coastal pelagic fishery was indicated by Mukundan (1969) and Alfred (1970).The distant insular freshwater and marine ecosystems of the Andaman and Nicobar islands and Lakshadweep Archipelago still remained unexplored faunistically and ecologically with reference to their inhabitant cladoceran communties. Some collections from freshwater biotopes of the former group of islands are currently being studied at Shillong while studies in these habitats are being initiated at Port Blair regional station of the Zoological Survey of India.

The investigations on the ecology of freshwater cladocerans deserved special mention as they have drawn a notable attention. The first refernce on seasonal occurrence of these organisms in a freshwater tank was made by Sewell (1953) but serious studies on this aspect were, however, initiated by Michael (1962, 1969) and George (1966). A majority of these contributions resulted during the last two decades covered under this review. A number of limnological investigation from various parts of this country invariable commented on the seasonal abundance and succession of the cladocerans as an important dominant or subdominant group. On other hand, ecological studies exclusively relating to these organisms were limited to about 25 references. Various earlier investigations largely dealt with planktonic cladoceran communities while littoral taxa remained primarily ignored. Amongst the scattered observations undertaken from different states of India,a good number of references were from the fish–ponds in West Bengal and some lakes in Kashmir valley while only a few publications related to cladoceran ecology from the lotic ecosystems. The reviewed literature indicated still insufficient information on synecological studies in general and also lacunae on particular aspects such as long–term observations on changes in species composition, vertical distributional patterns, population dynamics, growth and production, cyclomorphosis, energy budget, toxicological experiments and community structure in relation to eutrophication, effects of fertilization and impact of invertebrate and vertbrate predation on species composition.

A notable number of publications (about 35 papers) dealt with different biological aspects of freshwater representatives. These observations were initiated by Michael (1962) but all other contributions resulted during the last two decades (1971–1990). A majority of these studies included laboratory observations on various life history parameters i.e., longevity, instar durations, growth, fecundity and embryonic development etc. The mentioned aspects have been far examined in ten species of the family Daphniidae, two species each of the families Sididae and Moinidae and one species of the family Chydoridae. So far only two publications referred to the biology of the males of *Daphnia lumholtzi* and *Moina weismanni.* The observations on the hatchability of parthenogenetic eggs cultured in artificial media were made in *Simocephalus acutirostratus* and *Daphnia lumholtzi.* A couple of studies, during the last decade, dealt with the effect of inoculum densities on population growth and reproductive potential and the influence of different culture media on general life-history parameters. The experiments on mass culture of *Daphnia carinata* and *D. lumholtzi* were firstly attempted by Bhanot and Vass (1976) and Nandy *et. al.*, (1977) while culture possibility of *Daphnia pulex* in various culture media was recently explored by Vass and Raina (1988).

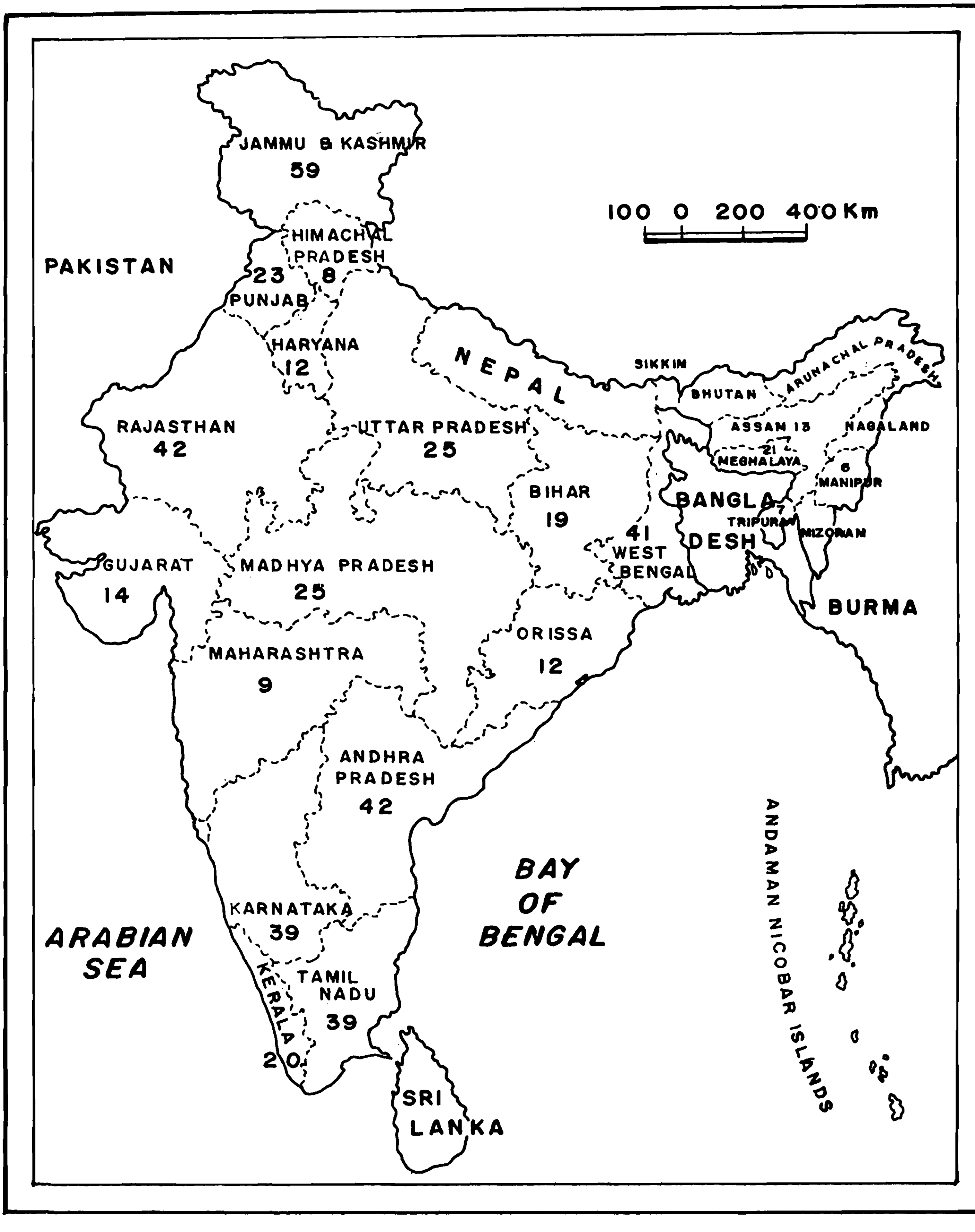
Estimation of Taxa

Out of eleven recognised families of this order, only nine families were so far reported from India. In analysing the composition and origin of the cladoceran fauna of this country, it is important to note that all the three phylogenetic stems of Cladocera (vide Smirnov and Timms, 1983) i.e., the Ctenopoda, the Anomopoda and the Gymnomera were represented. Among the Ctenopoda, which separated from the main phylogenetic stem in the remote past, only the members of the family Sididae were documented while the Holarctic Holopedidae were notably absent from India. The Gymnomera belonged to only three of their total five families. Of these, the reported members of the Holarctic Leptodoridae and Polyphemidae wee confined to temperate environs of the northern latitudes in this country and the family Podonidae included some marine elements. Turning to the Anomopoda, all the known families (Macrothricidae - Chydoridae - Bosminidae - Moinidae - Daphniidae) were present in Indian inland waters. the first two families of this series were claimed to be most similar to their Conchostracan ancestors (Freyer, 1968, 1974) and these mainly comprised of littoral and benthic forms.

In a more general sense, the presence of the families Leptodoridae and Polyphemidae differentiated the cladoceran fauna of India from other South-Asian countries (Table 1) and the Australian continent (Table 2). On the other hand, absence of the Holopedidae imparted it a different status from the fauna of Asia, Europe, North America and South America (Table 2). The occurrence of various mentioned Holarctic families assigned an intermediate character to Indian Cladocera in relation to the faunas of the northern and southern continents. such an overlap might be attributed to the wide range of environmental conditions prevalent in this country.

Among various families of Cladocera, Smirnov (1971) differentiated four sub-families of the Chydoridae. However, Indian chydorid taxa belonged to only three sub-families i.e., Eurycercinae, Aloninae and Chydorinae. In addition, family Macrothricidae was represented by only two (i.e., Macrothricinae and Ilyocryptinae) of the four recognised sub-families (Smirnov, 1976).

All the known genera of he families Daphniidae (*Daphnia, Simocephalus, Scapholeberis, Ceriodaphnia*), Bosminidae (*Bosmina, Bosminopsis*), Moinidae (*Moina, Moinodaphnia*) and Leptodoridae (*Leptodora*) were represented in Indian inland waters. Polyphemidae included only one genus (*Polyphemus*) while the family Sididae is represented by six out of its seven genera. However, lower generic diversity was noticed in the families Macrothricidae and Chydoridae; the former was represented by only five of the known 17 genera and the chydorids belonged to 19 of the described 32 genera. In contrast to endemic genera of these two families in the Holarctic region and Australasia, *Indialona* was the sole endemic genus noticed in the Indian fauna. Of many widespread genera of the mactrothricids and the chydorids (vide Smirnov and Timms, 1983), only *Sida* and *Eurycercus* occurred in this country while some primitive genera were represented by *Eurycercus* and *Ilyocryptus*. Although in view of inadequate collections from various regions of India, it might be premature to comment on distributional limits of different genera but *Eurycercus, Leptodora, Polyphemus, Daphniopsis, Dadaya, Greptoleberis, Streblocerus, Indialona, Acroperus* and *Camptocersus* were reported (Fernando and Kanduru, 1984; Sharma and Michael, 1987) to exhibit restricted distribution.



Number of the Cladoceran species reported from various parts of India.

TABLE 1

Composition of the Cladoceran Faunas in Inland Waters in South Asian Countries

Families	India	Sri Lanka	Malaysia	Nepal	Philippines	Thailand	Indian Subcontinent
	Number of species in						
Sididae	8	4	6	2	5	7	12
Holopedidae	0	0	0	0	0	0	0
Daphniidae	23	8	6	10	6	9	27
Moinidae	6	2	3	1	3	3	10
Bosminidae	4	3	1	2	3	3	4
Macrothricidae	11	8	10	2	7	5	15
Chydoridae	55	33	38	22	31	19	61
Leptodoridae	1	0	0	0	0	0	1
Cercopagidae	0	0	0	0	0	0	0
Polyphemidae	1	0	0	0	0	0	1
Total no. of species	109	58	64	39	55	46	131
No. of Endemics	7(?)	1	?	–	2(?)	–	8(?)

Source of Data : Sri Lanka - Fernando (1980); Malaysia Smirnov and Timms (1983), Sharma and Michael (1987); Philippines Smirnov and Timms (1983); Thailand and Nepal Sharma and Michael (1987); Indian subcontinent Fernando and Kanduru (1983), Sharma and Michael (1987).

The cladoceran taxonomy was stated (Frey, 1987) to be expanding explosively beyond the horizons percieved or imagined a few years ago because of more recent discoveries of various sibling-species complexes and strong support to idea of non-cosmopolitanism of various taxa. Hence, an estimate of overall diversity in this group could merely be speculative although so far over 400 species of freshwater Cladocera were known to be described from different parts of the world. Information about the number of species documented by various workers from Indian inland waters varied marginally. Fernando and Kanduru (1984) examined 87 species from this country; Sharma and Michael (1987) and Michael and Sharma (1988) dealt with 93 and 87 species respectively; 97 valid species were recognised from the list given by Raghunathan (1990) while 109 species of freshwater cladocerans are compiled in this account. The list of Indian Cladocera (109 species) appeared to be reasonably complete and corresponded well with 107 species reported from Africa. The cladoceran fauna of India reflected more species and generic diversity than other countries in this subcontinent and neighbouring South Asian faunas (Table 1).

Chydoridae, Daphniidae and Macrothricidae, in the stated order, comprised significant fraction of Indian Cladocera. The number of documented species of the first two families was broadly comparable with faunas of various parts of the world while family macrothricidae exhibited less species diversity when compared particularly with Asia, Australia, North America and South America. Commenting on the distribution of *Daphnia*, an important genus of the Daphniidae, Fernando (1980) states that usually one or two species of this genus occurred in a country or region in the tropical belt and about 10 or more species in a temperate region. This generalisation appeared to be valid concerning the occurrence of limnetic *Daphnia* spp. in tropical parts of this country but an overall report of 10 species from India broadly corresponded with other reports from Asia and Australia.

The limnetic cladoceran communties in alkaline inland waters in this country were invariably comprised of species of *Daphnia, Ceriodaphnia, Moina* and Diaphanosoma. *Bosmina longirostris*, however, was the most important planktonic member of this group in slightly acidic or nearly neutral waters particularly in North-Eastern India. In tropical parts of this country, *Daphnia carinata, Cerioldaphnia cornuta, Moina micrura, Diaphanosoma sarsi* and *D. excisum* occurred widely and often formed quantitatively important component of planktonic Cladocera; these also represented eurytopic and tropicopolitan forms. The first three mentioned species were noticed to exhibit frequent swarms (microaggregations) in eutrophic water bodies in hot and arid zones of this country.

Based on presently available information on distribution of various species, the Indian freshwater Cladocera were comprrised of five groups in terms of their zoogeographical relationships. The first group included some cosmopolitan species.

The third group comprised Palaearctic, Holarctic or other temperate species which also occurred in some parts of India. The disjunct distribution of some of these cladocerans might be due to their dispersal by bipolar migratory birds. In addition, their present restricted occurrence could be a relict of a wider distributional range in the past that changed by long-term fluctuations in the climatic conditions particularly during the Pleistocene glaciation (Berg, 1947).

The fourth group included Gondwanaland forms which were almost exclusively found in the southern continents (including India and Sri Lanka). Out of 24 such elements listed by Smirnov and Timms (1983), sixteen species were represented in India. Among these, *Dadaya macrops* was known to be distributed slightly beyond the Gondwanaland continents. In addition, *Alona globulosa* and *Chydorus ventricosus* were other species of this category documented from India. however, they were so far reported from South America and South Africa but not from the Australian continent.

The fifth group included the endemics which were represented by *Indialona ganapati*, *Alona taraporevalae* and *Moina oryzae*. Besides, Battish (1981) described three new species from Punjab i.e., *Alona dhilloni*, *Camptocercus kapuri* and *Ilyocryptus bhardwaji* while *Leydigia ankammaraoi* was described (Durga Prasad *et. al.*, 1985) from Andhra Pradesh; the specimens of these species need to be re-examined to ascertain their taxonomic status. In addition, Rane (1983-87) dealt with the descriptions of 12 new species and one new subspecies from Madhya Pradesh in Central India and comments on their systematic validity were made recently by Sharma and Sharma (1990). The paucity of endemic taxa in the fauna of South Asian countries in general and the Indian Cladocera in particular was in notable contrast to the Asian fauna (24 endemic species) or that of various other areas of the world (Table 2).

Referring to overall composition, the cladoceran taxa occurring in inland waters of India appeared to be relatively more diversified than other studied South-Asian faunas. Further, the cladoceran fauna of this country included species belonging primarily to the mentioned first four groups in comparison to its neighbouring countries wherein the documented taxa were restricted to only first three categories.

Marine taxa so far known from different parts of the world included eitht species of *Penilia*, *Evadne* and *Podon* and a subspeices of he family Bosminidae and 35 species of the superfamily Polyphemoidea. However, our knowledge of truely marine cladocerans from Indian coastal waters was very poor and included only three species i.e., *Penilia avirostris* (Family : Sididae) and *Evadne tergestina* and *Podon* sp. (both belonging to family Podonidae).

Classified Treatment

The cladoceran taxa so far documented from India belonged to nine families. Of these, the members of eitht families i.e., Sididae, Dephniidae, Moinidae, Bosminidae, Macrothricidae, Chydoridae, Leptodoridae and Polyphemidae occurred in inland waters in this country. The sididae also included one marine species while other reported taxa of this category belonged to the family Podonidae.

Family Sididae

It was represented by nine species spread over six genera. *Penilia avirostris*, the sole marine element of this family, was often reported to exhibit swarms in various ecological studies from the eastern and western coasts of this country. Among other species, *Pseudosida bidentata* and *Latonopsis australis* registered widespread distribution in this subcontinent and *Sarsilatona* serricauda (= *Latonopsis fernandoi*) was reported only from Central India. The Holarctic and Neotropical *Sida crystallina* could be termed as a northern element. The genus *Diaphanosoma* included four planktonic species. Of these, *D. excisum* and *D. sarsi* occurred across the whole latitudinal range south of 32°N (Sharma and Michael, 1987). The distinct occurrence of *D. senegal* in different states of this country broadly indicated its wider distribution. Fernando and Kanduru (1984) regarded *D. brachyurum* to be a northern species but it was also reported from Madhya Pradesh and Karnataka.

Little was known about ecology of Indian representatives of this family except for some observations made by Yousuf and Qadri (1981a) and Qadri and Yolusuf (1983). Other published information related to life history parameters of *Diaphanosoma excisum* in different culture media (Jana and Pal, 1948a) while Jana and Pal (1984b) studied population growth and reproduction of *Diaphanosoma senegal* under laboratory conditions. Some comments on epizoic associations of certain rotifers (*Brachionus rubens* and *B. sessilis*) on *Diaphanosoma* spp. were made by this author (Sharma, 1979, 1983).

Family Daphniidae

The members of this family formed an important component of Indian Cladocera. It included 23 species and all known genera of the daphnids were represented in our inland waters. The genus *Daphnia* was comprised of *Daphnia* s. str., *Ctenodaphnia* and *Daphniopsis* and these were represented by four, six and one species respectively. Of these, *Daphniopsis tibetana* and all species of *Daphnia* s. str. were restricted to > 24°N (Fernando and Kanduru, 1984). On the other hand, species of *Ctenodaphnia* were distributed in the Indogangetic plains and southwards. *Daphnia carinata* and *D. lumholtzi* occurred widely in water bodies in peninsular India while *D. cephalata* and *D. projecta* appeared to be confined to the extreme southern parts of this country. The presence of far few species of the genus *Daphnia* in the equatorial zone of this continent as compared to its more northern regions was elucidated by Fernando (1980) and Fernando and Kanduru (1984). Interestingly, this generalisation could not be applied to this author's fairly extensive collections from North-Eastern India (unpublished report). The paucity of *Daphnia* spp. in this region, however, was in confirmity with their occurrence in the neighbouring South Asian countries. In light of these observations, the distribution of different species of this daphniid might be attributed to far complex factors rather than mere latitudinal considerations.

The genus *Ceriodaphnia* was represented by seven species of which only cosmotropical *C. cornuta* was widely distributed in India while *C. pulchella* comprised a northern element as it was confined to Kashmir and Ladakh. The other species exhibited disjunct occurrence in different states of this country. The paucity of limnetic *Ceriodaphnia* spp. in North-Eastern India was again in agreement with those of tohber South Asian frunas. *Simocephalus* and *Scapholeberis* were represented by five and two species respectively. *Simocephalus vetulus, S. exspinosus* and *Scapholeberis kingi* occurred widely; *Simocephalus latirostris* and *S. serrulatus* were documented from a number of states; *Scapholeberis mucronata* was reported only frorm Madhya Pradesh while *Simocephalus acutirostratus* occurred in Central India and southwards.

Different planktonic forms of *Daphnia* and *Ceriodaphania* invariably figured in various synecological or general limnological studies from this country and were reported to comprise quantitatively important component of cladoceran communities in lentic freshwater environs. *Dephnia carinata, D. lumholtzi* and *Ceriodaphnia cornuta* often exhibited swarms in eutrophic astatic water bodies in warmer parts of India. Some observations on autecology of *Daphnia carinata* were made by Vijayaragavan (1970), Santharam *et. al.*, (1977) and Venkataraman (1981) while Michael (1962) dealt with seasonal events in *Ceriodaphnia cornuta* and population dynamics of this daphniid was analysed by Muregan (1990). Sharma and Pant (1984, 1985b, 1985c) studied energy budget, oxygen consumption and seasonal and populational variations in *Simocephalus vetulus* respectively. A few toxicological observations on *Daphnia* spp. were undertaken by Mitra and Thakurtha (1973) and Khangaroot and Battish (1984). The studies relating to various aspects of cyclomorphosis in our species of this genus were those by O'Brien and Vinyard (1978), Sharma and Dutta Gupta (1984), Venkataraman and Krishnaswamy (1986) and Manimegalia *et. al.*, (1986). In addition, comments on some epizoic rotifers on the planktonic daphniids were made by Sharma (1979, 1983).

The members of this family have received notable attention in various biological investigations from India and resulted in over 26 publications. Life-history parameters have so far been studied in *Daphnia carinata, D. cephalata, D. similis, D. lumholtzi, D. pulex, Ceriodaphnia cornuta, simocephalus acutirostratus. S. vetulus, S. exspinosus* and *Scapholeberis kingi.* Murugan (1975b) and Sharma *et. al.*, (1984a) commented on the influence of latitudinal variations on fecundity in *Ceriodaphnia cornuta* and *Daphnia lumholtzi* respectively. The biology of the male of the later species was worked out by Das *et. al.*, (1981). Some other observations related to in-vitro development and hatchability of the parthenogenetic eggs of *Simocephalus acutirostratus* and *Daphnia lumholtzi* in artificial media. In addition, Dutta Gupta and Maibam (1983), Jana and Pal (1985a), Venkataraman (1986) and Venkataraman and Krishnaswamy (1986) studied the effect of different culture media on life-history parameters of *Daphnia magna, D. carinata, D. similis* and *D. cephalata* respectively. A few investigations (Bhanot and Vass, 1976; Nandy *et. al.*, 1977; Vass and Raina, 1988) dealt with culture propects of *Daphnia carinata, D. lumholtzi* and *D. pulex.*

Family Moinidae

This family was represented by five species of *Moina* and only one species of the genus *Moinodaphnia* i.e., *M. macleayi. Moina oryzae*, an endemic element of this family was described by Hudac (1987) from a rice-fiedl in Tamil Nadu. *M. micrura* was widely distributed in India, *M. brachiata* and *M. macrocopa* were reported from a number of states from this country while *M. weismanni* was documented only from Gujarat and Tamil Nadu.

Moina micrura and *M. brachiata* were dealt with in many ecological investigations from India. The former appeared to be most common in eutrophic ponds, tanks and waste stabilization ponds; some observations on its population ecology in sewage waters were made by Krishnamurthy (1967) and Parabrahman *et. al.*, (1967). Population dynamics of *M. micrura* was studied by Murugan (1989). Laboratory observations on the biology were undertaken in *M. micrura* (Murugan, 1975a) and *M. weismanni* (Venkataraman, 1990c). In addition, Jana and Pal (1985a) analysed effect of inoculum density on growth, reproductive potential and population size in *M. micrura* while Jana and Pal (1985b) studied life-history parameters of the states species in five different culture media. Some comments relating to the rotifers epizoic on this moinid were made by Sharma (1979, 1983).

Family Bosminidae

Both the known genera of this family (*Bosmina* and *Bosminopsis*) were present in our inland waters. The former included two species i.e., *B. longirostris* and *B. coregoni* while another new species is being described from Tripura (Prof. Bhattacharya : personal communication). The latter genus was represented by *Bosminopsis deitersi. Bosmina coregoni* was so far reported only from Kashmir valley. Fernando and Kanduru (1984) commented that *Bosminopsis deitersi* showed a more southern distribution from Sri Lanka to Mymensingh (Bangladesh) in this subcontinent while *Bosmina longirostris* reflected a more northern distribution from Srinagar to Calcutta and the hilly areas, the Nilgiris and Coimbatore. however, this author's observations (unpublished data) extended the distributional range of the former species to North-Eastern India. Further, *B. longirostris* was observed to be most common and quantitatively important species of planktonic cladoceran communtics in different states of this region.

Ecological information on the documented species of this family remained practically neglected in this country except for the observations made by Yousuf and Qadri (1983) from Manasbal lake in Kashmir valley.

Family Macrothricidae

It included only eleven species belonging to two sub-families i.e., Macrothricinae and Ilyocryptinae. *Ilyocryptus bhardwaji* comptrised the sole endemic element of this family. *Macrothrix gröonlandica* and *Gurnaella rephaelis* indicated restricted occurrence and they were so far reported only from Ladakh and Kashmir respectively. Fernando and Kanduru (1984) considered *Grimaldina brazzai* to be strictly an equatorial species occurring below 12°N; this, however, was also reported (Rane, 1984d) from Madhya Pradesh in Central India. Some çomments on the ecology of the representatives of the Macrothricidae were made by Yousuf and Qadri (1983).

Family Chydoridae

The chydoridae, the largest family of this order, also comprised the most dominant component of Indian Cladocera and included 55 species belonging to nineteen genera. Important taxonomic information on the chydorids examined from this country, however, was confined to fewer publications. This family included the members of three subfamilies in our inland waters i.e., Eurycercinae, Chydorinae and Aloninae.

Eurycercinae was represented by *Eurycercus lamellatus* which was so far documented from Kashmir (above 32°N). The report on the occurrence of a head shield of Eurycercus from Jabalpur in Central India was accounted to be carried by a river originating in cold regions of the Himalayas (Adholia, 1979) although such an explaination was unlikely to be feasible. Interestingly, a species of this genus was collected by this author (unpublished report) from a pond and a paddy-field from lower altitudes in Jaintia Hills (Meghalaya) in North-Eastern India; a detailed report of the status of this species, however, awaits population analysis.

The subfamily Chydorinae was represented by 22 species spread over seven genera. The cosmopolitan *Chydorus sphaericus* was distributed across the whole latitudinal range in this subcontinent. *Alonella excisa, Chydorus eurynotus* and *C. ventricosus* occurred widely. *Pleuroxus trigonellus, P. laevis, Alonella nana, A. exigua* and *Dunhevedia crassa ciliocaudata* were not noticed south of 22°N. *Chydorus pubescens* was reported only from Assam. *Chydorus parvus, C. herrmanni, C. kallipygos, Dunhevedia serrata* and *Dadaya macrops* could be regarded as southern elements of this subfamily.

The third subfamily (aloninae) included 31 species belonging to eleven genera. *alona taraporevalae,* an interesting species, was described from a back bay at Bombay though confirmation about its original habitat was still required. Other endemic elements of Aloninae were represented by *Indialona ganapati, alona dhilloni, Camptocercus kapuri* and *Leydigia ankammaraoi*; the first species was reported only form Gujarat and Madhya Pradesh. *Acroperus angustatus* appeared to be a northern form; *Alona monocantha tridentata* and *Leydigia australis ceylonica* were restricted to southern parts of this country while *Alona rectangula richardi, A. davidi punctata, Oxyurella tenuicaudis* and *Kurzia latissima* were examined only from West Bengal.

Information on ecology of the chydorids was primarily confined to the investigations by Yousuf and Qadri (1981b) and Yousuf *et. al.* (1984). Population dynamics, biology and production ecology of *Chydorus sphaericus* was studied by Khan (1983a) while observations on life history parameters of *Leydigia acanthocercoides* were made by Murugan and Job (1982).

Family Leptodoridae

It was represented by single Holarctic species i.e., *Leptodora kindti* from Kashmir; its another report from Lower Bengal region of West Bengal (Mandal, 1980) was certainly questionable. Some comments on the ecology of this species were made by Yousuf and Qadri (1983).

Family Polyphemidae

This holarctic family was represented only by *Polyphemus pediculus* from Kashmir. However, there was no information about its ecology from India.

Family Podonidae

It included two truely marine taxa i.e., *Evadne tergestina* and *Podon* sp. The former species was reported to exhibit swarms in various ecological investigations along the eastern and western coasts of this country. However, information on the ecology of *Podon* sp. was much limited.

Current Studies

Inspite of notable increase in the number of faunistic contributions during the last decade, only few workers are currently actively engaged in systematic studies on these organisms in India. Sharma and co-workers at the Department of Zoology, North-Eastern Hill University, Shillong are working on the cladoceran faunas of various states of North-East. In this connenction, extensive studies have been initiated (in collaboration with Dr. S. Sharma, ERS, ZSI, Shillong) on the samples collected from Meghalaya and Tripura under 'State Fauna' Series programme of the Zoological Survey of India. Sharma is also studying collections from the States of West Bengal and Orissa and samples from the Andaman and Nicobar islands. Sharma is also working on the cladoceran fauna of Bihar in collaboration with Dr. R.K. Sinha of Patna University. B. K. Sharma and R.G. Michael continue to work on this group. Attempts are also being made to maintain national reference collections on Cladocera. Besides, taxonomic studies are being undertaken in Zoological Survey of India at its various regional stations.

Although routine limnological investigations invariably refer to the cladoceran communities but serious synecological researches on freshwater Cladocera are being carried out at North-Eastern Hill University, Gauhati University, Calcutta University, Kalyani University, Punjab University, Patna University, Aligarh Muslim University, Kashmir University and Kumaun University. The studies on certain aspects of biology are also in progress at some of the mentioned universities. The observations on the ecology of marine cladocerans are undertaken at National Institute of Oceanography, Goa, Indian Oceanic Biological Centre, Cochin and in other marine laboratories.

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COPEPODA

Introduction

The copepods form an important constituent of the crustacean fauna. Among the zooplankton, they comprise 70-80% of the total population. They feed on diatoms, bacteria and minute particles of organic material in the water and in turn serve as food for many of the larger aquatic animals, chiefly fish. Thus, they play an important role in the food chain of the aquatic ecosystem at various trophic levels and act as indicators of productivity. Copepodologists are quite convinced that quantitatively copepods are unrivalled by any other group of animals. Qualitatively, the number of species of the World is estimated somewhere between 10,000 and 12,000.

The Subclass Copepoda under Class Maxillopoda in Phylum/Super Class Crustacea is divided into eight Orders *viz.*, i) Calanoida, ii) Harpacticoida, iii) Cyclopoida, iv) Poecilostomatoida, v) Siphonostomatoida, vi) Monstrilloida, vii) Misophrioida & viii) Mormonillioda, depending upon the shape of body and structure of right antennule in male. Some copepods are sedentary, being commensal or semi-parasitic or parasitic on various aquatic animals, particularly fish, or restricted to the bottom. They are very small in size, ranging from half a millimeter to several millimeters in length. Parasitic forms have originally descended from free-living ancestors and indeed, while the semi-parasitic copepods form a transition between the two groups. Copepods of the calanoid group have the highest number of species forming an essential part of nourishment for several common food fishes. The Cyclopoida exhibit many modifications both in their appearance and habits, the latter affecting chiefly the structure of oral parts. The group exhibits some affinities with both the Calanoida and the Harpacticoida.

The Harpacticoida live near the shores among algae, sand or mud at different depths of sea. Several forms lead a Parasitic existence, attacking different invertebrate animals and fishes. However, the parasitism may be temporary or permanent. The mode of parasitism has a great influence on the structure of the oral parts of these copepods. The semi-parasitic forms belonging to the Orders Poecilostomatoida, Siphonostomatoida, Monstrilloida, Misophrioida and Mormonilloida were not well investigated. The available data shows that systematics, ecology, planktology and zoogeography are well investigated, while their embriology, genetics, biochemistry, aquaculture and evolution are least studied by the Indian scientists.

Historical Resumé

i) Pre-1900

Jurine (1820) was the first to give a comprehensive account of the fresh water Copepoda in France. Later, Baird (1850) published his monumental work "Natural History of the British Entomostraca" A well known scientific expedition *Novara* (1857-1859) had investigated the zooplankton of Indian Ocean from scattered stations. Our knowledge of the regional and seasonal distribution of the copepods of Indian Ocean is far from complete, although there were some valuable accounts along the coasts of India, Australia and South Africa. Well known international expeditions including *Gazelle* (1874-1876) and *Valdivia* (1998-1899) had investigated the zooplankton of Indian Ocean. Our knowledge of the oceanic species of calanoid copepods of Bay of Bengal, including the Andaman Sea is mainly due to works of Thompson (1900).

ii) 1901-1947

The earliest work on copepoda from oceanic waters around islands of the Arabian Sea was that of Cleve (1901). Subsequent investigations were made in the seas around India by Scott (1902),

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Thompson & Scott (1903), Cleve (1903, 1905), Wolfenden (1906), Pesta (1912) and Sewell (1929-1932). Well known international Indian Ocean expeditions including *Gauss* (1902-1903), *Sea Lark* (1905), *Planet* (1906-1907), *Mowe* (1912-1913), *Dana* (1928-1930), *Snellius* (1929), *Discovery II* (1930-1932, 1935, 1938), *Mabahiss* (1933-1934), *William Scoresby* (1935, 1936, 1950) and *Albatross* (1947) have investigated the zooplankton of Indian Ocean. Thompson and Scott (1903), Apstein (1907) Sewell (1913), Gurney (1916) and Sewell (1929, 1932) studied the calanoid copepods of Sri Lankan waters. Sewell (1914) created the genus *Acartiella* to accommodate the two new species from India. Gurney (1916) also described the new species of the genus *Heliodiaptomus* from India. Taxonomic discussion on copepods from inshore and estuarine waters of Arabian Sea was made by Sewell (1919). Sewell (1924) also described a new species of the genus *Heliodiaptomus* from India and also dealt (1929, 1932) with families that have been grouped by Giesbrecht in the Tribes Amphascandria and Heterarthrandria. After Sewell's monograph (1929, 1932) on the marine pelagic copepods, no comprehensive work on the group has been carried out from the Indian Seas. Kiefer (1939) in his final analysis of the genus *Neodiaptomus* included six species of which four were recorded from China, Burma, Celebes and Java and two from Southern India. Arora (1942) reported ecological and taxonomic studies of Calanoida collected from seven high mountain lakes in Kashmir during the summer of 1940.

iii) 1948-1990

Taxonomic Studies

Taxonomic studies on copepods of the Andaman & Nicobar Islands by Goswami, & Rao, (1981), Madhupratap *et al.* (1981), Pillai, (1969), Rao, (1970, 1985, 1986, 1987, 1988, 1989) and Wells & Rao, (1976, 1987), Roy (1978); Andhra Pradesh by Rao, (1951), Ganapati & Rao, (1958), Ganapati & Santhakumari (1961), Rao, & Ganapati (1969), Rao, (1969, 1972), Radhakrishna & Ranga Reddy (1976, 1978) Ranga Reddy (1977, 1979, 1980, 1984 & 1988), Ranga Reddy & Radhakrishna (1979, 1980, 1981, 1982, & 1984), Uma Devi & Shyamasundari (1980) and Uma Devi *et al.* (1980); the Arabian Sea by Goswami, (1983), Nair, (1983, 1985) and Pillai, (1967); Assam by Reddiah (1965); Bombay by Bal & Pradhan (1945, 1952), Goswmi, (1985), Nair, & Peter (1980), Ranade (1973, 1974), Rangnekar, (1955, 1956, 1957, 1959 & 1963), Rangnekar, & Murti, (1959, 1961, 1964), Rangnekar, & Rangnekar, (1972), Redkar & Rangnekar, (1950), Redkar, *et al.* (1949); Goa by Chandran (1980), Goswami, (1979, 1983, 1985), Jacob & Menon, (1947); Gujarat by Bhaskaran & Gopalkrishnan (1971); the Indian Ocean by Gopalkrishnan (1974), Pillai, (1974, 1976 & 1980), Saraswathy (1973, 1982), Silas & Pillai, (1967); Karnataka by Srinivasachar & Sundarabai (1974), Ummerkutty (1968, 1970); Kerala by George, (1953), George, (1958), Gopalkrishnan (1973), Hameed & Pillai, (1970, 1973), Kurian (1955, 1961), Madhupratap & Hari Das (1978), Menon, *et al.* (1972), Pillai, (1968, 1973), Pillai, & Natarajan (1977), Pillai, (1970), Saraswathy (1962, 1964, 1966), Tranter & Abraham (1971); the Laccadive Sea by Goswami, (1979, 1983), Goswami, (1979) and Hari Das & Mahupratip (1978); the Orissa by Debasundaram & Roy, (1954), Sehgal (1960, 1967, 1968) and Rao, (1969); Tamil Nadu by Gnanamuthu (1974, 1948, 1949, 1950, 1951, 1953 & 1957), Gnanamuthu & Krishnaswamy (1948), Krishnaswamy (1950, 1951, 1952, 1953, 1954, 1956, 1957, 1969), Krishnakartha (1959), Nair, & Pillai, (1987), Ranga Reddy (1985), Reddiah (1961, 1962, 1967, 1968, 1969, 1970), Reddiah & Mammen (1970), Sebastian & Pillai, (1973), Ummerkutty (1960, 1961, 1966, 1967, 1968, 1971); Tripura by Das & Bhattacharya (1974) and West Bengal by Gopalkrishnan (1971) and Roy, (1980).

Zoogeographical Studies

There have been relatively few zoogeographical studies by Indian scientists as a result of which about 27 articles have been published on this aspect. Our knowledge of the systematics and distributional patterns of the Copepoda of the Indian region is mainly due to the excellent accounts given by Panikkar (1970), Rajendran (1971), Kasturirangan *et al.* (1973), Pillai, (1974, 1980), Meenakshikunjamha (1974), Mohan, (1977), Devi, *et al.* (1979) and Goswami, (1982). Observations on the seasonal distribution of zooplankton including copepods in estuaries along the West coast of India is confined to Cochin backwaters by George, (1958), Tranter & Abraham (1971), Menon, *et al.* (1972), Nair, & Tranter (1972), Pillai, (1971), Pillai, *et al.* (1973), Madhupratap & Hari Das (1975) and Madhupratap (1979); Trivandrum coast by Menon, (1945). Goswami, & Singbal (1974) described the zooplankton community in relation to hydrography of the Mandovi-Zuari estuarine complex of Goa. Distribution and diversity of copepods in the Mandovi-Zuari estuarine system was studied by Goswami, (1979, 1982). Observations on the seasonal distribution of the zooplankton specially copepods in the Hugli-Matla estuarine system of the east coast of India were carried out by Dutta *et al.* (1954) and Shetty *et al.* (1961); Godavari estuary by Mohan, & Rao, (1972), Mohan, (1977) and Lawson's Bay Waltair by Ganapati & Santhakumari (1961). Further, an excellent work of the distributional pattern of the copepods of the Indian Ocean was carried out by Panikkar (1970), Saraswathy (1973), Kasturirangan *et al.* (1973) and Pillai, (1980).

Biological Studies

Feeding habits of the freshwater calanoid, *Rhinediaptomus indicus* have been reported by Singh (1973) and on parasitic copepods as *Larnaeenicus hemirhamphi* and *Mysis relicta* have been carried out by John & Nair, (1973) and Ramcharan *et al.* (1985). Earlier workers such as Krishnaswamy (1950, 1955), Ummerkutty (1960) and Abraham & Gopalan (1975) have carried out investigations on the larval stages of some species of the genus *Laophonte* for using detritus as food for development. Goswamy, (1977) reported the affect of food item as detritus for the development of different stages of *Laophonte setosa* which were reared in the Laboratory.

The development stages, sex ratio and variation in body size of a common calanoid *Pseudodiaptomus ardjuna* were studied by Alvarez & Kevalramni (1970) and *Pseudodiaptomus binghami* by Goswami, (1978). Further, development and predatory behaviour in a calanoid copepod, *Tortanus forcipatus* was studied by Goswami, (1977).

Observations were made on the development of the larval stages of the calanoid copepod, *Labidocera pectinata* by Pillai, (1972), harpacticoid copepod, *Euterpina acutifrons* by Goswami, (1976), cyclopoid copepod, *Cyclopina longifera* by Goswami, (1977), calanoid copepod, *Labidocera pavo* and *L. minuta* by Goswami, (1978) and *Megadiaptomus habes* by Ranga Reddy & Rama Devi (1985). Development of the harpacticoid copepod, *Macrosetella gracilis* was further studied by Krishnaswamy (1949, 1951), *Tisointra jonesi* by Ummerkutty (1960) and *Arenopontia indica* by Rao, (1967) and cyclopoid copepod by *Oithona rigida* by Rammohan Ral (1958). Bionomics, structure and development of the parasitic copepod, *Caligus russelli* was noted by Kurian (1952). Breeding periods of certain copepods were observed by Govindankutty & Nair, (1966, 1973), Prasad & Krishnakartha (1959) and Ummerkutty (1967).

Goswami, (1982) observed deviation from chromosomal normalcy in the calanoid copepod, *Paracalanus aculeatus* during solar eclipse. She further noted about the chromosomal structure etc. of the calanoid copepods, *Pontellopsis herdmoni* and *Pontella princeps* collected from Laccadive Sea in 1984. Biochemical composition in zooplankton specially of copepod specimens collected from the west coast of India and the Andaman Sea was studied by Goswami, (1981). John *et al.*, (1977) also studied the biochemical composition of the copepod, *Lernaeenicus hemirhamphi*.. Madhupratap *et al.*, (1979) also carried out similar type of studies on tropical zooplankton specially copepods. They studied the nature of distribution of glycogen and lipids in a parasitic copepod, *Hermilius longicornis* following the work done by John (1975).

An excellent work on respiration of copepods was carried out by Krishnaswamy (1959, 1960, 1962). Nature of infestation of parasitic copepods on different fishes from the south west coast of India was studied in detail by Radhakrishnan & Nair, (1981). Observations on acute toxicity using copepods were made by Abdul Kader *et al.*, (1976) and Ghosh *et al.*, (1974).

Fishery Studies

The abundance of copepods and fish production of an area are closely related. Hora (1944) while studying commercial freshwater fishes in West Bengal observed that there was a great mortality among the carp fisheries due to presence of the fish-louse, *Argulus foliaceous*. Jacob & Devi Das Menon (1947) observed that the fluctuations in copepod population in the West Hill plankton were correlated to those of the fishery of the plankton-feeding fishses of the Calicut coast for the years 1939-1944. Observations were also made by Shetty *et al.*, (1961) on th fluctuations of plankton and their relation to commercial fish landings in the Hugli-Matla estuarine system. Similar studies were also made along the north Kanara coast by Rammurthy (1965). Pillai, (1969) reported the plankton and the hydrographical conditions of the Bombay coastal waters and its fisheries. Mukundan (1971) reported the relationship of inshore water zooplankton with the coastal pelagic fishery at Calicut on Kerala Coast.

Taxonomic Studies on parasitic copepods

Basett-Smith (1898) first made studies on the fauna of the Indian Ocean. He described several parasitic copepods, collected from the Arabian Sea and Persian Gulf. Since then, no work could be made on this group except Kirtisinghee (1932-1964) from Sri Lanka waters. Gnanamuthu (1947-1957) studied the copepod fauna from the Bay of Bengal and Rangnekar (1953-1963) from the Arabian Sea. Needless to mention that their work were made significant addition to our knowledge of the Indian fauna. Pillai, (1961-1977) was made a series of publications on this group, parasitic on fishes, collected from the coastal waters of Kerala. Very interesting publications on the Indian fauna is available of the works of Redkar *et al.*, (1949), Kurian (1949-1951), Rao (1950-1951), Rangnekar, (1950-1964), Tripathy (1962), Bennet (1961-1974), Sebastian (1964-1968) and Hameed & Pillai (1972-1973). Pillai, (1985) gave very useful information as a Fauna of India, where he described 314 species of parasitic copepod of marine fishes, collected from the Indian waters.

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THYSANURA

Introduction

The Thysanura includes 'silver-fish' and 'bristle-tails', which are considerably larger insects than the other members belonging to Apterygota sub-class. The abdomen is composed of 10-11 segments. They bear on their ventral surface slender two segmented appendages known as styli. They have very long, many segmented antennae, cerci and a median tail. Blind as well as eyed forms occur and most species are heavily clothed with scales which give these insects a mottled black, brown, silvery or golden appearance. The members of the family Machilidae are capable of jumping by means of the apical ventral stylets. The free living forms are found in the forest floor, under bark of trees, under rocks, in the nests of ants and of termites. Few species (e.g. *Lepisma saccharina* and *Ctenolepisma longicaudata)* often cause damage to books, bakery houses and other household articles.

Historical Resumé

Like other apterygotes (except Collembola) this group is also least studied in India. Escherich (1903) studied the Indian thysanuran fauna for the first time. Thereafter Silvestri (1913, '38, '48), Janetschek (1964) and Wygodzinsky (1941, 1963, 1972, 1974) have contributed to our knowledge on Indian species. More recently, Hazra (1980) described some Indian Thysanura.

Estimation of Taxa

The world fauna of Thysanura consists of 5 families, about 130 genera and over 1250 species. In comparison to this, the Indian representatives are few. So far only 23 species belonging to 16 genera and 3 families are known from India. These are Machilidae (4 genera; 5 spp), Nicoletidae (5 genera; 6 spp.) and Lepismatidae (7 genera, 12 spp.).

Classified Treatment

There are two suborders in this order. Under sub-order Microcoryphia, there is one superfamily Machiloidea, which consists two families Machilidae and Meinertellidae. The sub-order Zygentoma has one superfamily Lepismatoidea, under which there are three families Lepidotrichidae, Nicoletiidae and Lepismatidae.

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DIPLURA

Introduction

Diplura still remains one of the least studied group of Indian fauna. These are soft bodied wingless insects. Mouthparts are retracted within the head capsule, eyes absent, body without scales (rarely with a few localised ones), cerci long and filiform or shorter and annular or forcep-like, and median tail appendages absent. These insects occur in large numbers in humus soil or in the forest floor throughout India.

Historical Resumé

Knowledge on the Indian Diplura is available due to the contributions of Silvestri (1913, 1937) and Conde (1957, 1972). In 1977 Rao and Mitra conducted some research on this group.

Estimation of Taxa

The world fauna of this group is represented by about 355 species under 77 genera. From India, so far only 16 species under seven genera are known, belonging to three families namely Japygidae, Projapygidae and Campodidae.

Classified Treatment

Diplura has two suborders, namely Rhabdura and Dicellurata. Under Rhabdura there are two superfamilies Projapygoidea and Campodeoidea. The former superfamily has two families Anjapygidae and Projapygidae, and the latter has two families namely Procampodeidae and Campodeidae. The suborder Dicellurata has only one superfamily, Japygoidea, under which there are two families namely Japygidae and Parajapygidae.

No one in India is actively engaged in studying this group and most parts of the country remain unexplored.

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PROTURA

Introduction

Proturans are curious soil inhabiting minute insects. Their body is cylindrical, antennae and eyes absent, first leg used as a tactile organ, abdomen in adults with 12 segments and cerci absent. Protura still remain one of the least studied group of Indian fauna.

Historical Resumé

The study of Indian Protura started with Schepoteiff (1909). But there was a long gap after that. Recent work on Indian Protura was done by Dr. N.R. Prabhoo of Kerala University (1960-1988).

Estimation of Taxa

According to Tuxen (1978) about 260 species belonging to 27 genera under four families have been recorded from the world. Three families are known from India, viz., Eosentomidae, Protentomidae and Acerentomidae. Till to date only 20 species have been recorded from India. Of these, 15 species have been recorded from Kerala State alone and rest five from other states. Prabhoo (1986) reported that 99% of India still remains to be explored as far as the proturan fauna is concerned.

Classified Treatment

All the three families recorded from India have been discussed by Prabhoo (1960, 1972 a, b, 1975, 1977, 1986). He reported four species under Eosentomidae; eight species under family Protentomidae and another eight species under family Acerentomidae.

No work is being carried out in India on this group at present.

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Animal Resources of India : 237–241 : 1991

COLLEMBOLA

Introduction

Collembolans have derived their name from the Greek word, *Colla* = glue and *Emblon* = bar, due to the presence of a barlike structure, the collophore underneath first abdominal segment. Another popular name of these insects is 'Springtail' owing to the presence of an spring like, forked jumping organ; underneath the forth abdominal segment. These insects are unique in having only six abdominal segments. Some authorities such as Handlirsch (1908) had emphasized their isolated position and accorded them a separate class status of Arthropods. Collembolans are, though, best considered as a specialized side evolutionary line, remote from main line of insect evolution (Imms, 1936).

Collembolans inhabit a wide range of ecological niche. Majority live where organic matter and moisture is present; such as litter, humus and subsoil layer of arable and forest land. These are also found localized under log, stones, loose bark, leaf moulds, moss fungus, lichens etc. There are a few inhabitants of ants and termite nests. Certain others live on the surface of fresh water bodies (ponds, lakes), while relatively few representatives inhabit intertidal seashore. Snow at high altitudes is also known to support certain collembolans.

These insects are often immensely abundant at a specially suitable patch or stretch of habitat. An acre of meadow has been estimated to support nearly 2,30,000,000 of these insects from the surface to a depth of nine inches (Imms., 1959).

Collembolans play a significant role in the breakdown of leaf litter alongwith certain other micro arthropods and consequently initiating the process of humification. The role acts in increased soil fertility. These are also known to enrich the organic content of the soil in the form of faecal matter. Schaller (1950) has shown that a population of the order of 100,000 m^2 produces 103 c.c. of faeces annually. This is equivalent to 0.2 mm deep layer.

Collembolans are also increasingly getting their due recognition as bio-indicator of soil conditions. These insects exhibit wide range responses to changes in soil factors. On the contrary it is also known that certain collembolans exhibit sustained tolerance against varied strength of pesticides including most toxic DDT.

Some of these insects, though, also have been ranked injurious, e.g. some Sminthurids; specially *Sminthurus viridis* has been known as pest of clover and lucerne (hence called 'lucerne fleas'). A small gray species, *Achorutes armatus* is sometimes found destructive to mushrooms in commercial production level (Ross, 1956). In India, there is an example of a collembolan (*Sinella curviseta* Brook) infesting potato crop in floating land at Srinagar (Bhat, 1987).

Collembolans range in size from 1/5 mm (genus *Megalothorax*) to 10 mm (Entomobryids and Podurids). The order is divisible into two suborders viz., Arthropleona and Symphybleona. Former represents majority of the collembolan species under families such as Isotomidae, Entomobryidae, Poduridae, Hybogastruridae, Oncopoduridae etc. The abdominal segments of the members of this suborder are all distinct and linearely disposed. On the other hand anterior abdominal segments are fused with thoracic to form a globular body in the suborder Symphypleona. This suborder comprises of two major families Neelildae and Sminthuridae.

Historical Resumé

Perusal of literature reveals that there was no work on Indian Collembola prior to the period of 1900, though contribution on world Collembola exists.

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i) 1901-1947

The first account of work on Indian Collembola goes to the credit of Ritter (1910). This contribution includes number of new Collembolans from India (Bombay), besides Ceylon (Sri Lanka); alongwith certain new thysanurans. This was closely followed by Imms (1912), which recorded significantly number of Indian Collembolans besides those from Burma and Ceylon. Four new genera *Dicranocentroides, Idiomurus, Pseudocyphoderus* and *Heteromuricus* and new subfamily - Heteromuricinae was established to accommodate last named genus with unique single median cercus to the fifth abdominal segment. This work also includes a catalogue of the Oriental Species of the order.

Carpenter (1913, 1917, 1924) contributed on Indian Collembola. These includes a new species from Calcutta, results of Abor expedition (1911-1912); new species under 6 genera, one genus *Cyphoderopsis* being new from North East Assam (Assam-Garo hills) and 4 new species of Entomobryidae. Handschin (1929) dealt with *several Collembolan species of South India,* mainly from the region of Nilgiri and Palini hills and includes 14 new species. Bonet (1929) dealt with some Indian Collembola, while Denis (1936) dealt with several Collembolans from North India based on material of Yale North India expedition.

Detailed anatomical studies were made by Mukherji (1932) on a new species viz., *Protunura carpenteri.* Same year Brown described a new species of Isotomid Collembola.

ii) 1948-1990

Baijal (1955 a & b; 1968) described nineteen species of Indian Collembola, based on Prof. M.S. Mani's Entomological expedition the Northwest Himalaya - 1954-56; 12 species among these were from the 'Nival zone of N.W. Himalaya' Two monotypic genera were also erected in above contributions viz., *Salmonia* and *Himlanura.*

Salmon (1951-1969) has contributed significantly to our knowledge of Indian Collembola. Some of the important contributions are : a new species of Hypogstraidae (Salmon, 1956 a) *Parafolssomia trioculata* while *Ceratophysella indica* was described in 1956 (b). Both these were from Sikkim (Gangtok). Two new species of Paronellilnâe (*Handischinphysa serrata* and *Pseudoparonellides bulbos* a) were described by Salmon (1957). Same year another new species of Entomobryidae *(Pseudentomobrya lampreyi)* was described by him from Tehri Garhwal (UP) A species of Onychiurid *(Spelaphorura clayee)* from Sikkim (Gangtok) in 1958; two new species (*Arropolites spadica* and *Corynepharia reticulata)* in 1963; a new sp. *(Paratullbergia indica)* in 1965; a new monotypic genus *Uchidanurida* (*U. attitudina*), a new Hypogastrurid (*Hypogastrura indovaria*) and a new Entomobryid (*Lepidosira unguserrata*) in 1970. Salmon (1951, 1956) had provided key to the world genera of Collembola, besides a comprehensive biblilography.

Yosii (1966) has dealt with a number of high altitude Collembola. These comprised of 38 new species and a new monotypic genus *Nepalanura* (*N. paranuroides*), representing 11 families. All these were based on material from Himalaya as the result of 'Himalayan Expedition of the Chiba University 1963' under the leadership of Prof. M. Namata.

Another significant contribution by Yosii (1966 b) of 20 new species was based on material obtained by 'KUPHE expedition - 1960', from Bombay and Calcutta. These species represented nine genera.

Prabhoo (1971 a) has dealt with Collembola of the suborder Arthropleona, inhabiting soil and liltter of South India; chiefly from tea plantations, besides various localities in Western Ghats. This is quite significant contribution on Collembola from South India. It deals with 48 species, including 23 new species and a new monotypic genus *Indoscopus* (*I. spinosus*). Majority (20 : 28) of the species represented Entomobryidae.

Collembola of the suborder Symphypleona from South India is dealt by Prabhoo (1971 b). This also deals with soil and litter inhabiting forms from tea growing areas in Western Ghats and certain other localities of Kerala. This contribution deals with 12 species (10 under Sminthuridae and 2 under Neellidae). Of these four were new species and five new records from India.

Mitra (1975) synomymised *Dicranocentroides* with *Campylothorax*. Later he (1973 a & b) has dealt with a new Paronellinae (Entomobryid) genus *Pseudosalina* from India, besides 3 new species and revision of Entomobryid genus *Salina*. Critical study on certain Entomobryid genera *Callyntrura* (Mitra, 1974) and *Dicranocentroides* and a new termitophilous genus under Cyphoderinae (Mitra, 1976) are significant contributions. Mitra (1977 a,b, c) has dealt with the status of genera *Glacialaea*; and Hypogastruridae genus *Xenylia*

Baijal & Agarwal (1972 a) described a new species under *Pararrhoplites*; while Baijal & Kohli (1972 b) described a new *Sminthurus*. Another new species of Sminthuridae (*Sminthurides*) was described by Baijal & Varma (1986).

Studies, other than taxonomy & faunistics on Indian Collembola are relatively far and few. First complete morphological and anatomical study on an Indian Collembola goes to the credit of Mukerji (1932). This was based on a new species, from Calcutta, belonging to genus *Protunura (P. carpenteri*) of the family Protonuridae.

Effect of temperature on each phase of life history of three species of *Onychiurus* (Onychiuridae) was studies by Choudhuri (1963 a); while he contributed on the effect of humidity and desication also on above 3 species. Choudhuri & Roy (1972 a) has significantly contributed on the Collembola of West Bengal; while he studied (1972 b) correlation between monthly population and certain soil factors on the Collembolans of uncultivated field in Burdwan (West Bengal).

Postembryonic morphological differences including Chetotaxy of an Entomobryid *Callyntrura (Handischinphys lineata)* was studied by Mitra (1974). Prabhoo (1976) gave ecological observations of certain Collembolans, alongwith soil-microarthropods inhabiting virgin forest floor and adjoining tea fields is Western Ghats (Kerala). Dhalliwal *et al.*, (1976) reported occurrence of an entomobryid (*Seria cinera*) on wheat and paddy seedlings.

Hazra (1978 a & b) has contributed on the effect of organic matter and water on the distribution of certain Collembola in an uncultivated field of Burdwan and on the ecology of certain Collembolans dwelling in the soil and leaf litter in a deciduous forest floor in Birbhum (West Bengal). Food composition consumed by three Collembolan species co-inhabiting in same ecosystem was observed; along with food preferences by Tanja (1978). Feeding habits of Collembola inhabiting an abandoned field in Kerala was also studied by Murleedharan and Prabhoo (1978).

Ecological observations on the Collembola inhabiting Eden gardens (Calcutta) were made by Mitra *et al.*, (1977). Population dynamics of certain Collembola, alongwith acarina in a grassland ecosystem was observed by Mitra *et al.*, (1981). Sinha *et al.*, (1988) also studied population fluctuation vis-a-vis Collembolans in a deciduous forest floor at Ranchi (Bihar). Reproductive rhythm were observed on Onychiurid Collembola by Choudhuri and Roy Choudhuri (1970).

Studies from Different Environs

On an analysis of the contributions it is evident that this group has been worked mostly on far and few scattered collections from different zones from Himalaya, specially Northwest Himalaya, Pir Panzal Range, Certain parts of North West India above the zone of Gangetic belt are also covered. These are in Uttar Pradesh (Badrinath, Bhowali; Tehri Garhwal). Material from Himachal Pradesh (Shimla, Kulu, Lahaul) and Kashmir (Srinagar) are recorded. On the North-Eastern side certain areas are covered such as Sikkim (Gangtok), Nagaland (Kohima), Meghalaya (Garo Hills and Shillong).

Gangetic belt is only covered by material from U.P. (Allahabad), Calcutta, certain other parts of West Bengal (Burdwan and Birbhum etc.). On the Eastern Ghats side only Chilka (Orissa) and on Western Ghats side many places of Kerala and Tamil Nadu (Calicut, Dodabetta, Kanyakumari, Ootacamund, Palghat, Vendiperiyar, Trivandram, Wynad) and certain parts of Maharashtra (Bombay, Nasik) are covered.

Estimation of Taxa

Collembolans are represented in India by approximately 200 species under 86 genera, 8 families and 2 suborders viz., Arthropleona and Symphypleona. World over this group of insects are known by a little more than 5000 species, 451 genera, 11 families and 2 suborders. The suborder Arthropleona are represented relatively, by more families both at India and World level (5:8). The suborder Symphypleona is having lesser family representation at India and World level (2:3). Out of families under former suborder Entomobryidae have maximum representation. Family Sminthuridae has maximum representations under suborder Symphypleona.

Current Studies

Systematics of Collembola is mainly worked in *Z.S.I.* by Mitra, who is engaged in Collembolan fauna of West Bengal under State Faunal resource study and Hazra has been engaged on certain aspects of ecology of these insects. Singh of B.H.U. Varanasi, Choudhuri and his team at University of Burdwan, and Prabhoo of Kerala University, at Trivandram, have been engaged on bio-ecological studies of Collembola. Baijal and Varma of Agra University, Agra, are engaged in faunistic and taxonomy of certain Collembola.

World over the order is worked out by various workers attached with different universities and institutes. Various aspects covered are taxonomy, faunistic,zoogeography, revision at various level of taxa; besides their ecology, biology etc. Some of the significant contributors are Bellinger, Christiansen, Dallai, Ghilarov, Lawrence, Rapport, Uchida, Yossi etc.

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EPHEMEROPTERA

Introduction

Ephemeroptera belong to Exopterygota (or Hemimetabola), i.e. with an incomplete metamorphosis. Its larva basically resembles the adult in appearance, with wings that develop externally as wing–buds in the immature stages, and with a life cycle divided into three definite stages of egg, larva and adult. The name Ephemeroptera (Greek *ephemeros* – lasting for a day; *pteron* – wing) refers to the brief life of the adult, which is sometimes called 'one–day fly' Adults do not feed, and live for only one or two hours in some species, but up to about fourteen days in some ovoviviparous species. These relatively primitive insects posses a number of traits that are thought to have been present in the earliest winged insects, such as tails and an inability to fold the wings flat over the body. These are unique among winged insects in having two adult stages. The first, called the *subimago,* emerges from the last larval stage and, depending on air temperature, usually moults within 24 hours to the second, called the *Imago* (plural *imagines*). Larvae are also called nymphs or naiads by some workers.

Ephemeropterans, which are commonly known as mayflies, are amphibiotic insects. Major part of their life cycle is spent in various freshwater ecosystems in their egg and larval stages. Adults are extremely short lived – 'ephemeral', hence the ordinal name 'Ephemeroptera' These insects essentially undergo an aquatic phase for completion of their life cycle. Ephemeroptera represents one of the Paleoptern insect orders, which have an independent line of evolution from earlier Pterygote insects. Their earliest fossil records are known from Devonian in Paleozoic. Carpenter (1933) recognized after restoration of fossil mayfly from Kansas shales – *Protereisma permianum,* the earliest well preserved mayfly from Permian. Mayflies, as a group of insects, seemingly reached their maximum relative abundance in the Permian.

Classification

Linnaeus originally placed ephemeropterans in Neuroptera, together with all other insects having net–veined wings. This Neuroptera was gradually split into several orders, including the Ephemeroptera. Classification of the order has undergone radical change since Linnaeus. The basis of Ephemeroptera classification was laid by Eaton in his Revisional Monograph. No suborders are presently recognized. This order of insects has a world fauna of 2146 species, under 213 genera and 20 families (Hubbard and Peters 1978). Indian representation is 96 species under 36 genera and 12 families. Among these the endemic component is of 72 species while the high altitude component comprises of 33 species (Srivastava, 1983 a and b).

Historical Resumé

i) Pre-1900

The first mayfly species described from India was *Palingenia indica* (Ephoron *indicus*) by Pictet (1843). Walker, working on the collections of the British Museum (1853) and on the collections of W. W. Saundrs (1860) described *Caenis perpusilla* and *Cloeon debilis* (*Procloeon debilis*) respectively from India. Hagen (1858) worked on baetine mayflies of Sri Lanka.

During the period upto 1900, only 5 species were described: two under *Ephemeridae,* two under *Palingenidae,* and one under *Heptageniidae.*

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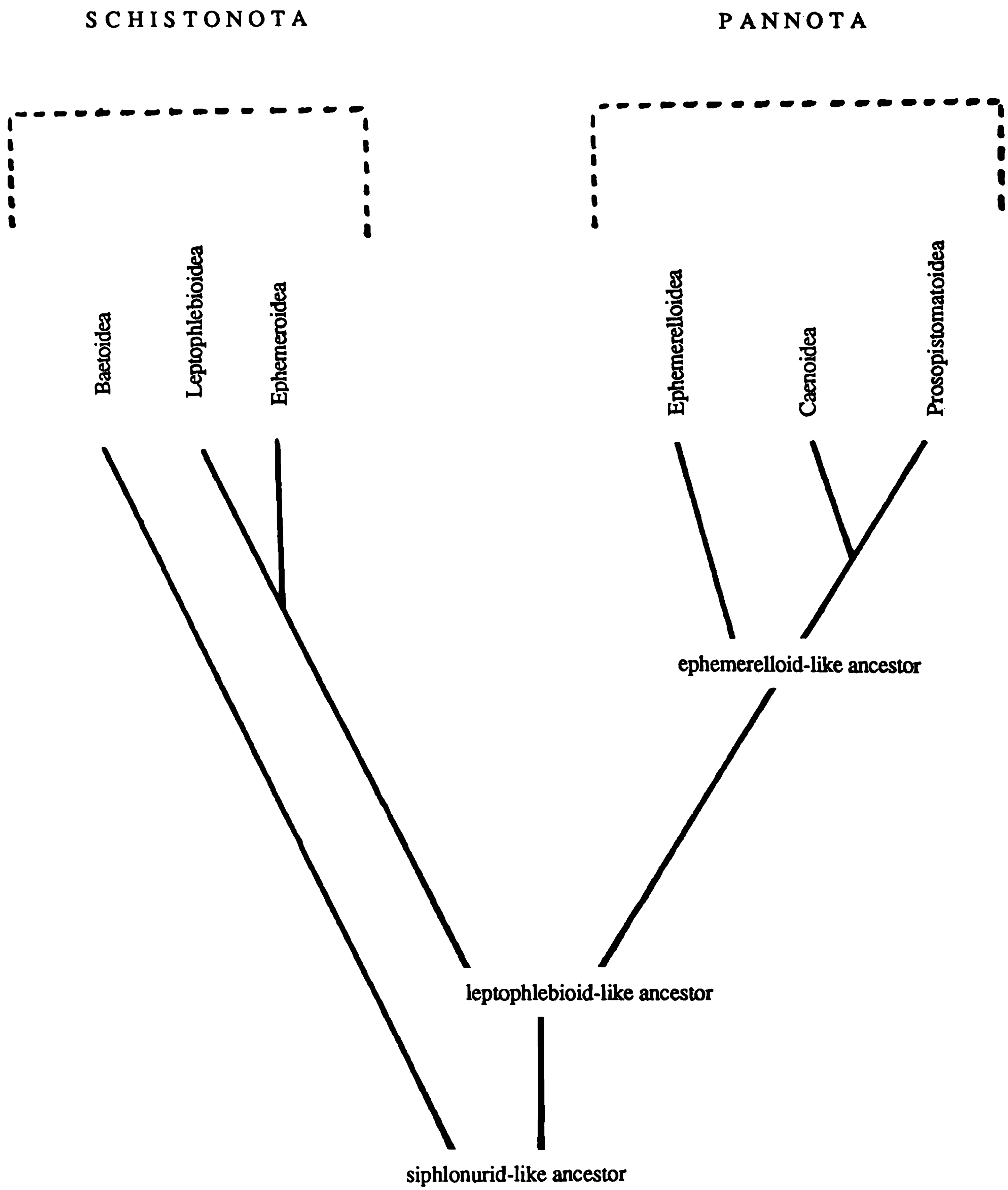


Phylogeny of the extant superfamilies and suborders of Ephemeroptera (after McCafferty & Edmunds 1979)

TABLE 1

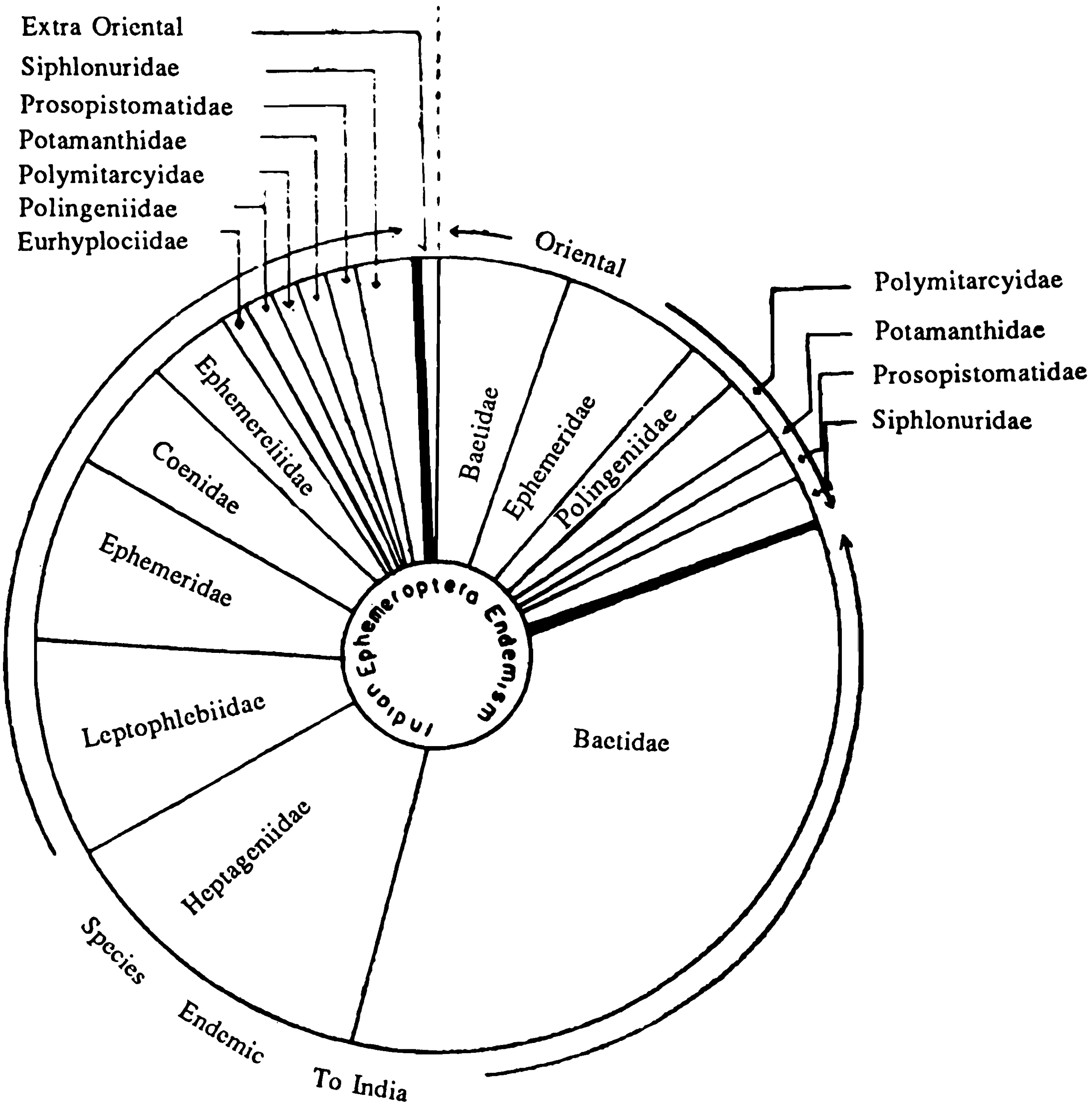
Higher Classification of the extant Ephemeroptera of the world, including suborders, superfamilies and families (those with asterisk occur in India).

Suborder	Schistonota
Superfamily	Baetoidea
Family	Siphlonuridae *
Family	Ametropodidae
Family	Baetidae *
Family	Metretopodidae
Family	Oligoneuriidae
Family	Heptageniidae *
Superfamily	Leptophlebioidea
Family	Leptophlebiidae *
Superfamily	Ephemeroidea
Family	Behningiidae
Family	Potamanthidae *
Family	Euthyplociidae *
Family	Polymitarcyidae *
Family	Ephemeridae *
Family	Palingeniidae *
Suborder	Pannota
Superfamily	Ephemerelloidea
Family	Ephemerellidae *
Family	Tricorythidae *
Superfamily	Caenoidea
Family	Neoephemeridae
Family	Caenidae *
Superfamily	Prosopistomatoidea
Family	Baetiscidae
Family	Prosopistomatidae *

ii) 1901-1947

Important contributors of this period were Chopra (1924, 1927), Hafiz (1937), Taver (1939), Needham (1909), Navas (1931) and Ulmer (1920)..

Chopra (1924) worked on the Ephemeroptera fauna of an island in the Chilka Lake. This included 2 species of Baetidae under genus *Cloeon* Leach, one species each of Ephemeridae (*Eatonigenia* Ulmer) and Caenidae (*Caenis* Stephens). Chopra (1927) dealt with Palingeniidae and Polymitarcyidae. Of these former family was represented, in his contribution, by subsequent record with additional male/female description, figures. Under the latter family additional description and figure of female imago was provided. Hafiz (1937) dealt with mayflies of Indian region including additional record, description and figures. Traver (1939) dealt with certain mayflies of the Himalayan zone. It include a species of each of the genera *Baetilla, Cloeon* and *Ororostsia.*



Indian Ephemeroptera : Endemic and Extra-endemic Components

Incidently the last one happens to be highest locality record for any Indian mayfly i.e. 5297 meters, and that too from a lake, Needham (1909) dealt with several Ephemeropteran species, which were present in the collection of Indian Museum (presently housed at the Zoological Survey of India). It includes addition records, etc of several Indian mayflies. Ulmer (1902) described *Ecdyonurus bengalensis* from Darjeeling, West Bengal.

iii) 1948-1990

Contributions of this period included Dubey (1970 a and b, 1971), Gilles (1949, 1951, 1957) Hubbard and Peters (1978), Kapur and Kriplani (1963), Kaul and Dubey (1970) Kimmins (1947), Mc Cafferty (1973) (a and b), Peters (1967, 1975), Srivastava (1980, 1990) Srivastava and Ray (1987) etc. *Prosopistoma indicum* was described from Kerala by Peters (1967). Peters and Edmunds (1970) made an extensive reivision of Eastern Hemisphere Leptophlebiidae in which a number of genera were established from India. Other contributions to the understanding of Leptophlebiidae of South India were made by Peters (1975), Sivaramakrishnan and Hubbard (1984), Sivaramakrishnan (1984–1987; etc.).

Studies from Different Environs

Bioecological observation on a *Cloeon* species from a lentic water body is dealt in Srivastava and Ray (1981), including seasonal fluctuations, description of male, female larva, subimago and imago. Srivastava (1986) has dealt with seasonal fluctuation, and relation with their Zygopteran predator. Bisht and Das (1983) have dealt ecology with ephemeroptera of high altitude lake. Gupta and Michael (1978, 1983) have dealt with seasonal fluctuation, relative abundance on benthic ephemeraptera and population ecology. Sivaramkrishnan and Job (1978) have done population dynamics of mayflies of stream. Map may be seen for areas studied.

Classified Treatment

Family Baetidae

This family, in India, is represented by 35 species, 6 genera, as compared to world component of 519 species under 6 genera. This is single largest family, among this genus *Baetis* Leach with 18 species is single largest genus. Most of these species are inhabitant of high altitude lotic water body, though members of *Cloeon* are also lentic inhabitants. These mostly occupy littoral zone. Imagos have much reduced venation, hind-wing may be reduced or even absent, while larvae are slender. Eyes in male or turbinate. Larvae of 5 Indian species are known.

Family Ephemeridae

This family is represented in India by 14 species under 3 genera vis-a-vis 99 species 8 genera world over. This family is the second largest family represented in India; Heptageniidae also comes under this family Ephemera Linnaeus is the genus on which early Ephemerida and subsequently subfamily Ephemerillinae was based. It received family status, alongwith Baetidae. Specimen of this family are relatively larger, veins much more than Baetidae, both wings well developed. Larvae are mostly benthic, and are broader and some what depressed. Larvae of only 2 Indian species are known.

Family Heptageniidae

This family is represented by 14 species, under 8 genera vis-a-vis 378 species and 28 genera world over. In a number of genera this family comes next only to Leptophlebiidae (10 genera). This family has its member mostly represented as benthic forms of lotic ecosystem. These have also both wings well developed, profusely reticulated; while larvae are conspicuously broad and flattened. Larvae of only 2 Indian species are known.

TABLE 2

Qualitative composition of Indian Ephemeroptera

Families	India		World		High Altitude			Distribution	
	G	S	G	S	G	S	ES	O	EO
Ametropodidae	–	–	1	4	–	–	–	–	–
Baetidae	6	35	17	519	3	15	29	5	1
Baetiscidae	–	–	1	12	–	–	–	–	–
Behningidae	–	–	3	5	–	–	–	–	–
Caenidae	2	7	6	81	1	1	4	1	–
Ephemerellidae	2	3	7	120	1	2	3	–	–
Ephemeridae	3	14	8	99	1	4	9	5	–
Euthyplociidae	1	1	7	12	–	–	1	–	–
Heptageniidae	8	14	28	378	6	7	12	1	–
Leptophlebiidae	9	10	62	377	2	2	9	1	–
Metrotropidae	–	–	2	7	–	–	–	–	–
Neolphemeridae	–	–	2	8	–	–	–	–	–
Oligoneuriidae	–	–	9	49	–	–	–	–	–
P{allingeniidae	1	3	6	31	–	–	1	2	–
Polymitarcyidae	2	3	6	70	–	–	1	2	–
Potamanthidae	1	1	7	27	–	–	1	–	–
Prosopistomatidae	1	1	1	11	–	–	1	–	–
Siphlanigmatidae	–	–	1	1	–	–	–	–	–
Siphlonuridae	1	1	26	163	1	1	1	–	–
Tricorythidae	–	–	13	122	–	–	–	–	–
Total	36	94	213	2146	15	32	72	71	1

EO = Extra Oriental, ES = Endemic Species, G = Genera, O = Oriental, S = Species.

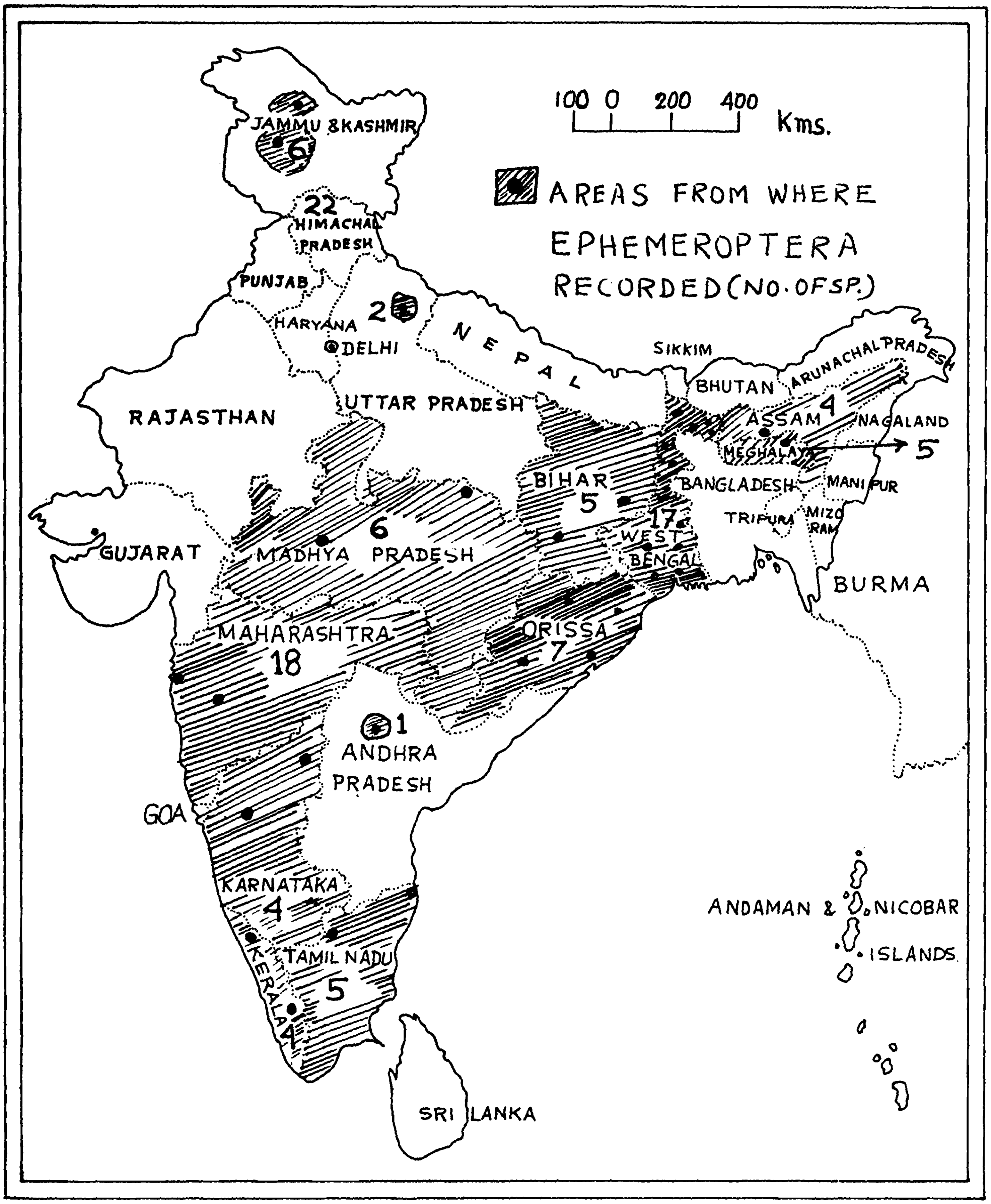
Family Leptophlebiidae

There are 12 species under 10 genera represented in India, as against world fauna of 377 species, 62 genera. This family has maximum number of genera within our limits. This family inhabits mostly in the benthic zone/under the shelter of rocks, pebbles in lotic water bodies. Both imagos and larvae are large and broad. Imagos have well developed pair of reticulated wings. Larvae of only 2 Indians species are known.

Family Caenidae

This family is represented in India by 7 species 2 genera vis-a-vis 81 species 6 genera world over. This family inhabits trash and bottom layer, and its members have protective gill cover of opercular nature. These are smaller mayflies, somewhat like those of members Baetidae, so are reduced wing reticulation. Larvae of only 2 Indian species are known.

The remaining seven families include 9 genera, 13 species. Out of these 13 Indian species, larvae of only 4 are known.



Areas surveyed for Ephemeroptera

Current Studies

In accordance with departmental stress on 'State Fauna' series, Ephemeroptera of Meghalaya with key to their identification and distribution pattern is being carried out in Z.S.I. Similar studies on West Bengal (Srivastava & Sinha,1990) and Orissa (Srivastava & Ray, 1987) have been completed.

Ephemeroptera work is also being carried out at certain institutes, colleges and universities. These are mainly on population dynamics (Gupta & Michael, N. E. Hill University, Shillong); life cycle microdistribution, trophic relationships, fecundity and behavioural pattern of emergence, mating, swarming, oviposition (Sivaramakrishnan and his team at Research Centre in Aquatic Entomology, Dept. of Zoology, Madura College, Madurai).

Ephemeroptera work, outside India, is being carried out on diversified aspects of this interesting group by various workers attached to certain University/Institutes abroad some of their work includes Indian mayflies; their name, address is given under the following item. Most of other workers are there on world fauna their names are not included. The diversified range includes applied aspects, Phylogeny and Systematics, Faunistics, Biology, Ecology, Behaviour reviewing and historical aspects of mayfly biology.

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ODONATA

Introduction

Odonates, which are commonly known as damselfly (Zygoptera) or dragonfly (Anisoptera), are amphibiotic insects. Major part of their life cycle is spent in freshwater ecosystem. This includes oviposition (exophytic and endophytic, amongst aquatic plants), prolarvae and larval stages upto ultimate stage. Adults are flying insects, but relatively of short life. These, thus, belong essentially to the ecogroup of aquatic insects, all members of which undergo aquatic phase wholly or partially for completion of their life cycle. This ecogroup comprises of three other insect orders besides Odonata, namely Ephemeroptera, Plecoptera and Trichoptera.

Odonates, along with Ephemeropterans are the present day representatives of the Insects of Palaeopterous orders. Palaeopterans are one of the oldest winged insects (Pterygota) which first appeared during upper Carboniferous period in Europe and North America, the other winged insects being Neoptera. In Palaeoptera insects were unable to fold their wings backwards to form a roof over the abdomen, while in Neoptera they can fold their wings backwards and form a chitinised cover. In dragonflies both fore and hind wings are in the primitive condition i.e., both are equal in size and similar in venation (primitive Zygopteroid types). In Jurassic period, a new evolutionary line arose and the hind wings became more specialised than forewings, and also more broader, specially in the anal area. These are the larger dragonflies or present day Anisoptera.

Odonata have colourful bodies, clear wings and make swift flying movements. Adults are large predacious insects while larvae are carnivorous and voracious feeders. Adults have a peculiar method of feeding. They capture their prey while on wings with the help of mouth parts and forwardly posed fore legs and consume while flying. Larvae, commonly known as naiads, are essentially aquatic and quite different morphologically. Metamorphosis is incomplete, therefore there is no pupal stage. The larva develops rudimentary wing-sheaths during early stage and has very little resemblance to the adult.

Economic Importance

Ecologically and economically the insects of this order are significant since they are predators of flies, mosquitoes, smaller moths, etc., and as such serve as scavengers. Larva forms an important link in the food chain of freshwater ecosystem being secondary consumers. Montgomery (*vide*, Kiauta, 1975) has aptly indicated its significance that the dragonflies (Odonata) comprise one of the most important group of aquatic animals. Being voracious predators in both immature (aquatic) and adult (aerial) stages, they are important elements of all, except the higher (or high alpine) environment in temperate and tropical regions, occupying a position at the apex of the food chain of invertebrate life. In addition to their biological importance of such environments, these relationships render them the ultimate accumulators of present compounds in polluted waters. They are thus one of ideal organisms to be used as indicators of water quality : pollution and contamination. Many species serve as intermediate hosts of fluke parasites of birds especially of domestic poultry and wild ducks, and thus are important in the transmission of parasitic diseases. Because of their unique morphology and physiology, dragonflies are used extensively in the study of many biological phenomena.

Historical Resumé

i) Pre-1900

The first mention of an Indian dragonfly is available in the *Sangam* literature, written before eight century A. D. (Bhaduri *et al.*, 1972). The first scientific description available is that of

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Neurobasis chinensis by Linnaeus (1758) based on a non-Indian specimen. Johanson (1768), Drury (1773) and Fabricius (1792-1798) contributed to the knowledge of Indian Odonata during the 18th century. A little over 20 species were added by Rambur (1842) from within the Indian limits. Selys - Longschamps (1850-1890) was a keen naturalist, whose contributions to Indian odonates could be described as a Selysian-Era in Indian Odonatology, as he described numerous taxa on the basis of material emanating from India.

ii) 1901-1947

After Selys died in 1890, the lacuna in Odonate studies was filled by Laidlaw and Fraser, and several other workers like Williamson, Ris, Lieftinck, Asahina etc. The three and a half decade beginnings from 1900 can be appropriately termed as the Laidlaw-Fraserian Era. Fraser (1902-1951) made significant contribution in his 40 publications, including three volumes of 'Fauna of British India' published in (1933, 1934, 1936). Laidlaw's (1917, 1922, 1923) studies were mostly confined to Indian Agriidae, Gomphidae, and several subfamilies of Coenagriidae. Fraser, under encouragement from Laidlaw, made two series of contributions, the first started in 1918 as "Indian dragonflies", and the other in 1922 as "*Dragonfly collecting*". These resulted in foundation of three volumes of *Fauna* on Odonata. Besides, Fraser's contributions on *Fissilabes* and account of Western Indian deserve special mention, although both Laidlaw and Fraser restricted their studies mostly within Eastern India and Western Ghats. Several other experts added to our knowledge of Odonata in India in this period. Tillyard (1921) described a relic species, *Epiophelabia laidlawi*, on the basis of larvae collected from the district Darjeeling in the northern mountain tract of West Bengal. Among other workers, Needham (1932) published a key to the Indian Odonata and of Eastern India. Subramanyam (1936) and Vasu (1944) published interesting notes on the ecology of Indian Odonata.

iii) 1948-1990

The post-independence era of Indian Odonatology was marked by a spate of contributions by several workers, but none as exhaustive as Laidlaw and Fraser. Bhasin (1953) has provided a consolidated list, along with their distribution, of Odonata present in Forest Research Institute & College, Dehra Dun, U.P. Later on, Singh & Baijal (1954, 1955a, 1955b and 1955c) studied the material collected by Entomological Expeditions to North-West Himalaya carried out under the leadership of Dr. M. S. Mani of the School of Entomology, St. John's College Agra. Agarwal (1957) reported the fauna of Pilani (Rajasthan) and Bhatnagar and Sahni (1964-65) that of Kumaon region (U.P.). In addition to these, several Indian and foreign workers studied the fauna of Himalaya and Kiauta (1975) published a valuable bibliography of Himalayan Odonate fauna which lists all works published till then.

In recent times, a number of workers, *viz.*, Kumar, Lahiri, Mitra, Prasad, Singh, Sinha, Srivastava and Ram from Zoological Survey of India have contributed several papers on Indian Odonata. Of these, Kumar (1971-1989), Kumar & Khanna (1983), Kumar & Prasad (1977-1971), Prasad (1974-1988), Prasad and Singh (1976-1977) mostly deal with taxonomy (adult & larval), bio-ecology, and Zoogeography of Odonata of Western Himalaya, Sangal & Kumar (1970) and Tyagi, (1971) were also engaged in the study of Odonata of Dehra Dun Valley (U.P.). Tyagi has made contributions on the cytotaxonomy of Odonata of Doon Valley. Consequent to these studies a total of 162 species of adult Odonata (66 Zygoptera and 96 Anisoptera) and 58 species of larvae have been reported from Western Himalaya, with brief descriptions of biotopes, phenology, life history of few species and zoogeography. The zoogeography of Odonata of Western Himalaya has been discussed by Kumar & Prasad (1981) and the species are classified into four faunal elements, *viz.*, Oriental (131 species), Palaearctic (28 species), Ethiopian (2 species) and Circumtropical (1 species). Kumar (1970-1983), Kumar & Prasad (1977, 1978) and Sangal & Kumar (1970) have provided taxonomic descriptions of the last larval instar, life history of a few species, key to their identification, notes on their larval ecology, habitat preference and morphological adaptation in relation to concealment, feeding and respiration etc. Varshney & Guha (1972) and Varshney & Prasad (1981) have reported variations in wings of two species.

TABLE 1

Qualitative Composition of Odonata in India

TAXA				INDIA	
SO	SF	F	SBF	SPECIES	GENERA
Z	COE	Coenagriidae	Amphicneminae	1	1
			Pseudagriinae	22	2
			Coenagriinae	3	2
			Ischnurinae	20	4
			Agriocneminae	13	2
			Agriinae	1	1
		Platystictidae	Platystictinae	11	3
		Protonuridae	Protonurinae	6	2
			Disparoneurinae	7	1
			Caconeurinae	10	4
		Platycnemididae	Platycneminae	6	2
			Calcneminae	10	3
	LES	Chlorolestidae	Chlorolestinae	–	–
			Megalestinae	2	1
		Lestidae	Lestinae	19	3
			Synpecmatinae	3	1
	CAL	Amphipterygidae	Philoganginae	1	1
		Chlorocyphidae		29	4
		Euphaeidae		9	4
		Calopterygidae	Caliphacinae	1	1
			Calopteryginae	3	2
		Agriidae	Agriinae	16	6
		Epallagidae		13	5
AZ	HET	Epiophlebiidae		1	1
A	CORD	Cordulegasteridae	Cordulegasterinae	6	2
			Chlorogomphinae	9	1
	AESH	Gomphidae	Gomphinae	65	15
			Ephiogomphinae	24	5
			Ictinogomphinae	10	2
		Aeshnidae	Brachtrinae	14	8
			Anactinae	10	3
			Aeshninae	4	1
			Gynacanthaginae	15	2
			Polycanthaginae	1	1
	LIB	Corduliidae	Idiomacromiinae	15	2
			Epopthalmiinae	22	3
		Libellulidae	Libellulinae	86	30
		Macrodiplactidae		4	4
3	7	19	32	491	135

A = Anisoptera, AESH = Aeshnoidea, AZ = Anisozygoptera,
CAL = Calopterygoidea, COE = Coenagrionidea, CORD = Cordulegasteridae,
F = Family, HET = Heterophlebiodea, LES = Lestoidea,
LIB = Libelluloidea, SBF = Subfamily, SF = Superfamily,
SO = Suborder, Z = Zygoptera.

Lahiri, Mitra, Ram, Sinha and Srivastava of Zoological Survey of India have studied the Odonata fauna of Eastern India. Their studies included taxonomy, faunistics and ecology. Raychaudhuri *et al.*, (1969) have reported the occurrence of complete and incomplete distal antenodal nervures in the wings of *Brachythemis contaminata*. Lahiri (1977, 1979) has studied the odonate fauna of different States of North Eastern India and has reported 33 species. Lahiri (1987) made a detailed study on the taxonomy of Odonata of Meghalaya reporting a total of 147 species and subspecies belonging to 77 genera and 14 families. Mitra (1983) and Ram *et al.* (1982) reported 59 species from Calcutta, West Bengal. Mitra (1986, 1988) reported 15 species from Mirzapur district (U.P.) and 39 species from Central India. Srivastava *et al.* (1987) have recorded 48 species from Orissa. Bose *et al.* (1976), Prasad & Thakur (1981) and Thakur (1985) have studied the odonate fauna of Rajasthan and recorded 29 species. 63 species of Odonata have been reported by Prasad & Kumar (1977) and Prasad & Varshney (1988) from Bihar. In this connection some field notes, distribution and zoogeography of these species have also been discussed.

Tembhare, an Indian odonate endocrinologist has described the structure of the endocrine system thoroughly. Tembhare and associates (1975-1984) have studied neurosecretory cells of the brain and ventral ganglia, the corpora cardica and other nemohaemal organs and the corpora allata of the nymphs (larva) and adults of *Orthetrum chrysis*, *Pantala flavescens* etc. Mathavan (1974-1984) studied the predatory behaviour in larvae of *Mesogomphus lineatus*, *Pantala flavescens* and *Brachythemis contaminata*. Mathavan (1984) studied the reproductive behaviour in *Brachythemis contaminata* and *Orthetrum sabina*. Chromosomal basis of sex determination in *Anax parthenope*, *Diplacodes trivialis*, *Orthetrum taeniolatum* and *N. tullia tullia* was reported by Thomas & Prasad (1984). Srivastava (1962), Srivastava & Suribabu (1984, 1985, 1988) and Suribabu (1983) have studied the reproductive organs in *Cocothemis s. servilia* and reproductive behaviour in *Ischnura aurora*, *Chloroneura quadrimaculata*, *Ceriagrion coromandelianum* and *Pseudagrion rubriceps*.

Studies from Different Environs

Early studies in India were made from Eastern India, Peninsular India (both eastern and western Ghats) and Western Himalaya. Recent studies add information from different zones, states and ecosystems (Map). States explored are Rajasthan, Jammu, Himachal Pradesh, U.P. (Himalayan portion), Bihar, Orissa, West Bengal, Meghalaya and Andaman and Nicobar Islands.

Odonata of Western Himalaya was studied by Kumar and Prasad (1981) in which 162 species from Jammu & Kashmir, Himachal Pradesh and U.P. were recorded. Prasad (1988) provided an account of male accessary genitalia of 63 species from Western Himalaya. Kumar & Khanna (1983) have provided information on larvae and a bibliography from Western Himalaya. Prasad & Kumar (1977) published a list from Punjab recording 36 species. Bose *et al* (1976), Prasad & Thakur (1981) and Thakur (1985) provided information on Odonata of Rajasthan recording altogether 29 species. Mitra (1986) published a list of 39 species from Central India.

A comprehensive study on the Odonata of Bihar was made by Prasad & Varshney (1988) reporting 63 species and subspecies. Ram *et al.*, (1982) and Mitra (1983) have published accounts on the Odonata of Calcutta reporting altogether 59 species.

From North Eastern India, Varshney (1971) reported some species from Khasi Hills. Lahiri (1987) studied the Odonata fauna of Meghalaya in detail. A total of 147 species and subspecies belonging to 77 genera under 14 families have been dealt with. Lahiri (1979) has published a list of 33 species from different States of North-East India.

Srivastava & Das (1987) have studied Odonata fauna of Orissa and recorded 44 species belonging to 7 families. Of these, 29 species are recorded for the first time from Orissa. Srivastava & Sinha (1990) have given a comprehensive account of 185 species of odonates from West Bengal.

Estuarine fauna of Odonata from West Bengal and Orissa coasts have been dealt with by Prasad & Ghosh (1988), reporting altogether 42 species. Odonata of Andaman and Nicobar Islands have been studied by Chhotani *et al.* (1983) and a total of 27 species and subspecies have been recorded.

Estimation of Taxa

The order Odonata is represented by 37 families clubbed under three suborders namely Zygoptera, Anisozygoptera and Anisoptera. A little over 5500 species belonging to 630 genera in 28 families are recorded from all over the world. Of these about 491 species are represented in India under 135 genera, in 32 subfamilies, 19 families, and 7 super families.

Suborder Zygoptera

Zygoptera first appeared in Upper Permian period. These are characterized by their fore-and hindwings being of almost same shape and size, with a definite discoidal cell formed below the arculus. Body is slender, hence the common name damselfly.

Family Coenagrionidae has maximum representation, 33 species 11 genera, in India. Members of families Coenagrionidae, Platycnemidae and Lestidae breed at the sides of fresh water bodies, while that of Platycnemididae, Protoneuridae, Synlestidae, Calopterygidae, Chlorocyphidae and Euphaeidae breed in hill streams, but sometimes also near waterbodies in the plains.

Suborder Anisozygoptera

It has a single superfamily Heterophbebioidea, comprised of 11 families, all of which, except Epiophlebiidae, have become extinct world over. This last named family is represented by a single species, name within our limits. There is another species found in Japan under this genus. It was described from Darjiling Dist. of West Bengal and has now been protected under schedule of Indian Wild Life Act.

Suborder Anisoptera

Suborder Anisoptera (dragonflies) are relatively robust in built as compared to Zygopterans. Their eyes are not separated by a space greater than own diameter. Wings are usually held horizontally or descended when at rest. In India, the suborder Anisoptera is represented by 285 species belonging to 79 genera under 13 sub-families, 6 families and 3 superfamilies.

Members of families Aeshnidae, Cordulegastridae, Corduliidae and Macromiidae are found in hilly tracts and breed in the hill streams, waterfalls, etc., while that of family Gomphidae is found near hill streams as well as near water bodies in the plains. Libellulidae is found only in the plains.

Current Studies

Scientists of the Zoological Survey of India are presently engaged in the study of Odonata of Meghalaya, Tripura, Gujarat and Uttar Pradesh. Scientists working in other Institutes in India, i.e. at the Department of Zoology, D.A.V. College, Dehra Dun U.P.; University of Saugar, Saugar; Nagpur University, Nagpur, and School of Biological Sciences, Kamraj University, Madurai, are working on the bioecology, endocrinology and toxicology aspects.

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PLECOPTERA

Introduction

Plecoptera or stone flies are generally found in the high altitude hill streams of cold temperate regions. The nymphs are found attached to stony surfaces of the fresh water bodies and the adults are found near the streams or on tree trunks, stones and bushes. They are not conspicuous insects, except the Chloroperlidae which are bright green in colour. The nymphs play an important role in the food chain of aquatic ecosystem. They are weak and fluttery fliers. Many species prefer to run rather than to fly to elude the predators. They are mostly diurnal, except a few species of the suborder Setipalpia which are nocturnal. Food of the adults consists of algae, lichen and foliage, though many species appear to be not feeding at all. The adults live only a few weeks. The composition of stonefly fauna varies in different seasons and habitats. Brachyptery or winglessness is usually found during the winter season. Plecoptera might have evolved from an ancestral form of Orthopteran and Blattaria type in the permian period. Further evolution and dispersal of the families probably took place in the paleozoic era.

Historical Resumé

Works on Plecoptera were done on the availability of material which were scanty. Needham (1909) was the first person who worked on Indian Plecoptera, followed by Banks (1914). In recent years a number of workers took up the group, viz., Kimmins (1946,1950), Aubert (1959, 1967), Jewett (1958, 1960, 1975), Kawai (1963), Singh (1971, 1977), Zwick and Sivec (1980) and Zwick (1981), who worked on taxonomy.

Area-wise Studies

In India this group mainly occur in the hilly regions. however, the collections made were very meagre. In the North-Eastern region, collections were made from West Bengal (Darjeeling dist.), Meghalaya, Arunachal Pradesh, Assam and Manipur, (Aubert 1967). In the North-West region, collections were made from Himachal Pradesh, Punjab and Uttar Pradesh (Jewett 1975, Zwick and Sivec, 1980). In Southern India collections were made from Tamil Nadu (Nilgiri hills, Anaimalai hills, Nagarcoil, Tinnevelly), Karnataka (Bhadravati, Shimoga) and Kerala (Kalpatti) (Zwick 1981). Thus many more areas in the country, particularly Himalayan belt, needed to be explored to augment the collections of this group.

Estimation of Taxa and Classified Treatment

A total of Seven families, 20 genera and 113 species have been recorded from India so far. Approximately 2100 species under 180 genera of 15 families have been known from the world.

Family Nemouridae : This is the largest family in India and composed of three genera and 66 species. Major works on this family have been done by Aubert (1959, 1967), Jewett (1958, 1960) Zwick and Sivec (1980), on the fauna of Eastern and N.W. Himalaya. Baumann (1975) has made a revision of the world genera. Quite a few species are endemic to Indian subcontinent.

Family Perlidae : The family is represented by eight genera and 32 species. Work on this group was done by Kawai (1963), Jewett (1958), Needham (1909), Banks (1914), Zwick and Sivec (1980, 1981). They worked on the fauna of Eastern, North-Western Himalaya and Southern India. Few species of this group are apparently endemic to Southern India.

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Family Perlodidae : Only two genera and three species of this family occur in India. This family has been worked out by Jewett (1958, 1960) from North-West Himalaya and Southern India.

Family Capniidae : The family is represented by only two genera and six species. Jewett (1958, 1960) has worked out the N. W. Himalaya and South Indian fauna.

Family Luctridae : Two genera and two species of this family are reported. Needham (1909), Banks (1914) and Jewett (1958) worked on the collections of Assam and Himachal Pradesh.

Family Taniopterygidae : This is represented by two genera and two species. This group has been dealt by Kimnins (1946), and Jewett (1958) from Himachal Pradesh.

Family Peltoperlidae : This family is represented by one genus and two species. Kimmins (1950) has worked on this group from Assam.

Besides these, few other publications by Kimmins (1946, 1950), and Zwick (1980) have dealt with the collections made from North-East Himalaya.

Current Studies

Studies on this group have been taken up by Das, Singh and others in ZSI recently. State wise fauna is being worked out on the basis of collected specimens and literature records. West Bengal fauna comprises of 21 species in 10 genera; and Meghalaya fauna comprises of 19 species in 8 genera.

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Animal Resources of India : 261–262 : 1991

ORTHOPTERA : Tettigonioidea

Introduction

The members of the family Tettigoniidea, popularly called long horned grasshoppers, are attractive in appearance. The arboreal species often resemble the leaves in colour and design and the ground living forms are dull and wingless.

The following are the diagnostic characters of this family:

i) Tarsi four jointed; ii) Female generally with well developed sword shaped ovipositor; iii) Fore tibiae with auditory Organs; iv) The antennae are elongated filiform structures often greatly exceeding the length of the body and composed of large number of small segments; v) Head of varied shape; and vi)Mouth parts are usually mandibulate, therefore, they are usually herbivorous.

A few species are agricultural pests, as they are commonly seen in green vegetations, upto ten feet height. These insects show a preference for soft leaves and tender stems of herbs and shrubs. Since such vegetations are common in moist humid tropical rain forest of plains and hills, they are distributed in moist parts of India, leaving out arid zones. However, seasonal fluctuation report show that there are two peak seasons in their abundance which coincide with the vegetations and agricultural practices. A few species are agricultural pests, hence economically important.

The difference members of the Tettigoniidae exhibit a great variety of methods of oviposition, some lay their eggs in the ground, on the twigs, the edges of leaves, rows on leaves and stems and others between the root, leaves or stems.

Historical Resumé

Tettigoniid fauna is poorly known and there are less published references on Indian Tettigoniidae. Contributions were made since the time of Linnaeus (1831). Servelle Audient (1839), Walker (1869), Saussure (1892) and Brunner (1895).

After 1900, Kirby, W.F. (1904-1910), Boliver, I. (1906), Caudel, A.N. (1908-1916), Karny, H. (1912-1913), Chopard, H. (1926), Zeuner, F.E. (1936), Bei-Bienko, G. Ya (1956), Beer, M. (1957), Ragge, D.R. (1957) and Barman, R.S. (1976) have made contributions on the systematics of the group.

Estimation of Taxa

The family Tettigoniidae is very poorly represented in India. The members of this family are widely distributed in tropical and subtropical parts of the world. It is observed that out of about 4,000 species of Tettigoniidae known from the world, only 80 species under 72 genera and 6 subfamilies are known from India.

The faunal exploration of this family has not been taken up sufficiently and except for certain areas in North-Eastern India, other areas are under explored. So, there is need to collect and study the material from other parts of India.

Studies from Different Environs

The family is distributed widely in North-Eastern part of India and in Eastern and Western Ghats of Peninsular India. Besides, they occur in Andaman and Nicobar Islands.

Z.S.I. collections are represented mostly from North Eastern India. It becomes thus apparent

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that surveys are needed in other states than the North Eastern States, to assess the actual faunal composition.

Classification

The Tettigoniidae is included under Order Orthoptera, Suborder Ensifera. Ander (1939) divided it into 21 subfamilies including one extinct subfamily in the world. Out of these, six subfamilies comprising 45 species under 32 genera have so far been recorded, mainly from the North Eastern region of India.

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ORTHOPTERA : Grylloidea

Introduction

The superfamily Grylloidea constitutes among Orthoptera an important section of the suborder Ensifera, which includes crickets and mole-crickets. The members of this group are not of much economic importance, except a few species of genera *Gryllotalpa*, *Gryllus* and *Trigonidium*, which are known to attack crops of paddy, potato, tea, jute and citrus. Crickets and mole-crickets are readily recognised by long antennae, presence of auditory organs on anterior tibiae, posterior legs with femora strongly dilated at base for jumping, all tarsi three-segmented, male elytron transformed into stridulatory organs, and ovipositor very large, usually extending much beyond the abdominal extremity. The habits of the grylllids are variable. Many of them live on the ground and often burrow a hole, while the others are found on different plants. Subterranean and cavernicolous species are also found. Gryllids are found in dry conditions, but most of them prefer moisture and some species have adapted to almost an aquatic habit. The food of crickets consists of all kinds of animal and vegetable matters.

Historical Resumé

Charpentier (1825) was probably the first worker to initiate studies on this group. Subsequently Serville (1831, 1939), Bolivar (1862, 1865), Saussure (1877-1878) and Walker (1859-1871) also conducted studies on gryllids. But the foundation for modern systematic work was laid down by Chopard who in 1926 undertook a revision of Indian gryllids. He published a series of papers on Indian gryllids and his efforts were culminated in the publication of a volume on Grylloidea in 1969 under 'Fauna of India' series. In this work,Chopard has also dealt with gryllid fauna of Burma, Malaya, Pakistan, Bangladesh and Sri Lanka.

Chopard's *Fauna* gave an impetus to workers in ZSI to explore and study the Grylloidea fauna of India. Bhowmik (1967- 1977 and 1985), Tandon and Shishodia (1972-1974), Shishodia and Tandon(1975-1977, 1987), Vasanth *et al.*, (1975), Vasanth (1980), Sinha *et al.* (1977), Bhargava (1982) and Agarwal *et al.* (1989) contributed substantially towards our knowledge of Grylloidea of India. As regards the world fauna, several workers like Gorokhov (1978-1987), Harz (1979), Holst (1987), Koehler and Sander (1986), Larochelle (1977), Love and Walker (1979), Otte (1983), Otte and Alexander (1983) Otte and Cade (1983), Otte and Rentz (1987), Toms and Otte (1989), Townsend (1983) and Vamasaki (1979) worked on Grylloidea and added numerous genera and species.

Cytotaxonomical researches have also been conducted on gryllids by various workers in India, e.g. Ali (1979), Arora and Rao (1979), Asana et al.(1940), Bhattacharjee and Manna (1967), Dutta (1949), Manna and Bhattacharjee (1970-1972), Manna (1979), Raman and Rao (1975), Singh (in press) and Vasintha and Bole Gowda (1967). These workers have studied chromosonal polymorphism, cytotaxonomical survey of the group, behaviour of chromosomes during meiosis, sex chromosomes, spermatogenesis, and general studies on chromosomes of some species of grylllids.

Estimation of Taxa

The gryllids are known to occur in almost all the major ecosystems in India. General faunistic surveys have been made by scientists of the department from different parts of the country for the past so many years.

Chopard (1967) has reported 2255 species distributed over 12 families and 364 genera from the

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world, of which 181 species and 64 genera are from India. Later, Bhowmik (1967-1985), Tandon and Shishodia (1972-1974), Shishodia and Tandon (1975-1987), Biswas *et al.* (1977), Vasanth *et al.* (1975), Vasanth (1980), Sinha *et al.*(1977), Bhargava (1982) and Agarwal *et al.* (1989) have described and recorded a number of new genera and species of Grylloidea from India. As a result of all these studies, a total of 225 species distributed over 67 genera are now known from India.

Classified Treatment

The classification of Grylloidea has been established by Saussure (1877- 1878). In his excellent monograph he has discussed the important morphological characters and divided the group into large divisions. Although a large number of species have been described since the publication of Saussure's work, yet his monograph still remains the basis of modern classification. Chopard (1967) has divided Grylloidea into 12 families as follows : Gryllotalpidae, Gryllidae, Myrmecophilidae, Mogoplistidae, Scleropteridae Cacoplistidae, Pteroplistidae, Pentacentridae, Oecanthidae, Phalangopsidae, Trigonidiidae and Eneopteridae.

Current Studies

At present the scientists of Zoological Survey of India are actively engaged in studying the taxonomy of the group under a scheme of State Fauna Series. The gryllid fauna of Orissa (Shishodia & Tandon, 1987), West Bengal (Shishodia & Tandon, in press) and Tripura (Shishodia & Tandon, in press) are the outcome of such studies.

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ORTHOPTERA : Tridactylodea

Introduction

The members of tridactylids are commonly known as Pigmy-mole-crickets. They live on the banks of stagnant or flowing water, though some can tolerate areas which have dried up and where no surface water remains. *Tridactylus quadrimaculatus* is exceptional, as it lives in elephant trails, in scrub jungle in Sri Lanka (Blackith, 1979). These insects burrow into sandy ground, apparently feeding on fragments of vegetable matter. They also feed by digesting bacterial, fungal and algal growth of the surface in the same way as do the earthworms. Faudras (quoted by Dufour, 1838) was the first to suggest that nematodes in river silt might form a significant item of Tridactyloid diet. These insects are completely absent in the areas covered by volcanic ash. The act of burrowing is not necessarily associated with feeding. Faudras (1.c.) was the first to discover that tridactyloids swallow silt and sand under natural conditions. These insects are also capable of moving on or beneath the water surface. Majority of the species are unable to fly in adult stage, in spite of their wings, but many species lack wings. Tridactyloids are harmless creatures, instead they fall prey to many other animals like the beetles, birds, lizards and wasps which forage in river beds.

Historical Resumé

Burmeister (1838) was the first who reported a tridactyloid in his 'Handbook of Entomology' Later, several other workers like Serville (1839), Scudder (1862), Walker (1871), Saussure (1874-1897), Brunner von Wattenwyl (1893), Bruner (1916), Kirby (1906), Ander (1934, 1938, 1939) etc. have worked on this group. Kirby (1906) has prepared a catalogue of this group alongwith the gryllids. Chopard (1928, 1935) has studied tridactyloids of Indian region. Chopard (1925, 1936) and Sandrasagara (1954) have studied tridactylids of Sri Lanka. Recently, Günther (1969-1986), Harz (1970) and Blackith (1987) have published a number of papers on the group.

Estimation of Taxa

Günther (1980) has prepared a Catalogue on Tridactylodea, and has reported 157 species distributed in 11 genera and 3 families from the world, of which 16 species under 3 genera are found in India. Blackith & Blackith (1979), Günther (1982), 1985, 1986) have added 6 more species from the world, but none of them are found in India.

Classified Treatment

The suborder Tridactylodea is divided into three families : Rhipipterygidae, Tridactylidae and Cylindrachetidae. The families Rhipipterygidae and Cylindrachetidae are not reported to occur in India. In other parts of world, the family Rhipipterygidae has 61 species under two genera, and family Cylindrachetidae has 7 species under two genera. The family Tridactylidae is divided into two subfamilies : Tridactylines and Dentridactylinae. Subfamily Tridactylinae has 85 species under four genera, whereas Dentridactylinae has 10 species under two genera known from the world, of which 16 species occur in India. Thus, out of 163 species reported from the world, only 16 species are recorded from India so far.

Current Studies

At present no Indian scientist is working on the taxonomy of Indian Tridactylodea. However, a

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number of workers, like, Blackith, Günther, Harz, Podgornaja etc. are actively engaged on the taxonomy, morphology and ecology of the group in other countries.

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ORTHOPTERA : Eumastacoidea

Introduction

This superfamily is a highly heterogeneous complex and probably polyphyletic in its origin. The knowledge on the group is scanty because of its rarity and cryptic habits. These grasshoppers are mainly found in tropical zones. There are nearly 800 species occurring throughout the world, which includes 28 Indian species. These are harmless insects, which live among bushes. Oviposition takes place in the soil.

Eumastacids may be characterised as follows: Body of variable shape; frons mostly flattened; antennae short, their lower apical part usually with tubercle-like antennal organ; posternal process absent; pronotum flattened dorsally brunner's organ present and tympanal organ absent.

Historical Resumé

Fossils of the group are negligible to be of any use in understanding the evolution and geographical distribution. The origin of Eumastacidae is assumed in the end of Palaeozoic period. The dispersal of these archaic forms, which are no longer to be found might have occurred during the Mesozoic.

Earlier workers on the group include Walker (1870), Stål (1875- 1877), Karsch (1889, 1896), Scudder (1898), Burr (1899, 1903), Brunner von Wattenwyl (1898), Brunner (1901) and Saussure (1903). However, the first attempt to study the Indian forms was made by Kirby (1914) and Bolivar (1914). Bolivar (1930, 1932 and 1944) has published many papers on Eumastacids. Bei-Bienko (1949) has revised one subfamily Gomphomastacinae and later Bei-Bienko & Mistshenko (1951) described the species of Eumastacidae of USSR. Rehn (1904, 1948 and 1952), Rehn & Grant (1958), Rehn & Hebard (1918), Rehn & Rehn (1934-1945) have contributed much towards the knowledge on the group. Recently, Descamps (1964-1975) has revised the group. He has published fauna of Eumastacids of Africa, America, Colombia, Congo, Indo-Malaya, Madagascar, Philippines and Venezuela.

Studies from Different Environs

The Eumastacoidea have a pantropical distribution, but certain subfamilies (Gomphomastacinae, Morseinae, Parepisactinae) are found in cool regions, sometimes in areas where very low temperature persists.

The Indo-Malayan fauna shows direct evolutionary connection with the Ethiopian fauna and to a lesser extent with the Neotropical fauna. No direct relationship is found, however, between the Ethiopian and Neotropical fauna, with the exception of one archaic family, Episactidae.

In India this group has been studied from South India, North-Eastern India and North-West Himalayan regions. It is found mostly in forest areas.

Estimation of Taxa

On the basis of characters of fossil and existing forms, in particular the extremity of male abdominal appendage, it is possible to distinguish altogether 7 families. Out of these, three families are found in Indian region, namely Chlorotypidae, Eumastacidae and Mastacideidae : having a total of 28 species. Mastacideidae is found only in South India.

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Classification

The classification of Eumastacoidea is followed here after Descamps (1973). Study of the endophallic structure in most of the 200 known genera from all over the world makes it possible to recognise four major groups of Eumastacoidea, namely Cryptophalli, Stenophalli, Euphalli and Disclerophalli. The Cryptophalli has two families, Chorotypidae and Episactidae. Chorotuypidae is divided into six subfamilies. These subfamilies (Chorotypinae, Prionacanthinae, Erianthinae, Eruciinae, Chininae, Mnesicleinae) are distributed in Indo-Malayan region except the subfamily Chorotypinae which is also distributed in Africa. Family Episactidae has four subfamilies, and all are distributed in Central America and Madagascar. The Stenophalli has two families, namely Morabidae and Eumastacidae. Family Morabidae has two subfamilies, which are distributed in Australian region. Family Eumastacidae has 9 subfamilies, which are distributed in America, except Gomphomastacinae whose distribution is in central Asia. The group Euphalli has only one family, Mastacideinae, with one subfamily, which is found only in India. The group Disclerophalli has two families, 9 subfamilies, all are distributed in Africa. Thus, there are 7 families and 31 subfamilies in the world, of which 3 families and 5 subfamilies occur in India.

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ORTHOPTERA : Acrididae

Introduction

The members of this family are commonly known as short horned grasshoppers. The migratory forms of this family are termed as locusts. Grasshoppers are readily recognized by the short antennae, usually shorter than the body, three segmented tarsi, auditory organs located on the first abdominal segment and the presence of a short stout ovipositor. Among the grasshoppers are found some of the most important agricultural pests of mankind. They have destroyed the crops of man from biblical days to the present time.

Historical Resumé

Probably Stål (1860, 1873) initiated the study of Indian Acrididae. Walker (1870, 1871) and Saussure (1884, 1888) also studied some Indian fauna. From 1990 onwards, major contributions were made by Bolivar (1902, 1909, 1917-1918). A notable taxonomical work on Acrididae was made by Kirby (1914) in the series 'Fauna of British India' Uvarov (1921, 1924, 1927, 1942) studied in detail Indian Acrididae. Roonwal (1936, 1945, 1946, 1958 and 1976) contributed some studies on the nymphal structures and ecology on Acrididae. Bhowmik (1964, 1965, 1986), Tandon and Shishodia (1969-1989) have contributed works on the taxonomy of this group. More recently, Shishodia and Hazra (1985), Tandon and Hazra (1988) have done work on taxonomy as well as on ecology of this group. Others notable ecological and biological works on Acrididae from India are of Hafez and Ibrahim (1958, 1962), Katiyar (1955), Iqbal and Aziz (1974), Parihar (1974), Muralirangan and Ananthakrishnan (1977), Tandon and Khera (1978), Julka *et al.* (1982), Hazra *et al.* (1981) and Tandon *et al.*, (1988).

Studies from Different Environs

The acridids are found in all ecosystems, from plains, agricultural lands mountain areas to semi-arid lands in India. A number of faunistic surveys have been made by parties of the Zoological Survey of India in different States of the country. The acridid fauna of the State of West Bengal (Hazra *et al.* 1990) are the out-come of such studies.

Estimation of Taxa

The family is divided into 17 subfamilies and altogether over 6000 species under about 1000 genera are known from the world. From India 14 subfamilies, 138 genera and 310 species have been reported.

Classified Treatment

Ander (1939) divided the order Orthoptera into two suborders namely Ensifera and Caelifera. The suborder Caelifera includes shorthorned grasshoppers. Dirsh (1961) regarded Acridoidea as a separate suborder. The number of known genera and species under Indian subfamilies are as follows:

Acridinae, 17 genera and 39 species; Truxallinae, 1 genus and 3 species; Gomphocerinae, 12 genera and 35 species; Oedipodinae, 22 genera and 45 species; Dericorythinae, 1 genus and 4 species; Romaleinae, 3 genera and 9 species; Hemiacridinae, 13 genera and 35 species; Oxyinae, 7 genera and 19 species; Coptacridinae, 4 genera and 12 species; Tropidopolinae, 6 genera and 7 species; Calliptaminae, 6 genera and 14 species;

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Eypreocnemidinae, 12 genera and 26 species; Catantopinae, 27 genera and 51 species and Cyrtacanthacridinae, 7 genera and 11 species.

Current Studies

At present the scientists of Zoological Survey of India are actively engaged in studying the taxonomy, ecology and biology of this group. S. K. Tandon is preparing a volume on Indian Acrididae under the 'Fauna of India' series. Recently, Usmani and Shafee (1985) from Aligarh Muslim University have contributed some work on the subfamily Oxyinae.

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Animal Resources of India : 275–277 : 1991

ORTHOPTERA : Pyrgomorphidae

Introduction

The Pyrgomorphidae represents a distinctive family of acridoid grasshoppers, called "bushhoppers", the majority of which are found in tropical and subtropical countries, chiefly of the Old world. The family name dates back from the vernacular, *Pyrgomorphiden* Brunner von Wattenwyl (1874). The members of this group are very harmful to the crops and other vegetations. Species of *Atractomorpha, Chrotogonus, Colemania* and *Poekilocerus* are notorious pests. The family is divided into two subfamilies, Pyrgacridinae and Pyrgomorphinae. There are altogether 440 species distributed under 148 genera known from the world, of which 40 species under 19 genera are known from India.

Historical Resumé

i) Pre–1900

The taxa included at present in Pyrgomorphidae were under "Familie Acridien" (Acridoidea), until Walker (1870) raised it as a "limited family", Phymat[e]idae, within the family Acrididae. Stål (1873) completely revised the classification of the "familia Acridoidea" and introduced an entirely new and more extensive concept of the group, which he called "Subfamilia Phymatidae" Brunner von Wattenwyl (1874) split Stål's Phymat[e]idae into two : "Zunft der Pyrgomorphiden" and "Zunft der Phymat[e]iden" Bolivar (1884) in his monograph assumed that Brunner had changed the name of the family, because of the confusion between Phymat[e]idae (Orthoptera) and Phymatidae (Hemiptera), but it was Bolivar (1884) himself (not Brunner) who pointed out the apparent (but not real) homonymy. Bolivar (l.c.) ignored Brunner's division and followed Stål's arrangement using Pyrgomorphidae to include all genera.

For sometime the group was recognised as a tribe of the family Acridoidea. Later authors began to regard these insects as constituting the "subfamily Pyrgomorphinae" of the "family Acridiidae" or Acrididae (McNeill 1896, Brunner 1900, Rehn 1904, 1907 etc.). Brunner von Wattenwyl (1862, 1893 and 1898) studied the taxonomy of the group from Sri Lanka, Burma, Java and Malaya. Walker (1870, 1871) has prepared a Catalogue of genera and species known upto that period. Stål (1877) studied the genus *Tagasta* from Philippines. General observations on the zoogeography of the Pyrgomorphidae were published by Bolivar (1884). Bolivar (1898) studied the taxonomy of Indomalayan taxa. Barlow (1896) studied the Indian species exclusively, for the first time.

ii) 1901–1947

Bolivar (1902, 1921), Maxwell–Lefroy & Howlett (1909–1910) and Fletcher (1914) reported the Pyrgomorphids of Indian region. Kirby (1910, 1914) prepared a Catalogue for Acrididae, including this group of the world, and a volume of 'Fauna of British India', including fauna of Pakistan, Bangladesh, Sri Lanka and Burma. Later Chopard (1924), Uvarov (1925, 1928 and 1929), Ramakrishna Ayyar (1940) have also worked on Indian species of Pyrgomorphidae.

iii) 1948–1990

Chapman & Robertson (1958), Phipps (1959–1970), Chapman (1961–1964), Ramsay (1964), Descamps and Wintrebert (1966), Dirsh (1968), Jago (1968, 1973), Keven (1974, 1975) and Parihar (1971, 1972) have worked on biology, ecology and distribution of this group. Tandon & Khera (1978), Hazra *et al.* (1981), Mondal & Shishodia (1982), Julka *et al.* (1982) Shishodia &

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Dey (1982) and Hazra *et al.* (1984) have worked in recent times on various aspects of ecology and distribution of Indian Pyrgomorphids. Shrinivasan (1988) has presented the zoogeography of S. Indian grasshoppers covering Pyrgomorphids.

Keven (1953–1970) has worked on taxonomy of Oriental taxa. Keven & Akbar (1964) revised some species. Sandrasagara (1950) has worked on the taxonomy of this group from Sri Lanka. Roonwal *et al.* (1951) and Bhasin & Roonwal (1954) have reported Indian species. Bhowmik (1964, 1984), Tandon & Shishodia (1969–1989), Singh & Keven (1976), Tandon *et al.* (1976), Bhowmik & Halder (1976, 1983), Usmani *et al.* (1985), Shishodia & Hazra (1986) and Shrinivasan (1986) have worked on the taxonomy of various genera and species from different parts of Indian region. A biometric study of *Poekilocerus pictus* has been made by Varshney & Nahar (1980).

Classified Treatment

As there are not much differences in external morphology and phallic structure, many workers do not divide this family into subfamilies. Dirsh (1956) though tried to divide the group into tribes on the basis of phallic structures, but failed. Recently, Keven (1977) has divided this family into two subfamilies, Pyrgacridinae and Pyrgomorphinae. The Pyrgacridinae has one genus and two species only, which do not occur in India. The Pyrgomorphinae is divided into two, Orthacrides and Pyrgomorphides. The Orthacrides has several supertribes, tribes, subtribes, and includes 54 genera and 149 species from the world, of which 6 genera and 18 species are found in India.

The Pyrgomorphides has been divided into several supertribes, tribes, subtribes as well and includes 94 genera and 291 species from all over the world, of which 13 genera and 22 species are found in India. Thus, a total of 440 species under 148 genera have been recorded from the world, of which 19 genera and 40 species are known from India.

Current Studies

No survey work has been done exclusively for the group from the Head Quarters of Zoological Survey of India. The group has been collected by different parties of ZSI, along with other orthopteran specimens from different environs. Singh & Keven (1965) have dealtwith the species of the subtribe Orthacridina, found in South India. Tandon & Shishodia (1989) have given a faunistic account of Acridoidea, including Pyrgomorphidae, of Orissa.

D. K. McE. Keven is actively engaged on studying the taxonomy, ecology, distribution and zoogeography of the group. Asket Singh (retired from the Zoological Survey of India) with McE.Keven, is engaged in writing a volume of 'Fauna of India' on Pyrgomorphidae of Indian subcontinent. Identification and related studies are undertaken in the Orthoptera Section at ZSI (H.O.) Calcutta and at its Canning Field Station.

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ORTHOPTERA : Tetrigoidea

Introduction

The members of the superfamily Tetrigoidea are popularly known as "Grouse-Locusts" These are small to moderate sized orthopterans of variable colour. They commonly occur in meadows or swamps, or on wet rocks along the sides of streams and pools, while a few are found on or around the crops. Both the adults and immature forms of grouse-locusts are known to feed on mosses and other lower forms of vegetations. Very little is known about their economic importance.

Tetrigids are readily recognised from other allied superfamily, Acridoidea, by the absence of arolium between the tarsal claws; the anterior and middle tarsi consists of two segments while the posterior tarsi with three segments; the backward extension of pronotum forms a hood-like covering over the body; and elytra short and scale-like.

The classification for Indian Tetrigidae is followed after Hancock (1915). He divided the family into six subfamilies, namely Tripetalcerinae, Batrachidinae, Cladonotinae, Tettiginae, Scelimeninae and Metrodorinae.

Steinmann (1970) adopted the same classification of Hancock (1915), except that for the names Batrachidinae and Tettiginae, which he called Batrachideinae and Tetricinae respectively. The subfamily Tetricinae is now called Tetriginae.

Historical Resumé

Westwood (1834) was the first to describe a tetrigid. This was followed by Serville (1839). In 1842, it was de Haan who proposed a synoptical table for these insects to separate them from the other allied groups. Saussure (1861), Walker (1871) studied the collections of Orthoptera which were present in the Geneva Museum and the British Museum respectively. Later on Stal (1873), Bolivar (1887-1918), Brunner von Wattenwyl (1893), Kirby (1910, 1914) and Hancock (1904-1915) did a lot of work on tetrigids. Günther (1935-1941) and Steinmann (1962-1971) also contributed to the knowledge on the group. But nobody has worked on Indian tetrigids, except Kirby (1910, 1914), Hancock (1912, 1915), Bolivar (1909, 1918) and Günther (1938, 1939). Kirby (1914) has described 5 new genera and 10 new species, besides the already known 23 genera and 73 species. Hancock (1912, 1915) studied the Indian Tetrigidae which was available in the then Imperial Agricultural Research Institute, Pusa, Bihar (now Indian Agricultural Research Institute, New Delhi) and Indian Museum (now at the Zoo. Surv. India, Calcutta) respectively. In the later study he has described two new genera and 35 new species besides the other already known species. Fletcher (1921) gave a full list of synonyms and references along with the distribution for the Tetrigidae of India and the adjacent countries. Hebard (1929) studied the South Indian Tetrigids. Günther (1935-1941) has revised the subfamilies of Tetrigidae except those of Batrachideinae and Tetriginae. Steinmann (1964-1971) has compiled the taxonomical work of the family Tetrigidae in the form of Checklist which gives us a zoogeographical picture of the species of the world. Grant (1966) has studied the genera of Batrachideinae. Recently Shishodia (in press) has submitted a paper on the 'Taxonomy and zoogeography of the Tetrigidae of North eastern India' In this paper, 77 species are dealt with, of which 13 species are new, 6 are new records for India, one new genus is proposed and two new synonyms are established.

As far as the world fauna on the group is concerned, several workers like Blackith & Blackith (1987), Blackith (1988), Cejchan (1983), De Fault (1987), Gunes (1989), Günther (1979), Holst (1987), Ingrisch (1983, 1987), Key (1987), Larochelle (1978), Harz (1978, 1988), Liang (1988), Liang & Zheng (1984, 1985), Llorente (1982), Nishida (1979-80), Podgornaja (1976, 1982,

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1986), Ortega & Marquez (1989, 1989), Voisin (1979) and Zheng & Liang (1985, 1987) have worked and added numerous species to the world fauna.

Studies from Different Environs

The tetrigids are found in almost all the ecosystems in India ranging from the sea-level to the mountains. In general the tetrigids have been collected from all over the country by different survey parties of ZSI for the past so many years. Recently, Zoological Survey of India has taken up a programme under which detailed state-wise studies are being carried out. The tetrigid fauna of the state of Orissa (Shishodia, 1987), and Maharashtra (Shishodia, 1990) are the outcome of such studies.

Estimation of Taxa

Westwood (1834) was the first to describe the tetrigids, followed by Serville (1839), Haan (1842), Saussure (1861), Walker (1871), Stål (1873), Bolivar (1887-1918), Brunner (1893), Hancock (1904-1915), Kirby (1910, 1914) and Günther (1935-1941). But the study on Indian tetrigids was initiated by Walker (1871), Bolivar (1909-1918), Kirby (1910, 1914) and Hancock (1908-1915). As a result of above studies, a total of 988 species distributed under 195 genera were recorded from all over the world (Steinmann, 1971). Of these, 122 species under 35 genera are found in India. Recently, Shishodia (in press) has described 13 more species and a new genus, thus making a total of 135 species and 36 genera from India.

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PHASMIDA

Introduction

The order Phasmida includes stick and leaf insects, some of which represent curious examples of mimicry. It is a group of large tropical insects with well developed sclerotised bodies (Gunther, 1953).The stick insects possess elongate and cylindrical body and are often apterous. They resemble twigs in colour and appearance. The leaf insects are flattened and leaf-like, with lamellate expansions of the legs.

Historical Resumé

The Phasmid fauna of India was not studied until 1859. Westwood (1859) was the pioneer worker, who had rearranged the Phasmida of the British Museum and published a monograph, under the title of 'Catalogue of Orthopterous insects' Other works are those of Westwood (1859), Bates, (1865), Woodmason (1875), Brunner von Wattenwyl, (1906-08), Kirby (1910) and Gunther (1938, 1953) who have dealt with the Indian fauna.

Estimation of Taxa

About 2,500 species are known from various parts of the world, out of which 60 species are recorded from India. The Indian species belong to 25 genera under 8 subfamilies.

Most of the Indian Phasmida are recorded from North Eastern Region. However, more surveys are required in mountain regions and forests of the country to better understand the group.

Classification

Gunther (1953) has divided the Order Phasmida into two families, viz., Phylliidae and Phasmatidae; each possesses a number of subfamilies.

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DERMAPTERA

Introduction

Dermaptera, commonly known as earwigs, constitute a well-defined group of homogeneous insects. These are characterised by three segmented tarsi and a pair of unsegmented, chitinized cerci or forceps, present at the hind end of the body. Economically these insects are not of much importance, except that a few species act as pollinators when they inhabit flowers, or feed on pollen grains, and destroy tender parts of plants. *Euborellia stali* (Dohrn) causes damage to groundnut by boring through the pods and completing life cycle inside it (Cherian and Basheer, 1940).

Dermaptera are spread all over the world, but attain their maximum development in terms of numbers in tropical and subtropical parts of the world. The occur in variety of habitats, such as dead and decaying matter, bamboo scales, leaf axils, flowers, under loose bark of trees and occasionally in bird nests. A large number of species are found under dung of various animals. A few species are recorded from high altitudes up to *ca* 4500 m and even on snow. They generally occur in humid places, in small to large groups, but it is not unusual to find solitary individuals. Parental care is exhibited by a few species.

Classification

Verhoeff (1902) gave entirely a new line of thought in the taxonomy of the group, by using male genitalia as the basis of classification. However, in the absence of detailed descriptions and illustrations it was not of much value. Later it was further elaborated by Zacher (1911). Bormans (1900) and Burr (1911) provided a detailed classification, which was based on morphological characters. Besides, Burr (1915-16) made hurried genitalic studies, utilizing Zacher's (I.c.) observations in support of his arrangement. His work was discontinued abruptly due to his involvement in Ist world war. Popham (1965) made made a comprehensive survey of male genitalia and presented a modified classification. Recently, Steinmann (1975) has provided an improved arrangement, which in essence is the extension of Popham's work. The outlines of this classification are presented as follows, with some modification :

I. Superfamily PYGIDICRANOIDEA (= Protodermaptera Zacher)

1. Family Pygidicranidae Verhoeff

Subfamilies Anataeliinae Burr, Challinae Steinmann, Pygidicraninae Verhoeff, Diplatyinae Verhoeff, Esphalmeninae Burr, Brindlensiinae Srivastava, Balndicinae Burr, Pyragrinae Burr, Karschiellinae Burr, Cylindrogastrinae Maccagno, Diplatymorphinae Boeseman and Prolabiscinae Bey-Bienko.

II. Superfamily ANISOLABIOIDEA

2. Family Anisolabididae Sakai

Subfamilies Platylabininae Burr, Gonolabidinae Popham and Brindle, Titanolabidinae Srivastava, Anopthalmolabidinae Steinmann, Carcinophorinae Hincks, Brachylabidinae Burr, Isolabidinae Steinmann, Antisolabidinae Brindle, Parisolabidinae Verhoeff, Idolopsalidinae Steinmann and Isolaboidinae Brindle.

3. Family Labiduridae Verhoeff

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Subfamilies Allostethinae Burr, Nalinae Steinmann and Labidurinae Burr.

III. Superfamily APACHYOIDEA (= Paradermaptera Verhoeff)

4. Family Apachyidae Verhoeff

Subfamily Apachyinae Burr

IV. Superfamily FORFICULOIDEA (= Eudermaptera Verhoeff)

5. Family Spongiphoridae Verhoeff (= Labiidae Burr)

Subfamilies Pericominae Burr, Nesogastrinae Verhoeff, Ramamurthinae Steinmann (= Physogastrinae Ramamurthi), Vandicinae Burr, Strongylopsalidinae Burr, Sparattinae Burr, Geracinae Brindle, Isopyginae Borelli, Cosmogeracinae Brindle, Irdexinae Srivastava, Spongiphorinae Burr, Homotaginae Srivastava and Labiinae Burr.

6. Family Chelisochidae Burr

Subfamilies Chelisochellinae Steinmann and Chelisochinae Burr.

7. Family Forficulidae Stephens

Subfamilies Ancistrogastrinae Burr, Sarcinatrinae Steinmann, Cosmiellinae Steinmann, Opisthocosmiinae Verhoeff, Diperasticinae Burr, Allodahlinae Verhoeff, Anechurinae Burr, Eudohrniinae Burr, Rhycolabinae Steinmann, Neolobophorinae Burr and Forficulinae Burr.

Historical Resumé

Linnaeus (1758) described two species and altogether 17 species of Dermaptera were described by Fabricius (1775). Some of these species are now worldwide in distribution and are also found in Indian subcontinent.

The earliest record of a species is by Guerin-Meneville (1838) from South India based on a female named as *Pygidicrana picta*. Subsequently, other authors namely Dohrn (1863 and 1865), Bormans (1888 and 1894), Kirby (1891) and Bolivar (1897) dealt with and added several new species to the list of Indian Dermaptera. Bormans (1900) published a world monograph on Dermaptera, which brought at one place for the first time, the scattered informations on the group.

During the years 1900-1907, Burr published a number of papers partly based on the collections in the Indian Museum, Calcutta and described a large number of species from India and adjacent countries. In the year, 1910 Burr's monograph on Dermaptera under the *Fauna of British India* series appeared. His other works (1911, 1913 and 1914) mainly dealt with Indian fauna on the material preserved in the Indian Museum, which was passed on in 1916 to the Zoological Survey of India. Borelli (1909, 1911, 1912 and 1931) published four papers dealing with Indian fauna. In his work in 1911 he described one interesting genus with a new species. Hebard (1917) described two new species from India and in 1923 published another paper exclusively on Indian fauna and established two new genera and 10 new species besides several known ones. In this work he also laid stress on the intraspecific variations.

Bey-Bienko's (1936) monograph on the fauna of U.S.S.R. and adjacent countries, dealt with a few species occurring in Kashmir. In his another paper (1959), on fauna of South China, he dealt with species that also occur in North-eastern India.

Hincks (1955 and 1959) revised Family Pygidicranidae at the world level, on the basis of male genitalia, recording several new species from India. He described some more new species from India and neighbouring countries in his subsequent works (1954, 1957 and 1960). In recent years the work of Hinks (1955-1960), Brindle (1965-1980), Steinmann (1973-1990) and Srivastava (1968-

Table showing zoogeographical composition of Dermaptera species from the Indian region including Andaman & Nicobar Islands.

Families & Subfamilies	Genera	Species	ORIENTAL Indian peninsular	ORIENTAL North India including Himalaya & N.E. mountains	ORIENTAL Sri Lanka	ORIENTAL Rest of area	P	E	AS	WW
PYGIDICRANIDAE										
Pygidicraninae	1	20	10	7	2	2	—	—	—	—
Diplatyinae	4	45	23	27	6	6	—	—	—	—
Echinosomatinae	1	7#	3	3	1	1	—	—	—	—
Prolabiscinae	1	1	—	1	—	—	—	—	—	—
ANISOLABIDIDAE										
Platylabininae	1	2	1	1	—	—	—	—	—	—
Titanolabidinae	1	2	2	—	1	—	—	—	—	—
Carcinophorinae	10	40	17	20	12	7	2	3	2	2
Brachylabidinae	4	9	2	5	2	—	—	—	—	—
Isolabidinae	2	4	1	—	3	—	—	—	—	—
Antisolabidinae	1	1	1	—	—	—	—	—	—	—
Parisolabidinae	1	2	—	2	—	—	—	—	—	—
Isolaboidinae	1	4	—	4	—	—	—	—	—	—
LABIDURIDAE										
Allostethinae	2	4	4	—	—	—	—	—	—	—
Nalinae	1	3	1	3	1	2	1	1	1	1
Labidurinae	2	14†	3	15	2	4	1	1	1	1
APACHYIDAE										
Apachyinae	2	2	—	1	1	1	—	—	—	—
SPONGIPHORIDAE (= LABIIDAE)										
Sparattinae	1	2	2	—	—	—	—	—	—	—
Irdexinae	1	3	2	1	1	1	—	—	—	—
Spongiphorinae	2	5	5	3	3	3	1	1	1	1
Homotaginae	1	2	—	2	—	1	—	—	—	—
Labiinae	4	30	12	20	7	8	2	2	2	2
CHELISOCHIDAE										
Chelisochellinae	1	1	—	1	—	1	—	—	—	—
Chelisochinae	7	27 *	9	18	2	12	1	1	1	1
FORFICULIDAE										
Cosmiellinae	1	6	—	6	—	—	—	—	—	—
Opisthocosmiinae	9	20	6	11	3	4	—	—	—	—
Allodahlinae	1	9	—	9	—	1	—	—	—	—
Anechurinae	4	10	1	9	—	—	8	—	—	—
Eudohrniinae	3	11	3	9	2	2	—	—	—	—
Forficulinae	4	34	4	29	2	8	24	2	1	1
TOTAL	74	320	112	207	51	64	40	11	9	8

* Including one from Andaman Is. # Including two from Andaman Is. † Including three from Anadman Is.
P = Palaearctic, E = Ethiopian, AS = Australian, WW = World wide.

1990) have contributed much on the Indian Fauna. Besides, a number of known or new taxa from India were described in the works of Baijal and Singh (1954), Singh (1955), Gangola (1965), Ramamurthi (1960-1968), Kapoor (1966-1980) and Kapoor and Bharadwaj (1968). Srivastava's (1976) Catalogue on Oriental Dermaptera, Sakai's (1970-1991) Dermapterorum Catalogus Praeliminaris, and Steinmann's (1989) World Catalogue of Dermaptera deserve mention.

Prior to 1960, studies on Indian Dermaptera were carried out mostly by foreign experts, who received collections for their study from Museums of Asiatic Society, Indian Museum and Zoological Survey of India. Ramamurthi (1960-1968) was probably the first Indian to start systematic work on Indian Dermaptera. He worked on materials from South India at the Loyola College, Madras. Kapoor (1966-1980) made notable contributions while working at Agra College, Agra, Division of Entomology, Indian Agricultural Research Institute, New Delhi and Tribhuan University, Kirtipur Campus, Kathmandu (Nepal). Gangola worked at D.S.B. College, Nainital (U.P.) and has published (1965) two papers on Dermaptera of Kumaon Hills. Srivastava is working in the Zoological Survey of India at Calcutta and contributing papers since 1968 on the systematics of Indian Dermaptera extensively.

The Zoological Survey of India has infrastructure to collect material from the field and procure materials in exchange, as a result of which a large collection specimens of known species and several new species are incorporated.

Estimation of Taxa

About 1800 species are known all over the world, out of which 320 species belonging to 74 genera and 7 families are recorded from India and adjacent countries. The accompanying table provides composition of Dermaptera from the area. (See table).

Although most of the States of India have been faunistically surveyed for Dermaptera, intensive surveys of Manipur, Tripura, Meghalaya, Mizoram, Madhya Pradesh and Western Ghats (Goa and Coorg) may yield interesting forms, since the fauna of these areas do not seem to be fully explored in view of the rich forest cover or remoteness of certain areas.

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EMBIOPTERA

Introduction

The Embioptera constitute one of the smallest and most unique order of insects. These are commonly known as embiids or web–spinners. These insects exhibit a number of unique specialisation along with certain primitive features. This led Imms (1913) to remark that these are worthy of being compared with Peripatus and Anaspids, among other Arthropods. These are medium–sized (5–25 mm), slender built, campodeiform insects, with chewing mouth parts and metatarsus of fore–legs swollen containing glands and spinnuettes. Females are apterous while males may be either apterous or winged. Reproductive both sexually and parthenogenetically.

The habit and habitat are also specialised, for the order. Embiids occur in humid places, usually shun light and are noctural; the adults sometimes move about during the daytime if the sky is overcast. They, in all life stages, live gregariously in the silken tunnel under bark, stone or soil. They spin with their feet. The threads are formed from a slaction that comes out of a few tubular bristles on their feet andhardens on contact with the air. The tunnels help in protection against predaceous insects. Oviposition and the number of eggs laid under natural conditions, varies.

Besides tunnel, there are other specialized habitats. In Sudan, *Embia termitophila* is termitophilous and live in the colony of *Bellicositermes natalensis* while in India, some species of the genus *Oligotoma, viz., O. greeniana, O. ceylonica indica* and *O. minuscula* live in association with the social spider *Stegodyphus sarasinorum.* Generally, ants and spiders are common enemies of these insects. The Proctotrupid, *Embidobia urichi* is an egg–parasite and Bathylid, *Mystrocnemis embiidarum* larval ectoparasite.

The Embiopterans are not of much economic importance neither these are beneficial nor harmful to man and his agriculture, forestry etc. Even their role in food–chain is of very minor significance. These insects are known to feed on decaying vegetable matter; thus they play the role of humification of soil. The fuller knowledge of the order may be helpful from the point of view of theories of evolution and zoogeography. The male embiopterans could also serve as an ideal demonstrating generalised anatomy of Pterygote, as pointed out by Ross (1970).

The Palaentological records of embiopterans are fragmentry, owing presumbly due to their fragile body. The first member [*Oligotoma antiqua* Pictet = *Haplaembia antiqua* (Pictet)] appeared in the Tertiary Baltic Amber and in the shales of the Lower Permian of Kansas (*Colothoda spp.*), Florissant, Colo. and in Post–tertiary of Africa and Asia. The phylogeny of embiopterans is, therefore, not definite. There does not exist unanimity in entomologists on this aspect.

Tillyard (1926) opined that some of these forms belong to the order Protembiaria, which may be an offshoot of the Protorthoptera. Treading on the same line, Snodgrass (1937) basing on the male genitalia, and Kershaw (1914), basing on embryology firmly postulate that may be an Orthopteroid group. Mukherjee (1927) thought that these are only survivors of Protorthoptera.

Classification

The classification of the order has its own history. The name Embioptera was coined by Shipley (1904) and it is being used consistently by Imms (1930), Metcalf and Flint (1932), Falsom and Wardle (1934), Davis (1939), and Ross (1940). Before this, certain other names were coined *viz.* Embidina Hagen (1885), Embidopteres Lame'ere (1900), Embiidina Enderlein (1903), Embiodea Kusnezow (1903), Embioidea Embiania Handlirsch (1903), Adenopoda Verhoff (1904), Oligoneura Borner (1904) etc.

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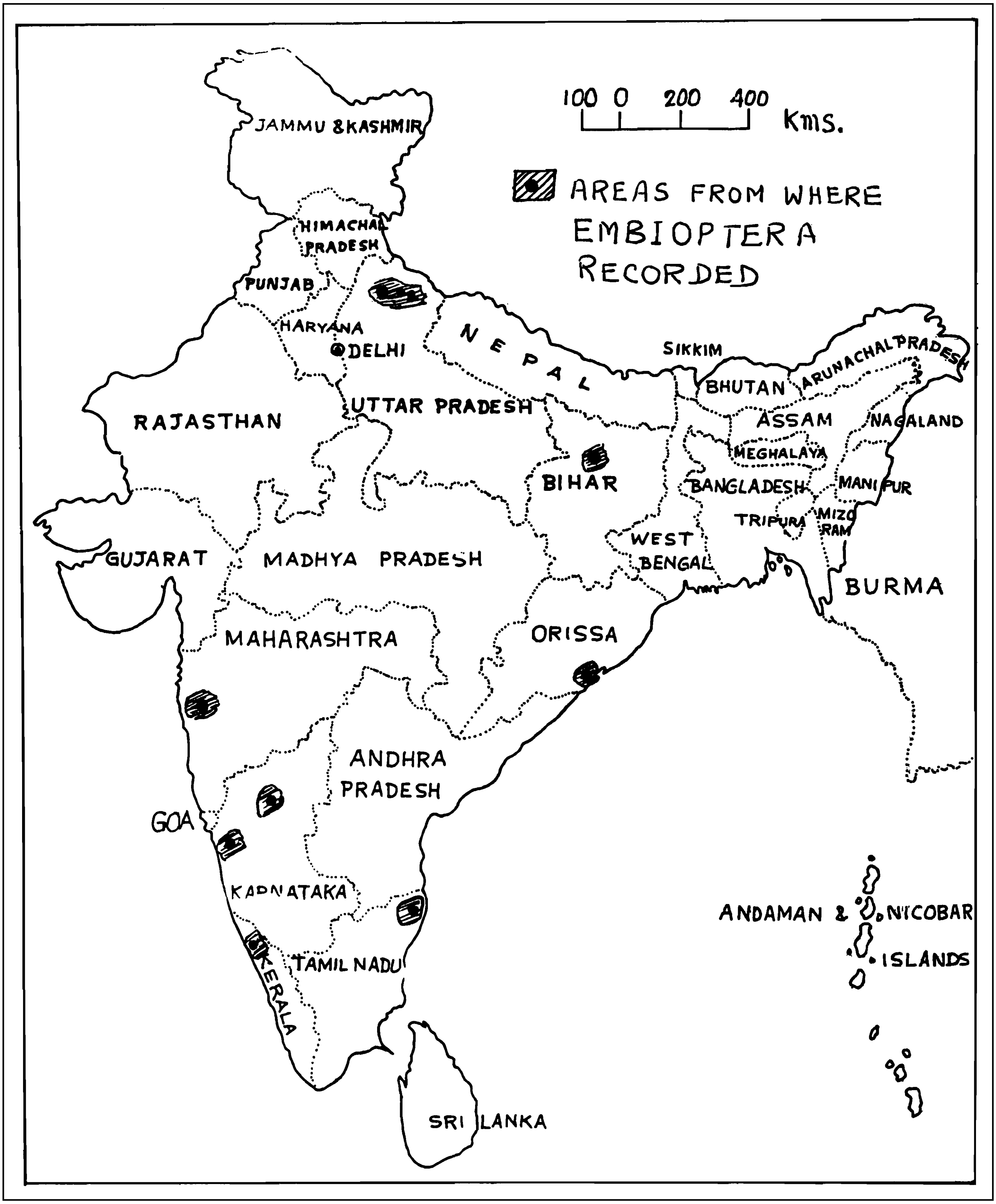

Areas surveyed for Embioptera

The classification of the order, presently accepted, is based on Ross (1970). The character of unique asymmetrical male genitalia is utilised as the basis of classification of the order; in contrast, no reliable characters of taxonomic significance have been developed for females.

Ross (1970) divided the suborder Embioptera into 4 suborders viz., Embioptera and 3 suborders as "A", "B" and "C" The former is the main group, with 5 families : *Clothodidae, Embiidae, Notoligotomidae, Embonychidae* and *Anisembiidae*. Suborder "A" of Ross included *Australembiidae*; suborder "B" included a family to accommodate *Enveja bequaertic* Navas and the complex of closely related species only known from Katanga and Northern Zambia. The last suborder, designated "C", included 2 families namely *Oligotomidae* and *Teratembiidae*. It is thus seen that the order is mainly comprised of 8 families having about 200 species from the whole world. Ross (1972) indicated the possibility of many more species to be added. Indian component of the order comprises only 33 species, so far known, under 4 genera and 2 families *viz., Embiidae* and *Oligotomidae*.

Historical Resume

A perusal of literature on the development of Embiopteran studies, reveals that it is relatively much less known than other members of "Orthopteroid" group of insects.

i) Pre-1900

During this period no Embiopteran work was contributed on the Indian material, either by Indian or foreign entomologists. However, some contributions are worth mentioning from other parts of the world. Hagen (1885) first published a consolidated report on seventeen species. In the twentieth century, Krauss (1911) reported fifth species and Enderbin (1912) recorded sixty species. Davis (1940) constructed a key for identification of 140 species recorded from different parts of the world. Ross (1940, 1944) added significantly to the knowledge of the group in his "Embioptera of North America" and "A Revision" of the Embioptera or the Web spinners of the New World" Davis (1938, 44) published "Studies on Australian Embioptera" and the "Revision of Embioptera of Western Australia"

ii) 1901-1947

The first record of Indian Embioptera is available in Imms (1913) wherein he described *Embia major* from the Himalayas. He was followed by Mukherjee (1927) who described *Embia minor* from Calcutta. He also provided the biology and the bionomics of the species. Davis (1940) discovered *Pseudembia paradoxa* and *P. truncata*. Ross (1943) described *Metembia flava* and *Oligotoma folias* and also the lectotype of *O. borensis*.

iii) 1948-1990

Ross (1950) in his *"The Embiidae of India"* constructed a key for identification of genera and species known from India during that period. This included about a dozen species. Among the Indian workers Bhasin (1953) first reported three species from India present in the collection of the Forest Research Institute and Colleges, Dehra Dun. Ananthakrishnan and Ananthasubramanian (1956) recorded some species from South India. Kapur and Kripalani (1957) worked and contributed on Indian Oligotomidae and added *Oligotoma greeniana* Enderlein to the fauna of India, originally described from Sri Lanka. A number of new species *Oligotoma pruthii, O. anandalei, O. signata, O. gravelyi, O. montana* and *O. himalayensis* were also added. Bradoo and Joseph (1970) reported *O. greeniana* from Kerala. Bradoo (1971) observed seven species of Embiids from Karnataka and Kerala coastal area, of which *Oligotoma dharwariana* and *O. josephii* were new to science. First record of bionomics on Indian Embioptera was by Mukherjee (*cf.* above). Ananthasubramanian (1956) reported the biology of *Oligotoma humbertiana* Saussure and Ananthasubramanian and Ananthakrishnan (1960) of *Oligotoma minuscula* Enderbin, the smallest Oligotomid, from

Madras. Bradoo (1967) studied the life–history and bionomics of *Oligotoma ceylonica* Enderlin and its commensalism with the social spider *Stegodyphus sarasinorum* Karsch. Bradoo and Joseph (1970) recorded the life history of *O. greeniana* and its commensalism with *Stegodyphus sarasinorum.*

The study on the Embiopteran fauna of different ecosystems in India is quite limited. *Embia* and *Oligotoma* and important genera occurring in India. Of these *O. nigra* Hagen is abundant in northern India; *O. saundersii* Westwood is common in the plains of West Bengal; while *O. latereillei* Rambur is common also the West Coast of India.

Following is a synopsis of the fauna recorded from different ecosystem of India :

a) *Species recorded from the Himalayas :*

Embia major Imms; *Oligotoma gravelyi* Kapur and Kripalani; *O. montana* Kapur and Kripalani; *O. himalayensis* Kapur and Kripalani etc.

b) *Species recorded from the Gangetic alluvium :*

Embia saundersii Westwood, *E. minor* Mukherjee, *Oligotoma greeniana* Enderbin etc.

c) *Species recorded from Barkuda Island, Orissa : Oligotoma anadabi* Kapur and Kripalani

d) *Species recorded from Eastern Ghats : Oligotoma pruthii* Kapur and Kripalani

e) *Species recorded from the West Coast of India :*

Oligotoma ceylonica ceylonica Enderlin, *O. c. indica* Davis, *O. dharwariana* Bradoo, *O. greeniana* Enderlin, *O. humbertiana* (Saussure), *O. josephii* Bradoo, *O. latereillei* Rambur, *O. minuculav* Endubin, *O. saundarsii* Westwood and *Pseudembia truncata* Davis.

Estimation of Taxa

In India, there are about thirty three species, spread over four genera and two families *viz.* Embiidae and Oligotomidae. World fauna of this group of insects is represented by 200 species in 8 families.

In Embiidae, the genus *Embia* Latreille occurs from Mediteranean to South Africa and India. *Pseudembia* Davis and *Metembia* Davis occur from Iraq to India. In the family Oligotomidae, the only genus *Oligotoma* Westwood occurs in Africa, India, Papua, etc.

The following species are endemic to India:–

a) *Family : Embiidae* : This family has 5 endemic species under 3 genera viz., *Embia major, E. minor, Pseudembia paradoxa,P. truncata* and *Metembia flava.*

b) *Family : Oligotomidae* : This family has 9 endemic species representing only single genus *Oligotoma* Westwood, viz., *Oligotoma annandalei, O. folias, O. gravelyi, O. ceylonica indica, O. dharwariana, O. himalayensis, O. josephii, O. montana,* and *O. pruthii.*

Classified Treatment

This insect group, as known, is a mixture of primitive and specialized features, having discontinuous distribution. The differences in opinion on the phylogeny of the group have made its taxonomy a puzzle, and the classification is dependent on males only.

The classification proposed by Ross (1970) is generally accepted.

The following break–up indicates the status of the order in India :

Family	*Genus*	*Species*
1. Embiidae	*Pseudembia*	6
	Embia (Paraembia)	8
	Metaembia	3

2. Oligotomidae *Oligotoma* 16

The Family Embiidae Burmeister, is relatively quite well represented.This family has been considered to be a'Catch – Call' of several discrete generic groups. This is mostly confined to the Old World, with its greatest concentration in India and Africa, though the genera *Embia* and *Paraembia*, range up to Southern Europe and Middle East.

The family *Oligotomidae* Enderlein, is a well established family, including many common embiopterans. The members of this family are mainly restricted to Asia and Australia, except for the genus *Haptoembia* Verhoeff, which has westward extended distribution up to the Mediterranean and Black Sea. The largest genus of the family is *Oligotoma* Westwood, which has probably differentiated in Peninsular India. The Indian embiopterans under this genus are represented by 16 species.

The other 6 families of Embioptera which are not represented in India, may also be briefly discussed. The family *Clothidae* Enderlein is small, but not well defined. This includes most generalized Embioptera [*Clothoda nobilis* (Gerstaceker)]. Members of this family are confined to tropical forest of Amazon, North America and Trinidad. The family *Notoligotomidae* Ross is stated to be limited to certain Tropical Asian zone, Thailand and Australia. *Embonychidae* Navas is represented by a single known species, *Embonycha interrupta* Navas from northern part of North Vietnam. *Anisembiidae* Davis is strictly a New World family. *Austraembiidae* Ross embraces East Australian genera *Australembia* Ross and *Metaoligotoma* Davis.

The habit and habitat of embiopterans have been studied but their importance in humus formation has not been assessed quantitatively. Although some enemies have been discovered but detailed studies have not yet been made. Therefore, it can be said that there is enough scope of studies on the ecology of the group. In India, only sporadic records of collection of the group are available. Therefore, no definite idea could be formed on zoogeography and fauna of the country.

Current Studies

The order Embioptera is relatively much less represented and worked out group. There is initiation in shape of listing, distribution pattern of Indian Embioptera at Z.S.I. The taxonomy and bionomics of the order has been tackled by workers at some Indian Universities and Colleges (Loyola College, Madras; D.A.V. College, Abohar and Calicut University).

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DICTYOPTERA : Blattaria

Introduction

The name 'Cockroach' has been derived from Spanish Cucaracha. From the geological aspect they constitute a very old order, many genera and species having existed as early as the Carboniferous and Permian. This ancient group of insect is source of origin of the majority of Hemimetabolous orders, which can fold their wings at rest and is further characterised by a jugal field with many veins, and usually possessing many Malpighian tubules.

Cockroaches are placed within the Order Dictyoptera. Dictyoptera means dictyon, a network; pteron, a wing. Most cockroaches are moderately large insects, even though some species measure only 5 mm in length. The body is strongly depressed and the abdomen bears two caudal appendages. Besides this, males have two further appendages. They are brown or brownish - black in general colour. The head is bent downward and covered by a shield - like pronotum. The mouthparts are formed for chewing. The antennae are long and many - jointed. They are usually four winged, though some species may be wingless. They are more fully developed in the males; in the females they may be reduced or absent. The two pairs of wings differ in size and structure. The fore-wings are generally stronger, tough and elytra-like, the hind wings broad and membranous. They are not used much for flight, however, for cockroaches fly only short distances, the chief organs of locomotion being the legs which have greatly developed coxae and five-jointed tarsi. The metamorphosis is incomplete. The eggs are enclosed in characteristic purse-like Oothecae which the females carry at the end of the abdomen often for several days until they find a place to conceal the capsule.

The members of this group have economic and medical importance. This topic falls under three headings (1) Consumption of human food stuffs or crops, (2) Vectors of disease or parasitic organisms of man or domestic animals, (3) Spoilation of food and nuisance value in houses and buildings as a troublesome pest. There are a number of records of cockroaches causing damage to plants by eating roots or flowers of the plants. Cockroaches feed upon the bark of trees or fruits. P. surinamensis (L) is the most often cited species causing massive destruction of tobacco plants, according to Roeser (1940). The importance of cockroaches as vectors of vertebrate pathogens is well known.

Classification

The higher classification of the Order poses certain difficulties according to Rehn (1951). The modern classification centre round the work of Chopard (1938), Princis (1962-65), Rehn (1951) and Mckittrick (1964), whose main interest were directed towards living forms. Princis (1951-1971) reviewed many aspects of cockroach taxonomy. According to Mckittrick, Rehn and Princis have developed separate classifications solely on the ground of skeletal characters of different groups and therefore he attempted to employ skeletal, myological and behavioural informations on the elucidation of systematic relationships. Roth's contribution is mainly based on applied work in this group. Princis divided Indian Blattids into 14 families and 8 subfamilies.

Historical Resumé

Earlier workers like Saussure (1863-1896), Brunner (1865-1893), Walker (1868, 1871), Kirby (1903, 1904), Chopard (1921, 1924) and in recent years, Rehn (1903, 1951), Bey-Bienko (1938, 1950, 1957, 1965,1969), Mckittrick (1964-1965), Asahina (1955, 1964), Princis (1951, 1971) and Roth (1952, 1986) have described a number of species. As a result of above studies a total of about

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4,200 species are recorded from all over the world, out of these 156 species are found in India.

Studies from Different Environs

Cockroaches thrive best in tropical and subtropical climates and are introduced throughout the world through transportation of commercial products. District-wise distribution of Indian species is not yet fully known, except for Orissa and West Bengal.

Blattids are known to occur in almost all the major ecosystems in India. Although general faunistic surveys have been made by scientists of Z.S.I. from various parts of the country, still further more explorations are needed for obtaining comprehensive knowledge on the group. Recently the Zoological Survey of India has undertaken the project of preparing 'State Fauna' of different States of India and the Blattid Fauna of Orissa and West Bengal are outcome of such studies.

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Animal Resources of India : 299–300 : 1991

DICTYOPTERA : Mantodea

Introduction

The common name of 'praying mantis' has been applied to this group, because of the habit of adults in holding their grasping fore-legs in 'namaste' posture while waiting for the prey. These are carnivorous insects. Their body is elongated, specially the prothorax and the forelegs are long and spinous for capturing prey. They prefer warm moist climate of tropical and sub-tropical zones of the world. Mantids are considered beneficial for their role as predators of insect pests of field crops.

Historical Resumé

The mantid fauna of India was not studied until J. Wood-Mason, the then curator of Indian Museum, who became a pioneer worker on this group of insects in India and contributed good number of publications in 1877, '78, '82, '84, '89, '91.

The other notable workers were Giglio-Tos (1912, '15, '17, '19, '27), Werner (1926, '30, '31, '33, '35) and Beier (1931, '46, '63). Nadkerny (1965) catalogued a total of 55 species present in the collections of the Bombay Natural History Society. Recently in Zoological Survey of India, work on Indian Mantids has been taken up.

Estimation of Taxa

An analysis of known records reveals that about 86 species under 44 genera are known from the North Eastern region. 55 species under 29 genera occur in Southern India. Madhya Pradesh, Andhra Pradesh, Orissa, Manipur, Tripura, Bihar and Goa are underexplored.

The world fauna of praying mantids consists of 8 families, 28 sub-families, about 360 genera and over 2000 species. Nearly 50% of world fauna occurs in Ethiopian region and about 20% in Oriental region. From India 6 families, 161 species under 67 genera have been recorded so far.

Classified Treatment

Considering their unique distinctive features, mantids are sometimes separated from Order Dictyoptera and dealt as a separate Order Mantodea (Beier, 1964).

Families Metallyticidae, Amorphoscelidae and Eremiaphilidae are represented by only one species each from India. The subfamily Acromantinae, under family Hymenopodidae has 7 species under 2 genera. The better known family Mantidae has 14 subfamilies covering 122 species under 50 genera. The family Empusidae is represented by 2 subfamilies with 7 species under 3 genera.

Current Studies

In Zoological Survey of India a study on the Indian Mantid fauna, under the Collaborative Research Project Scheme, has been conducted by Dr. T.K. Mukherjee of Darjeeling Govt. College.

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Animal Resources of India : 301–307 : 1991

ISOPTERA

Introduction

Termites or white ants belong to a small order of insects, Isoptera. They are one of the most fascinating group of insects due to their primitiveness in orgin in the Cretaceous period, ubiquitous in distribution in the tropics, polymorphic caste system, cryptobiotic mode of life helping them pass unnoticed, superb architectural ability in making nests, unique ecological adjustment, and for their immense economic importance. In search of food and shelter, termites cause considerable damage to wood in forest and agricultural crops, to timbers in storage and in buildings, to books, clothes and other articles of cellulosic orgin. It is estimated that the amount of loss thus caused by termites in India alone runs to several millions of rupees per year and the loss all over the world must be something colossal.

India being a tropical country with varied physiography, climate and vegetaion, has more than 200 species of termites, distributed from the plains to the high altitude of the Himalaya. Termite distribution is generally limited by certain combination of factors, such as, tropical climate, restricted diet of cellulose, consequence of soft body forcing them to live in closed nests, vulnerability to predators and weak flight. The phylogeny of the termite genera is better known than many other groups of animals of comparable size. This is due to constellation of multiple characters available from imago, soldier and worker castes, availability of more than 60 fossil species, receprocal phylogeny of termitophiles, symbiotic flagellates, etc. Moreover, phylogeny in many instances is correlated with ecological, geographical and palaeontological parameters.

The study of termites has been used to illustrate various evolutionary principles, such as, homology, covergence, parallelism, divergence, progressive and regressive, and adaptive evolutionary concepts.

Large number of invertebrate (beetles, flies, and others) including some fungi, have well adopted to living either in termite gut (flagellates) or in their nest from the very bigining of their evolution, leading to interesting relationships. Such intimate relationship with termitophiles and symbiotes has thrown light to understand the reciprocal evolution of both the host termites and their associates.

The cryptobiotic mode of life in termites has made them unique subject of study. The main attraction is due to their role in disintegration of wood and cellulose, their place in the food chain of many tropical animals, their close association with fungi, termitophiles and parasites, their unique symbiotic relationship with protozoans and bacteria; their complex behaviour and nest constuction, their mechanism of caste differentiation, intricate social life, etc.

The recognition of the species in termites is very difficult due to minor variations in morphological characters in all the castes, namely, imagos, soldiers and workers. However, the soldiers, primarily adapted for defence of the colony, exhibit comparatively significant characters for taxonomic identity. As such the museum collections represented by soldiers, are essential for taxonomic purpose. Imagoes and workers associated with the soldiers are identified indirectly in most of of the cases. However, the generic identification is easy as compared to that of species.

Historical Resumé

i) Pre–1900

India has the oldest citation of reference on termites in literature by the name as *ghuna* (wood destroyer) particularly in the ancient sanskrit text, the *Rig Veda* (*ca.* 1350 B.C.); and as

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kasthaharika in the Ramayana and other sanskrit literature. The oldest scientific name of a termite species, *Termes fatale* "from Indiae" appeared in "Systema Naturae" 10th edition, which is considered as the starting point of animal taxonomy published by Linnaeus (1758). Linnaeus recognized three species of termites, and put them under two different orders, namely, Neuroptera and Aptera. However, the species, *Termes fatale* is actually from Surinam, South America, and not from India.

Work from India was initiated in 1779 by Konig on a mound building termite in south India. This was later on identified as *Odontotermes redemanni* (Wasmann) by Roonwal (1970) although others referred to it as *Termes fatalis* König (Hagen, 1858; Green, 1913). The other three species dealt with by König (1779) are now in *Anacanthotermes* Jacobson, *Macrotermes* Holmgren and *Hospitalitermes* Holmgren. After König's publication, only 16 species were brought to light upto the end of 19th Century by Rambur (1842); Walker (1853); Hagen (1858, 1859); Brauer (1986); Wasmann (1893, 1896) and others.

Classification : Since the time of Linnaeus, the termites were assigned to different Orders, Suborders and Tribes, until Brulle (1832) put them in the order 'Isopteres' The placement of termites in this order was not accepted by the then workers (Latereille, 1802; Walker, 1852 and Hagen 1858). However, after a lapse of many years, Comstock and Comstock (1895) revived the status of the order Isoptera. Credit goes to Hagen (1858) who recognised for the first time four genera under the Order, namely, *Kalotermes* Hagen, *Termopsis* Desneux, *Hodotermes* Hagen and *Termes* Linnaeus, and to Froggatta (1896) for recognising four sub-families namely Calotermitinae, Rhinotermitinae, Glyptotermitinae and Termitinae under a single family Termitidae. Thus, the foundation of termite classification was laid during this period.

Catalogues, lists, etc. : The list of Neuropterous insects (including termites) were published by Walker (1853) and Hagen (1858). The latter author also published a synopsis of Neuroptera of Sri Lanka in successive years (1858 and 1859).

ii) 1901-1947

The resident zoologists in India, mainly attached to Imperial Agricultural Research Institute, Pusa; Forest Research Institute, Dehra Dun; and Zoological Survey of India, Calcutta, realised the importance of studying these noxius insects and got them identified from foreign experts. Termites from some parts of India and Sri Lanka were worked out by Wasmann (1902) and Desneux (1904, 1906, 1908); those from Sri Lanka by Holmgren (1911), from south India by Holmgren (1912, 1913), from different areas of India by Holmgren and Holmgren (1917), from Abor Hills by Silvestri (1914), from Barkuda Island by Silvestri (1923), from Sri Lanka by Bugnion (1912, 1913, 1914), Bugnion and Ferrier (1911), Bugnion and Popoff (1910), John (1925), and Kemner (1926, 1932); from India by Snyder (1933, 1934), from India and Burma by Gardner (1944) and others. As a result, an addition of about 130 species was made during this period.

References to termites were made by different workers in their books etc. Lefroy (1909) in *'Indian Insect Life'* listed 20 species grouped in three genera. Fletcher (1914) listed only three species and Ayyar (1940) in his book on South Indian insects made some casual mention of termites. However, valuable biological information on 50 species is available in the book *'The Ecology and Control of Forest Insects of India and the neighbouring countries'* by Beeson (1941).

Classification : At the begining of 20th century, Desneux (1904) compiled the available knowledge in the 'Genera Insectorum' under Isoptera, with inclusion of a single family Termitidae containing three subfamilies, Calotermitinae, Mastotermitinae and Termitinae. However, Mastotermitinae gained the status of a family later on (Silvestri, 1909). Synder (1949) published a more sound classificatory catalogue, following the contributions of various workers including those from the Indian region (Holmgren, 1910, 1911; Green, 1913; Snyder, 1920, 1933; Light, 1921; Margabandhu, 1934, etc.).

Phylogeny : The phylogenetic aspects of termites were first discussed by Holmgren (1911,

1912) including some genera from the Indian region, who put emphasis on the characteristic of imago-worker mandibles. This has been proved an ideal conservative character on which the present day phylogenetic study is based, supported by some other characters. On the other hand, Hare (1937) based his phylogenetic study on the basis of the development of soldier's mandible, which today seems to be less sound.

Catalogues, lists, etc. : The references of some 30 species of termites from the Indian subregion, could be found in a catalogue compiled by Desneux (1904), 44 species from Sri Lanka by Green (1913) and of 119 species from India and Sri Lanka by Margabandhu (1934, 1935).

iii) 1948 - 1990

This is the most productive period as far as the termite research is concerned in the entire world including the Indian region. The basic impetus came from two outstanding publications, namely World Catalogue by Snyder (1949) and Phylogeny of World Termite Genera by Ahmad (1950).

The taxonomic work in India gained its maximum momentum during this period under the initiative of Roonwal first at the FRI, Dehra Dun and later at ZSI, Calcutta and ZSI, Jodhpur. He along with his collaborators namely Sen-Sarma, Kumar Krishna, Chhotani, Chatterjee, Thakur, Thapa, Bose, Maiti, Verma, Rathore, etc, worked on different aspects. The termite research at ZSI, Calcutta flourished from 1956 under Roonwal and his students, Chhotani, Bose and Maiti, with reference to taxonomy, morphology, phylogeny, zoogeography, biology and ecology. Numerous publications were made, including a '*Fauna of India*' volume on the lower termites by Roonwal and Chhotani (1989). Another volume in this series is awaiting publication.

Revisionary Works : At the begining, emphasis was laid to revise common genera containing disputed species, for example *Neotermes* Holmg. and *Glyptotermes* Frogg. were revised by Roonwal and Sen-Sarma (1960), *Coptotermes* Wasmann by Roonwal and Chhotani (1962), *Cryptotermes* Banks by Chhotani (1970), *Glyptotermes* by Chhotani (1975), *Stylotermes* Holmg. and Holmg. by Mathur and Chhotani (1959), *Microcerotermes* Silvestri by Prashad, Sen-Sarma and Thapa (1967), *Microtermes* Wasmann by Chatterjee and Thakur (1964), *Hypotermes* Holmg. by Chatterjee and Thakur (1963); *Eurytermes* Wasmann by Roonwal and Chhotani (1966), *Nasutitermes* Dudley by Prashad and Sen-Sarma (1966), *Odontotermes* Holmg. by Thakur (1981) and *Heterotermes* Frogg. by Thakur and Sen-Sarma (1979).

State Fauna : Considering the vastness of the Indian subcontinent, State-wise study of termite fauna gained importance. The fauna of Assam region (N.E. India) was published by Roonwal and Chhotani (1962), Rajasthan by Roonwal and Bose (1964), Tripura by Sen-Sarma and Thakur (1979), West Bengal by Maiti (1983), Orissa by Chhotani and Das (1983), and South India by Bose (1984). The fauna of some neighbouring countries were also studied, for instance, the fauna of Paksitan by Ahmad (1955), Indonesia by Roonwal and Maiti (1966), Bangladesh by Akhtar (1975), Bhutan by Roonwal and Chhotani (1977), and Sabah, West Malaysia by Thapa (1982).

Many important discoveries were made during this period. The most significant is the discovery of a family Indotermitidae (Roonwal and Sen-Sarma, 1960), with type genus *Indotermes*. The validity of this family however, has been questioned (Krishna, 1979). A number of genera, namely, *Postelectrotermes* Krishna, *Epicalotermes* Silvestri, *Calcaritermes* Snyder, *Psammotermes* Desn., *Speculitermes* Wasmann, *Anoplotermes* Muller, etc., were recorded for the first time from Indian region indicating zoogeographical significance. A total of 157 species were added to the known fauna, to make a total of about 300 species altogether known from the region.

Classification : The foundation of present day Isoptera classification was laid by Synder (1949) and Grassé (1949) in two separate contributions, which have been generally accepted with some minor modifications. Both the classifications recognized six families, but Mastotermitidae was divided into two families in one (Synder, 1949) and Hodotermitidae into two families in another (Grassé, 1949). This system was further substantiated by phylogenetic study based mainly on the character of imago-worker mandibles.

Out of nine families recognised so far, except two families, Mastotermitidae (confined to Australia) and Serritermitidae (Brazil), all other families, namely Kalotermitidae, Termopsidae, Hodotermitidae, Rhinotermitidae, Stylotermitidae, Indotermitidae and Termitidae occur in the Indian region. The largest family, Termitidae, often referred to as higher termites, contains three-fourth of the known species. The subfamilies, Termopsinae and Stylotermitinae were raised to family level by Grassé (1949) and by Chatterjee and Thakur (1964) respectively.

Phylogenetic Studies : The first phylogenetic account was proposed by Ahmad (1950) mainly based on the characteristic feature of the imago-worker mandibles. This pattern remained almost unchanged except some additional works done subsequently, e.g. by the study of entiric valve of digestive tract and wing-micro-sculpturing (Roonwal and co-workers 1974-1988).The phylogeny of Kalotermitidae was revised by Krishna (1961), Nasutitermitidae by Sands (1957), *Capritermes* complex by Krishna (1968), Stylotermitidae and Indotermitidae by Roonwal (1975), Nasutitermitinae by Sen-Sarma (1968), *Anoplotermes - Speculitermes* - complex by Roonwal and Chhotani (1966), and *Grallatotermes* - complex by Sen-Sarma (1966).

Catalogues, lists, bibliographies, reviews etc. : The first ever world Catalogue was published by Snyder (1949), which stimulated research around the world. Catalogue of the Indian Isoptera was published by Rattan Lal and Menon (1953), and that of Isoptera collection present in F.R.I., by Roonwal and Pant (1953), which was revised by Mathur and Thapa (1962). Roonwal (1962) gave an excellent review of the systematic work done on world termites (1949-'60), appended with a catalogue and a bibliography. More recently, Chhotani (1972,1977) reviewed the taxonomic work done on termites of the Indian region appended with a catalogue and a bibliography.

Zoogeography : The first analysis of origin, dispersal and zoogeography of the world termites was made by Emerson (1955). Zoogeography of the regional fauna has been discussed by many authors, e.g. of Assam region by Roonwal and Chhotani (1965), Bhutan by Roonwal and Chhotani (1977), Rajasthan by Roonwal and Bose (1964), Andaman and Nicobar Islands by Roonwal and Bose (1965,1970), West Bengal by Maiti (1983), Bangladesh and Pakistan by Akhtar (1974,1975). Zoogeography of some genera, namely, *Cryptotermes* (Chhotani, 1970), *Glyptotermes* (Chhotani, 1975) and *Odontotermes* (Thakur, 1976), were also analysed. The origin, dispersal and evolution of termites in the islands of Andaman and Nicobar have been discussed by Maiti (1977,1979).

Biology: The progress on biological research of Indian species, however, does not commensurate with that of taxonomic research. Some biological notes were incorporated in the faunistic reports. Specific studies on different termites are limited to the nature of infestation in wood and wood products, nest structure, gallery pattern, swarming period, colony development,fungus comb, nest population, etc. The data on these aspects are available in the contributions of Beeson (1941), Mukherjee and Mitra (1949), Roonwal (1970,1979), Sen-Sarma et al. (1975) and Maiti (1983).

The nest structure of *Coptotermes* (Roonwal, 1954,1959; Roonwal and Chhotani, 1962,1967), *Microcerotermes* (Roonwal, 1979), *Odontotermes* (Roonwal, 1973) and arborial carton nests of *Nasutitermes* (Chhotani and Bose 1979) have been described in detail. The general biology of local termite fauna of Dehra Dun (Mathur and Sen-Sarma, 1959, 1960,1962; Chatterjee and Sen-Sarma 1962; Sen-Sarma, 1962), West Bengal (Maiti, 1983), Rajasthan (Roonwal and Verma, 1973; Roonwal and Rathore, 1974, 1975, 1976, 1978; Roonwal 1975) and penisular India (Roonwal, 1978) are studied.

Ecology: The ecological investigations on Indian termites gained less attention than it deserves. Only a few species have been studied with reference to temparature and humidity responses (Sen-Sarma, 1969, 1974, Sen-Sarma and Gupta.1968; Sen-Sarma and Misra, 1969, 1971, 1976), termite and fungus interactions (Bakshi, 1962, Mukherjee and Mitra, 1949), termite and symbiotic flagellate association (De Mello 1919, 1928,1937, 1941; Chakraborty and Banerjee, 1956; Das, 1972, 1974, 1983; Uttangi, 1959, 1962; Mukherjee and Maiti, 1988,1989) and swarming period (Mathur, 1962; Maiti, 1983).

Studies from Different Environs

During the post Independence period, some preliminary work on the composition and faunal strength of termite fauna of different environs has been available. The arid zone fauna of Rajasthan was studied by Roonwal and Bose (1964); that of humid zone of North - east India by Roonwal and Chhotani (1962); of temperate and montane areas of the north-west Himalaya by Chatterjee and Thakur (1967); the deltaic and the sub-Himalayan West Bengal by Maiti (1983); of Bhutan Himalaya by Roonwal and Chhotani (1977); of the peninsular tract by Bose (1984); and the insular areas of the Andaman and Nicobar by Roonwal and Bose (1965, 1970) and Maiti (1977, 1979). Studies on termites of Meghalaya and Tripura are in progress at ZSI, Calcutta.

Estimation of Taxa

Out of nine families recognised so far, seven families are represented so far in the Indian region. The scrutiny of literature shows that about 300 species under 45 genera occur as shown below :

Family	No. of Genera	No. of Species
Termopsidae	1	1
Hodotermitidae	1	4
Kalotermitidae	11	55
Rhinotermitidae	8	28
Stylotermitidae	1	8
Termitidae	22	201
Indotermitidae	1	3
Total	45	300

Classified Treatment

Family Termopsidae

Members of this family inhabit primarily wood. They are divided into three genera all over the world. In India, the family is represented by species, *Archotermopsis wroughtoni* (Desneux), described in 1904 from the Himalaya. This species has undergone several nomenclatural changes and its biology is worked out better than any other species.

Family Hodotermitidae

Out of five living genera known so far from the world with a total of 12 species only, one genus *Anacanthotermes* occurs in this region, represented by four species, of which *A. baluchistanicus* Akhtar is described recently from Pakistan (Akhtar, 1972). The taxonomy and distribution of all the species have been dealt recently by Roonwal and Chhotani (1989).

Family Kalotermitidae

The members of this family strictly inhabit wood in its many forms, including dead portion of live trees. Out of 24 genera known so far, nine genera represented by 56 species occur in this region, which have been extensively studied by Indian workers (Roonwal and Chhotani, 1989). Of these genera, *Postelectrotermes* Krishna, *Calcaritermes* Snyder and *Epicalotermes* Silvestri are recent addition to the Indian fauna (Roonwal and Maiti, 1966; Roonwal and Chhotani, 1983; Chaudhury and Ahmad, 1972). Altogether 33 species are described recently.

Family Rhinotermitidae

The members of this family feed on dead and decaying wood and live in cracks and crevices of the trees, with or without soil connection. Some species are capable of transporation through floating logs like that of coconuts, and thus got introduced in the coastal areas of different continents. Eight genera represented by 28 species occur in this region. Out of a total of 13 genera known from the world, 12 species have been described as new to science by recent workers, *vide* Roonwal and Chhotani (1987).

Family Stylotermitidae

This small family contains a single living genus *Stylotermes* distributed in the Oriental region. It has three segmented tarsi as also in Indotermitidae and also share some characters of Kalotermitidae and Rhinotermitidae. All the members inhabit the dead and decaying portions of standing trees. Since its establishment by Holmgren and Holmgren, 1913, the family was represented by only species *Stylotermes fletcheri* Holmgren and Holmgren, until seven more species have been added by the recent workers.

Family Indotermitidae

This small family is represented by single genus *Indotermes* Roonwal and Sen-Sarma, (1958). *Sinotermes* erected by He and Xia (1981) from China has recently been merged under it (Roonwal and Chhotani, 1989). As Such, genus *Indotermes* contains seven species from South and South-East Asia. All its members are subterranean in habit.

Current Studies

Active research on termites is being conducted in ZSI, and its Desert Regional Station, Jodhpur, and in FRI, Dehra Dun. Recently biological investigations are also being taken up in the Department of Zoology, Vishwa Bharati, Santiniketan. Some research activities are also in progress in certain Universities in South India.

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Animal Resources of India : 309–312 : 1991

PSOCOPTERA

Introduction

Psocoptera, popularly known as 'Book Lice', or 'Psocids' is peculiar of Insecta. Earlier Burmeister (1839) named Psocopterans as 'Corrodentia', then Wardle (1937) placed it in the order 'Psocoptera' These are very small, soft bodied insects and may be winged or apterous, with two or three segmented tarsi. Mouth parts are biting–type, maxillae single lobed, the lacina used for rasping of fragments of bark or other tissues. These are gregarious in habit. A number of arboreal species are found either on bark or on foliage, others may be found mainly on litter or associated with building and domestic habitats or with haystacks, organic debris, lichens or yeasts. A group of Psocopterans also have special preference for cellulose in form of books, papers and book binding materials, hence the common name 'Book Lice.' Arboreal and litter forms lay eggs in groups, covered with silken webs.

There exists a number of theories indicating the *origin and phylogeny* of the order. Sellards (1909), Crampton (1919), Zellasky (1937) and Smithers (1972) have traced the probable origin from the 'Neuropteroid' group of Insects.

Prosoptera are relatively inconspicuous and less represented order of Insects. Most of these are of little economic importance, except of course, extensive damage caused by those which inhabits our valuable books, zoological and botanical specimens, herbariums and other house hold material. A few individuals may occasionally deseminate plant disease by feeding pathogenic fungi and leaving viable spores in faeces deposited elsewhere (New, 1971). They may also act as vectors for some animal parasites. Allen (1959) reported that Psocids were vectors of the fringed tape worms of sheep in North America.

Historical Resumé

i) Pre–1900

Perusal of literature reveals that there was no work done on this group either in India or in the world. Burmeister (1839) and McLachlan (1866) are the pioneers in Psocoptera; and former is credited with coining of word *Corrodentia* for this Order. It was later changed to '*Psocoptera*' by Wardle (1937). McLachlan (1866) summarised and added a few genera and species.

ii) 1900–1947

The credit of first consolidated monograph from Systematic point of view goes to Enderlin (1903), who recognised 115 species from Indo–Australian regions. From mainland India within Oriental region, Enderlin (1903) described two species of the genus *Ectopocus* viz, *E. denudants* and *E. myrmecophilus*. The latter species was placed under *Micropsocus* by Enderlin (1903).

Another comprehensive account by Banks appeared in 1920 dealing with 23 species and published in a monograph from covering Philippines, Luzon, Borneo and Singapore. Tillyard (1923), published a monograph embracing 13 species from New Zealand. Pearman (1929) reported a dozen species from domestic stored cereal. In the same year Banks (1929), Karny (1931) and Lameere (1935) gave the classification of Psocoptera, while Roester (1944) is credited with contributions of keys of world genera of these insects. It is thus seen that, during this period, there was contribution only on basic understanding of Psocoptera, but none on Indian component of these insects.

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iii) 1948–1990

During this period the first important contribution goes to the credit of Badonel (1955). This was after an gap of 11 years since Roester's contribution. On world basis 'Catalogue of The Psocoptera of World' including Indian component was published by Smithers (1965), with a comprehensive bibliography by Smithers (1967). Lee and Thorton (1967) contributed on the family Pseudocaecilidae of Oriental and Pacific areas comprising thirty three species. A check list of Peripsocid fauna of the Oriental and Pacific region has been published dealing with 53 species. Thornton and Wong (1968) dealt in further details: Peripsocid fauna of Oriental and Pacific regions. Under this seven species (5 under *Ectopsocus* and 2 under *Peripsocus*) from India are dealt with.

Dutta 1965–1977 has contributed number of taxa, including new ones, from India. Contributions are thus on 5 families viz. Peripsocidae (3 sp.), Pseudocaeciliidae (1 sp.); Mypsocidae (1 sp.), Psocidae (3 sp.); 1969a : Redescription of *Dypsocus coleoptratus* Hagen; 1969b : a new sp. *Hemipsocus* (Hemipsocidae) and further descriptions of a Psocidae (*Amphigerontia nubila* Enderlin); 1969 c. 1 ns. sp. of Caeciliidae. Peripsocidae – 2 species; Psocidae – 1 species; 1969d : *Peripocus* 1 sp.; 1969e: on 4 families 1 n. sp. of each, Stenopsocidae, Mypsocidae, Psocidae, Phyllipsocidae. Dutta (1977) gave further description of *Ectopsocus briggse* McLachlan (Peripsocidae).

New (1977) brought out a review of Psocopteran species from Indian sub-continent, along with oriental region. Roy (1979) dealt with 17 species under 11 families from Calcutta and four other districts of West Bengal. Badonnel (1981) contributed two papers recording 14 Psocopteran species from Darjiling (West Bengal), Assam and Uttar Pradesh. Roy (1984) dealt with 43 Psocopterans, representing several families, from north eastern India. Roy (1987) contributed on the bioecology and seasonal fluctuation of three Psocopteran species, collected from Rabindra Sarobar, Calcutta. Out of these two species were under *Ecotopsocus* (Ectopsocidae) and one species of genus *Tapinella* (Pachytroctidae).

Srivastava (1990) has brought out an comprehensive account of 17 species of Psocoptera under nine genera and five families from West Bengal, with keys for all level of taxa. It included two tables; one indicating composition of Psocoptera from West Bengal vis-a-vis India and world fauna of this group of insect, other table dealt with distribution pattern and known male, female and larvae of each of the species.

Studies from Different Environs

It is seen, on perusal of literature, that Psocopteran fauna of India have been extensively explored and worked out from north eastern India. This included mainly from West Bengal, Assam, Manipur and Meghalaya. It is also seen that detail bioecological studies, seasonal fluctuation and population dynamics and a comprehensive account of Psocopterans with keys have been made on the fauna of West Bengal. Besides, above Psocoptera of Uttar Pradesh, Karnataka, Kerala and Tamil Nadu have also somewhat received attention, but no comprehensive account is available and studies are generally based on sporadic exploration and collections. It is found that Himalayan range (north western Indian states), Gangetic plains (Uttar Pradesh, West Bengal) and Penninsular region (Orissa, Kerala, Karnataka and Tamil Nadu) have been explored, though not very comprehensively.

Estimation of Taxa

Indian component of Psocopteran insects comprises of 85 species under 40 genera in 18 families; while the world fauna is about 2500 species under 230 genera in 31 families. Smithers (1967) classification and taxonomy of the order is presently accepted. Major component of Indian Psocoptera are represented under following families: Peripsocidae (10 species) Psocidae, Caeciliidae (nine species each). These three families taken together represent a little more than half of Indian Psocoptera (28:57). Other families worth mentioning are Lipodopsocidae (two species), Psyllipsocidae (three), Liposcelidae (four), Pachytroctidae (four), Epipsocidae, Amphipsocidae (two), Myopsocidae (three).

Classified Treatment

Psocoptera fauna of India vis–a–vis world, is being presented hereunder with obvious stress on Indian component. It comprises of species, genera and 12 families. World fauna of these families are also indicated for giving relative representation.

To begin with, following table gives at a glance a qualitative composition, of Indian Psocoptera vis–a–vis world under main Psocopteran families :

Family	INDIA		WORLD	
	Species	Genera	Species	Genera
Lepidopsocidae	2	2	90	7
Psyllipsocidae	3	2	21	4
Liposcelidae	4	2	90	6
Pachytroctidae	4	2	34	4
Epipsocidae	2	1	42	4
Caecillidae	9	1	247	25
Amphipsocidae	2	2	44	7
Peripsocidae	10	2	96	5
Hemipsocidae	1	1	9	1
Pseudocaeciliidae	2	1	42	6
Psocidae	9	7	182	27
Myopsocidae	3	1	42	7
Total	51	24	939	103

NOTE : There are 19 more Psocopteran families found in other parts of world, represented by 309 species and 70 genera.

Analysis of Psocopteran faunal component, reveal that Indian Psocoptera are represented maximum by Peripsocidae ten species followed by Caeçillidae and Psocidae (each with nine species). Maximum number of genera, under single family in India belongs to the family Psocidae (seven genera). In contrast, world component of Psocoptera reveals that the maximum number of species (247) is known to be under family Caecillidae; while maximum number of genera (27) is under the family Psocidae. Peripsocidae, Lepidopsocidae and Liposcelidae are represented in world fauna by 96, 90 and 90 species respectively, whereas they are represented by only 10, 2 and 4 species in India.

Current Studies

Psocopterans are being studied in Z.S.I. from the view point of current stress on State faunal resources. Under this programme the fauna of Psocoptera is studied belonging to different ecozone. Study of Psocoptera is not receiving much attention in other parts of India, though it is getting relatively more attention in other countries.

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Animal Resources of India : 313–321 : 1991

PHTHIRAPTERA

Introduction

The Lice (the 'chewing-, bird-, biting-, or feather-lice', and the 'sucking-lice' are dorso-ventrally flattened obligatory ecto-parasitic insects on the warm blooded vertebrates, viz., birds and mammals. While the chewing-lice are parasitic on both birds and mammals, the sucking-lice are exclusive to mammals. There are about 2900 (Clay, 1974) to 3000 species (Pilgrim, 1970) of chewing-lice, and about 450 species of sucking-lice.

The lice live in the plumage of the birds, or pelage of mammals, and well adapted to live in the micro-environment of the feather, or hair cover, which not only offer them shelter, but also food, and the parasites are thus exposed very little to the external or macroclimatic fluctuations to which the hosts are exposed. They live in one zone, feed in another, and oviposit in yet another, depending on the species involved (Ash, 1960). Their food chiefly consists of the feathers, hair sebum, serum and blood in case of the chewing-lice, and serum and blood in case of the sucking-lice. As the popular name indicates those species with typical mandibulate or masticating type of mouth parts are called 'chewing-lice', and those species adapted for typical piercing and sucking type of mouth parts are included under 'sucking-lice' However, this is not exclusively true from a functional angle, since some chewing-lice with well developed mandibles like the Ricinidae developed a modified piercing and sucking apparatus, and the Haematomyzidae have mandibles rotated 180° so that their cutting or dentated edges face away from one another and probably at the most useful for anchoring to the host body, and the species live more by sucking. The sexes are separate, more often females outnumber males, and in quite a few instances the males are even unknown, and probably the species are parthenogenic. There are occasional predominance of males over females, and at least in one case of *Piagetiella* parasitic on the grey pelican, it was attributed to the adverse conditions faced by the host and its health was affected (Madhav, Ramana Rao, & Lakshminarayana, 1990). The males also sometimes show extreme sexual dimorphism. Not only asymmetry played a dominant part in the sexual isolation amongst the sympatric species, there are certain genera of chewing-lice where only exclusively asymmetrical forms are known (Lakshminaryana, 1977, 1979 & Lakshminarayana & Emerson, 1971, 1978). The life-cycle is simple with an egg, three nymphal instars, and the adult.

The lice cause dermatitis, spread diseases like rickettsiasis, murine typhus, etc., causing annoyance to the host during the course of feeding or movement, known to effect the egg production, and in case of heavy infestations the hosts not only present sickly appearance, but also become exposed to secondary infections. Those species feeding on the hair may damage the coat, and those that feed on the serum and blood are capable of producing toxaemia, inject toxins and other germs like viruses and bacteria. Some of the chewing-lice act as intermediate hosts, for example, the swift filarial worm *Filaria cypseli* is transmitted by *Dennyus minor*, dog cestode by *Trichodectes canis*, transmission of typhus in guinea pig by *Trimenopon hispidum*, and infectious anaemia of horses by *Werneckiella equi*. Emerson (1973) states that the eastern *equine enceph lomyelitis* virus and *Bedsonia* organisms in pheasants were also found in the chewing-lice of the respective hosts. The role of the chewing-lice in disease transmission is however, little explored, and with the increased interest in the wild-life conservation and epizoology and diseases, we should have better understanding on the role of lice in disease transmission.

They have no intermediate hosts unlike many other parasites, and the transmission from one host to the other is possible only between the sexes during feeding, roosting, or mating, between the offspring and the parent; also possible between the prey and the predator, or foster parent and the brood parasite, during dust baths, and rarely by phoresy. However, it is seen that the

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transmission is direct, and the non-establishment of species on unrelated hosts, prey and predator (majority cases), the foster parent and its brood parasites indicate their host specificity. In fact, the lice and their hosts evolved hand in-hand, and therefore, the study of evolution in one reflects that of the other. This has been taken as advantage by the parasitologists and they suggested host relationships and host distribution.

Hopkins (1949, 1957) reported that the ancestors of Amblycerophtihrina (the most primitive member of the chewing-lice) possibly began their life as ecto-parasites of vertebrates during the Triassiac Period (225-190 million years ago), and parasitized the early birds and mammals, and possibly their reptilian ancestors. True Amblycerophthirina possibly evolved at least in Jurassic (190-135 m.y. ago), Ischnocerophthirina type of Chewing-lice might have been in existence since early Cretaceous (135-65 m.y. ago), or even in late Jurassic, and the Siphunculophthirina (sucking-lice) not later than middle Cretaceous. The evidence of Rhynchopthirina chewing-lice is too scanty, but it must have evolved earlier than Eocene Epoch (54-38 m.y. ago), and possibly existed even in Cretaceous Period.

Classification

A lot of confusion prevailed regarding the classification, priorities and authorship of various suprageneric taxa in the lice as a whole. A good review on the nomenclatural problems, priorities, and authorships was presented in Lakshminarayana (1970, 1976). Majority of phthirapterologists now accept Phthiraptera the name of the Order. The former suborders Amblycera, Ischnocera, Rhynchophthirina of Mallophaga (chewing-lice), and Siphunculata (Anoplura, sucking-lice) emended as Amblycerophthirina, Ischnocerophthirina, and Siphunculophthirina on par with Rhynchophthirina Ferris, which also indicate their natural relationship (Lakshminarayana, 1970, 1976) are now considered as suborders of Phthiraptera. Hopkins & Clay (1952) included the families Menoponidae (incl. Trinotonidae), Laemobothriidae, Ricinidae, Boopiidae, Trimenoponidae, and Gyropidae under Amblycerophthirina, Philopteridae, Trichodectidae, and Heptapsogasteridae under Ischnocerophthirina and the monotypic family Haematomyzidae under Rhynchophthirina. Mukerji & Sen-Sarma (1955) suggested to separate the suborder Rhynchophthirina as Rhynchophthiraptera. Carriker (1960) proposed a new family Trochiliphagidae with type genus *Trochiloecetes*. Clay (1962) changed it as *Trochiloecetidae*. Keler (1964) revised earlier classification. Emerson & Price (1976) erected the family Abrocomophagidae under Amblycerophthirina. Lyal (1985) thoroughly revised the family Trichodectidae.

Ferris (1951) revised his earlier series of monographs on sucking-lice (1919-1933) and divided them under six families *viz.*, Echinophthiriidae, Haematopinidae, Pediculidae, Hoplopleuridae, Neolinognathidae, and Linognathidae. Hopkins (1949, 1957) gave a thorough account of lice of mammals and the host relationships. Johnson (1964) removed the subfamily Pedicininae from Hoplopleuridae; he also proposed (1969) a new family Haemophthiridae to accommodate the solitary species *Haemophthirus galeopitheci* removing it from Hoplopleuridae. Kim (1970) proposed a seven family classification transferring Pedicininae back to Hoplopleuridae.

The present classification is as follows : Order Phthiraptera; Suborder Amblycerophthirina (Boopiidae, Menoponidae *s.l.*, Trinotonidae, Laemobothriidae, Ricinidae, Trochiliphagidae (Trochiloecetidae), Gyropidae, Abrocomophagidae, Trimenoponidae), Suborder Ischnocerophthirina (Philopteridae, *s.l.*, Heptapsogasteridae, and Trichodectidae) and the Suborder Rhynchophthirina (Haematomyzidae) under chewing-lice. The Suborder Siphunculophthirina (Siphunculata or Anopluta *auct.*) (Echinophthiridae, Haematopinidae, Linognathidae, Pediculidae, Neolinognathidae, Hoplopleuridae) (see fig. 1).

Historical Resumé

i) Pre–1900

Denny (1842) gave a historical account of lice from the Biblical times. There are other three works on the pre-Christian Era *viz.*, Herakleitos Ephesius (500 B.C.), Aristotle (350 B.C.), and Diophanes of Bithynia (100 B.C.).

Lice were however, been known from much earlier times in India. In *Manava Dharma Sastra* (Vedic Period), flies mosquitoes, lice and bugs were classed amongst the animals that bred in sweat (*svedaja*). Umasvati's classification in *Tatvarthadigama* (circa 40 A.D.) in which the lice were classed *Trapusarja* and *Karpasathika* on the basis of their sense organs. In the *Sangam* literature of South India (a period assigned between 3000 B.C. to 1915 A.D., according to some and from 4 A.D. to 8 A.D. according to others), are found plentiful reference to various insects like ants, bees, wasps, dragonflies, white-ants, and lice as well as scorpions, besides the habits and habitats of other animals like birds. Emperor Asoka (273-232 B.C.) established a number of veterinary hospitals whose inmates include various birds and mammals and the doctors in-charge of these hospitals were said to have a good knowledge of their scourges. Moghul Emperors seem to have a fair knowledge of birds. Abul Fazl, a courtier to Akbar, is said to have referred in his works, that Kashmir vallery was infested with such undesirables like gnats, flies, fleas, and lice, etc. In Ancient India, several birds like domestic hen, geese, pigeons and doves (for carrying post), peafowl 'parrots' (probably paraquets), and mynahs, and various mammals like cattle, elephants, horses, etc, were domesticated, their habits were well known, diseases were carefully observed, and treatises like *Gajasastra, Aswasastra, samhitas* like *Charaka* and *Susruta* were written. These treatises included various diseases their causative organisms including lice, and their cures. Lice even entered in proverbial literature. For example, there is a proverb in Telugu that !"*Penuku* (lice) *pettanamichchina* (if power is given) *tala tega korukun* (bites the head completely)"!, thereby meaning, if power is given to undesirables, they misuse it.

The first scientific report of lice on Indian birds apparently dates back to J. C. Fabricius (1775) who described the habitat of *Pediculus vulturis (Laemobothrion vulturis* as *Indiae Orientalis vulturibis*. It was followed by *Pediculus tantali (Ardeicola tantali)* from the painted stork *Tantalus leucocephalus (Ibis leucocephalus* (Pennant)) from Tranquebar (Tamil Nadu) in 1798 described *Lipeurus himalayensis* (now *Reticulipeurus himalayensis*) from the western horned pheasant, *Tragopon hastingii (T. melanocephalus)*. Few other references to the Indian species of chewing-lice are found in Giebel (1874), Piaget (1869) Walker (1871) and Richtar (1871).

ii) 1901-1947

Kellogg (1908), Gaiger (1910, 1915) Piaget (1915) and Paipe (1912) were based from material collected from animals in the European zoological gardens, or museum skins. Kellogg & Paine (1914) were the first to study the material collected actually from India by the Indian Museum, Calcutta (now in ZSI). This was followed by another short list by Kellogg & Nakayama (1915). Notable contributions made before 1947 are as follows, chiefly by westerners: Ansari (1943-1944), Bhattacharjee (1939), Clay (1936, 1938, 1940, 1947), Clay & Meintertzhagen (1937, 1938 a-b, 1941), Conci (1941, 1942), Gaiger (1910, 1915), Overgaard (1943), Quadri (1935, 1936 a-c), Salim Ali (1927, 1936), Sen (1942), Thompson (1937, 1938, 1939, 1940 a-c), and Waterston (1928).

iii) 1948-1990

Agarwal (1967), Agarwal & Gupta (1970), Agarwal & Saxena (1977, 1978 a-b, 1979 a-b, 1980 a-b), Ansari (1947, 1951 a-b, 1954, 1955 a-g, 1956 a-i, 1957 a-e, 1958, 1959, 1967), Arora & Chopra (1957, 1959), Brelih (1965), Carriker (1976), Chopra (1969), Clay (1947, 1949 a, 1958 a-b, 1959, 1962a, 1963, 1965a, 1966 a-b, 1970b, 1973, 1974a), Clay & Hopkins (1950, 1951, 1954, 1960), Dalgleish (1969), Dhanda (1961), Elbel (1967), Elbel & Price (1970, 1973), Emerson (1954), 1955, 1965, 1971, 1972 a-b, 1973), Emerson & Elbel (1956, 1957 a-c), 1961, Emerson & Price (1968, 1974), Guimaraes (1974), Hajela (1970), Hajela & Tandan (1967, 1970), Hopkins & Clay (1952, 1953, 1955), Hopkins & Timmermann (1954), Keler (1939, 1958, 1960, 1964, 1971), Klockenhoff (1969 a-b, 1973, 1980, 181), Klockenhoff & Schirmers (1976)

Klockenhoff, Rheinwald, & Wink (1973), Kumar & Tandan (1968, 1971), Lakshminarayana (1968 a-b, 1969, 1970 a-d, 1972 a-b, 1973 a-b, 1975 a-b, 1976, 1977 a-c, 1979 a-c, 1980, 1981, 1982 a-b, 1983, 1984, 1985, 1986, 1987, 1988, 1990), Lakshminarayana, Vijayalakshmi & Talukdar (1980), Ledger (1970, 1971), Lyal (1985), Madhav, Ramana Rao & Lakshminarayana (1986 a-b, 1990), Mukerji & Sarma (1955), Nelson & Price (1965), Price (1964 a-b, 1965, 1967, 1968, 1970 a, 1970 b-c, 1971, 1974, 1975, 1977), Price & Beer (1963 a-d, 1964, 1965 a-c), Price & Elbel (1969), Price & Emerson (1966,a,b 1967, 1974, 1975, 1977), Price & Beer (1963 a-d, 1964, 1965 a-c), Price & Elbel (1969), Price & Emerson (1966a, b, 1967, 1974, 1975, 1977), Rai (1977, 1978), Rai & Lakshminarayana (1980), Rakshapal (1959), Rao, Khuddus, & Channabasavanna (1975), Rheinwald (1968), Ryan & Price (1669), Saxena & Agarwal (1977, 1978, 1979, 1980 a-d), Scharf & Price (1977), Sen & Fletcher (1962), Seneviratna (1963), Somadder & Tandan (1970), Srivastava (1977, 1978), Tandan (1951, 1952 a-b, 1955, 1958, 1963, 1978, 1973, 1976), Tandan & Clay (1971), Tandan & Kumar (1969), Tendeiro (1958, 1962, 1963, 1965 a-c, 1667 a, 1969 a-b, 1972, 1973 a, 1974), Thompson (1948 a-c, 1950 a-c, 1948), Timmermann (1952, 1954 a-c, 1955, 1962, 1965), Ward (1955), and Werneck (1950 have contributed on the subject.

The full references to the above works may be found in Keler (1960, *Mitt. zool. Mus. Berl.*, **36** (2) : 146-403), Eichler & Zotorzycha (1969, *Angew, Parasit.*, **10** (1) : 53-60), Eichler, Ribbeck & Zotorzycka (1973, *Mitt. zool. Mus. Berl.*, **49** : 423-461), and Lakshminarayana (1972, *Angew. Parasit.*, **13** (3) 169-178; 1973, *Angew. Parasit.*, **16**(1) : 28-30; 1986, *Misc. publ. Occ. pap. Rec. zool. Surv. India*, **81** : 1-63).

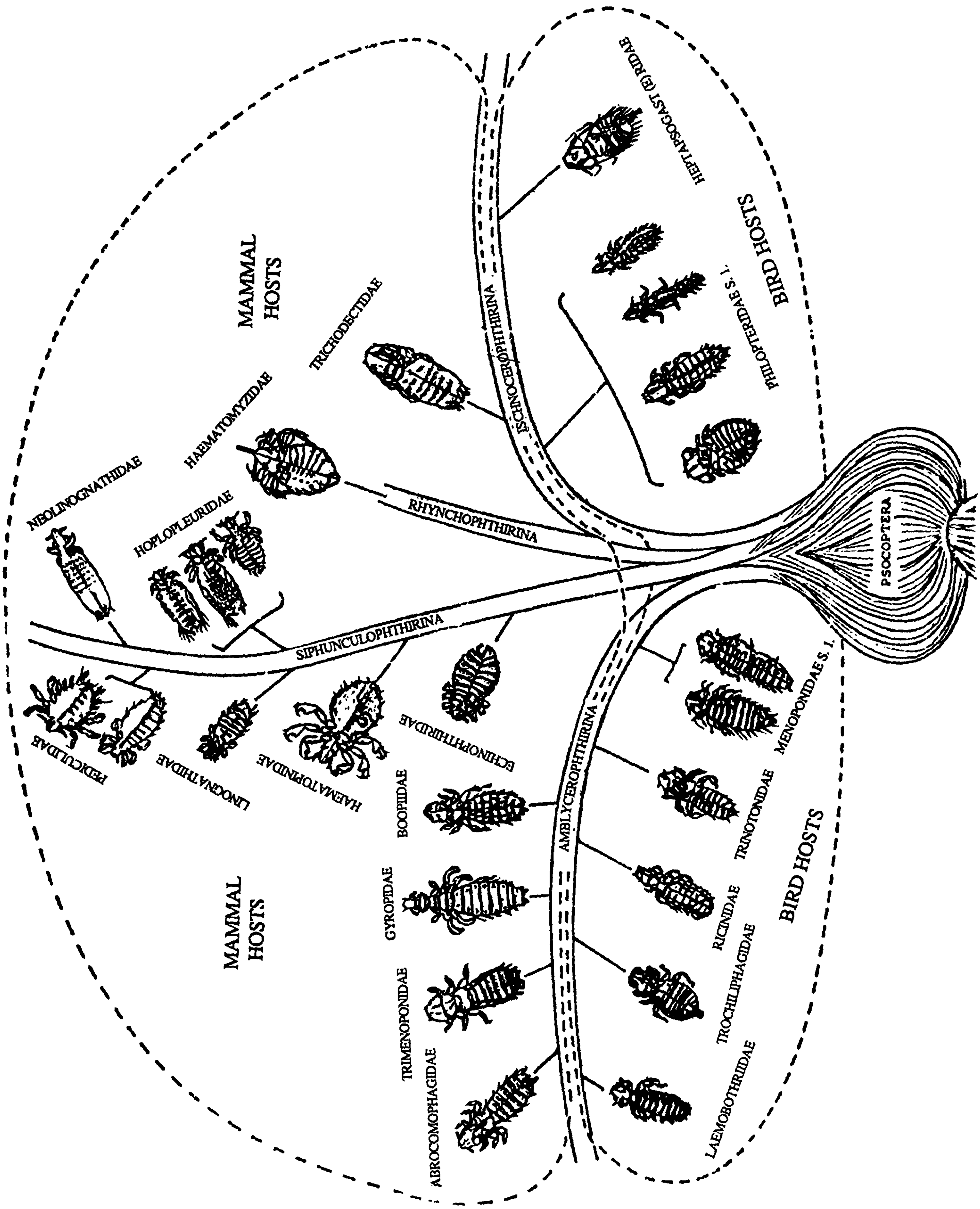
Biological Studies

The distribution of parasites (specially obligatory ones like lice) depends mostly on the geographical distribution of the host, and synchronises with the latter. Thus, studies on the basis of hosts is more relevant and scientific. Most of the Eueropean and American workers based their studies on the collections made during the colonial rule, specially by Col. Dr. Meinertzhagen, collections made by the SEATO in the south-east Asia, few collections made by individual scientific groups either from India and adjacent countries or from their zoo hosts. Dr Ansari worked in this region who based his studies on collections made from Delhi and Izzatnagar (U.P.) in India and Pakistan and Bangladesh. Agarwal & his coworkers, Arora & Chopra, Tandan, Dhanda and coworkers and Qadri from U.P. and Punjab; Lakshminarayana, Rai, Vijayalakshmi and Talukdar from Z.S.I. from Eastern India, Nepal, Andaman & Nicobar, Lakshminarayana, Madhav & Ramana Rao from Andhra Pradesh, worked on lice fauna.

Estimation of Taxa

A perview of the avian lice indicates that a greater number of genera of chewing-lice are parasitic on aquatic & semi-aquatic birds than terrestrial ones, as follows:

Avian fauna of the World	*No.of Host Genera*	*Parasite Genera*	
Aquatic,semi-aquatic,shore birds & waders	275	71	25.8%
Terrestrial birds	1786	170	9.5%



Schematic representation of the suborders and families of Phthiraptera

Lakshminarayana (1986) presented the country-wise distribution of the chewing-lice as follows:

Country	*Genera*	*Species*
Afghanistan	11	26
Bangladesh	5	6
Bhutan	4	4
China(Yunnan,Szechwan,Tibet & Kashgar)	8	25
India	85	389
Myanmar (Burma)	36	68
Nepal	32	83
Pakistan	27	178
Sri Lanka	8	43

Lakshminarayana (1986) also stated that the reported species from India, Afghanistan, Bangladesh, Bhutan, China, (adjoining areas to India), Myanmar (Burma), Nepal, Pakistan and Sri Lanka are as follows:

Families	*No. of*	
	Genera	*Species*
Suborder : **Amblycerophthirina**		
1. Boopiidae	2	2
2. Laemobothriidae	2	5
3. Menoponidae s.c.	26	172
4. Trinotonidae	1	4
5. Ricinidae	1	7
Suborder : **Ischnocerophthirina**		
6. Philopteridae s.l,	67	369
7. Trichodectidaae	3	16
Suborder : **Rhynchophthirina**		
8. Haematomyzidae	1	1
Total	103	576

Our knowledge on Indian mammalian chewing-lice is practically nil, confined only to about 9 host species. Hopkins (1949) while reviewing the lice on mammals stated that we know considerable number of lice from Ethiopian Region, but our knowledge of lice from Oriental Region is practically nil, although, the Oriental Region is equally rich in mammals. This statement holds true even now. Unless greater interest on wild life epizoology is generated and diseases of the wild life are taken up simultaneously with its conservation programme, the position is not likely to change.

Classified Treatment

Systematics

Keys for the identification of the suborders and families from India are given in

Lakshminarayana (1970,1986). Keys for the identification of genera and species are also given in Blagoveshthenskii (1964,1967), Clay (1947,1976,1977,1978). The valid genera and species alongwith type-hosts and first references can be found in Hopkins (1949,1957), Hopkins & Clay (1952,1953,1955), Lyal (1985), Price (1973), Price & Emerson (1966,1967) and the list of species from India and adjacent countries in Lakshminarayana (1979,1982).

Morphology

Mukerji & Sen Sarma (1955) studied the morphology of the elephant louse, *Haematomyzus elephantis* in detail. Rao et al. (1975) studied the mouth parts of the chewing-lice. A glossary of taxonomic characters (Lakshminarayana, 1985) were given. The role of asymmetry was discussed in Lakshminarayana (1973a,b, 1977a,1979b), and Lakshminarayana & Emerson(1971,1978). The trends in the evolution of the sitophore sclerite and male genitalia were discussed in the *Laemobothrion-complex* (Lakshminarayana, 1970b).

Anatomy

Mukerji & Sen Sarma (1955) studied the anatomy of the elephant louse, *Haematomyzus elephantis*. Srivastava (1974) studied the poultry louse, *Numidilipeurus lawrensis tropicalis* which was also studied in detail by Agarwal & Saxena, (1978, 1979b, 1980). Saxena & Agarwal, (1980a-c) dealt with the crop, teeth, tracheal, vascular and genital systems.

Histology

The histology of various organs in *Haematomyzus elephantis* was discussed in Mukerji & Sen Sarma (1955). Srivastava (1974), and Saxena and Agarwal (1979,1980d) also discussed on this problem with reference to *N.I. tropicalis*. Agarwal & Saxena(1977) worked out the histology of peri-oesophageal nephrocytes in some lice.

Behaviour

Rakshapal (1959) observed the behaviour of the pigeon louse, *Columbicola columbae*. Agarwal & Saxena (1980) studied the feeding behaviour of *N.I. tropicalis*. Clay (1949c) discussed the behaviour and its impact on the morphological evolution. Lakshminarayana & Emerson (1971,1978) discussed on the probable changes brought about in two sympatric species of *Goniodes* consequent to the evolution, isolation, and reunion of two species of its host genus viz., *Pavo* in the Oriental Region. Lakshminarayana (1973b) also attributed the morphological changes due to feeding habit in the head asymmetry in *Struthiolipeurus*. It was contended that an ancestral form originally parasitic probably on Falconiformes, secondarily parasitized Struthioniformes and Rheiiformes, developed the asymmetry due to the feather structure in the latter group of hosts.

Bionomics

Ansari (1944a,b) studied the bionomics of the lice of domestic chicken. Arora & Chopra(1957,1959) studied the biology of *N.I.tropicalis*. Agarwal(1967),studied the bionomics of *Falcolipeurus frater*. Agarwal & Saxena(1978,1979a) studied the seasonal dynamics of *N.I.tropicalis* and its feeding habits (Agarwal & Saxena, 1980a). Rai & Lakshminarayana (1980) discussed techniques for in *vitro* studies on the chewing-lice. Evaluation of secondary infestations on the basis of immature stages was discussed in Lakshminarayana (1972a). Madhav et al(1990) studied sex ratio and importance of *Piagetiella* on grey pelican-population control.

Development

Ansari (1954) studied the pre-imaginal instars of the chewing-lice and applied the *growth principles*. Agarwal(1967) studied the development of *Falcolipeurus frater*. Agarwal & Gupta (1970) studied the effect of low temperatures on the viability of the eggs and development in *F.*

frater. Rai & Lakshminarayana (op.cit.) gave method of rearing artificially.

Cytotaxonomy

Practically no work is available on this aspect. However, Manna (1990) reported the chromosomal numbers of six species.

Expertise

INDIA

In Z.S.I.

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Richardo L. Palma, National Museum of New Zealand, P.O. Box 467, Wellington, (New Zealand)[Taxonomy].

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HEMIPTERA

Introduction

In the Insect World, Hemiptera is the largest and most important Order of exopterygote insects. These are small to medium–sized insects called "bugs", with piercing and sucking type of mouth parts, atrophied palpi, labium in the form of a dorsally grooved sheath receiving two pairs of bristle like stylets, and two pairs of wings of which fore wings are often of harder consistancy than hind-wings.

Hemiptera comprises bugs, cicadas, leaf–hoppers, scale insects etc. It is divided into i) Heteroptera, which includes stink and shield bugs, assassin bugs, lace bugs, bed bugs and many families of water bugs; and ii) Homoptera, which includes cicadas, mealy bugs, Aphids, Psyllids, Aleyrodids, Cicadellids, Membracids etc.

These insects are of great economic importance. Most of the species entail direct or indirect injury to various plants. Some are very destructive e.g. leaf hoppers (Cicadellids), the white flies (Aleyrodidae), the plant lice (Aphids) and scale insects (Coccids). The extensive damage caused by these insects is due to sucking of plant sap and very fast rate of reproduction (often by parthenogenesis) in case of many Homoptera. Some of the coccids are, however, useful to mankind, because these insects are either the source of stick lac of commerce in India or of dye stuff like cochineal and kermes. Some of the Hemipterans are remarkable for polymorphism and polyphytophagism and feed on leaves, stem, roots, fruit and seeds. Some heteropteran insects are predaceous and thus keep check on the populations of other insect pests; others like Cimicidae (bed bugs), Tritomidae and Polyctenidae are blood suckers and vectors of various diseases to a variety of crops, vegetable and fruit trees.

Aquatic hemipteran insects are of variable sizes from minute 1.5 mm to large 110.0 mm, living mainly in lentic and lotic fresh water, some even live in brackish water, only one or two species are marine. They are different in morphology and feeding habit from their terrestrial forms. Some are truly aquatic, provided with effective swimming and respiratory structures along with modificatin of body shape and size. Others are semi–aquatic forms living near the water bodies, on shores, or over the surface, or among the water weeds. Water bugs are effectively predaceous on zooplanktons and other aquatic microfauna ranging from minute mosquito larvae to considerable sizes of fish–fry or tadpoles or other insects, whatsoever they get on their way. Thus, they are predatory and saprophagous and perform an important role in the aquatic ecosystem in nature. Because of their predatory habit some water bugs are studied for the biological control of mosquito larvae, while some others are causing menace to the fish and frog culture by destroying the fishfry and tadpoles in considerable number as their food.

No consolidated account is available on this group of insects but the compilation of the stray published accounts reveal that at present approximately 80,000 species are so far known from the World under the Order Hemiptera of which 6,500 species occur in India.

Probably no other Order of insects than this is so directly concerned with the mankind on account of its direct and indirect injuries to vegetation. Amongst the most destructive species are the cotton strainers, chinch bug, leaf hoppers, white flies, plant lice, scale insects and mealy bugs. Certain Homoptera play vital role in transmitting plant viral diseases e.g. 'mosaic', 'leaf role', 'yellows' etc. Hemipterans are important from the view point of rapid rate of reproduction, polyphagy and complicated life–cycle. Water bugs like notonectids play important role in biological control of mosquito larvae. Water bugs, predaceous on zooplanktons play a vital role in the aquatic ecosystem for energy transformation. Hemipteran insects afford many instances of

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resemblance to insects of their own and of other Orders. Varied morphological pecularities are seen among water bugs in relation to their respiration and locomotion (Bueno 1916).

Classification of the Order – Hemiptera

Order Hemiptera

Suborder – Homoptera		Suborder – Heteroptera	
Superfamily	: Fulgoroidea	Superfamily	: Tingoidea
	: Cercopoidea		: Reduvoidea
	: Cicadoidea		: Cimicoidea
	: Cicadelloidea		: Dipsocoroidea
	: Psylloidea		: Saldoidea
	: Aleyrodoidea		: Aradoidea
	: Aphidoidea		: Lygaeoidea
	: Coccoidea		: Pyrrhocoroidea
			: Coreoidea
			: Pentatomoidea
			: Gerroidea
			: Ochteroidea
			: Notonectoidea
			: Corixoidea

Historical Resumé

i) Pre-1900

Homoptera

Knowledge of Oriental Homoptera dates back some 190 years, when Donovan (1800) in his 'Natural History of Insects in India' included two genera, '*Fulgora*' and '*Cicada*' Atkinson (1885–89) published a number of notes on Indian Rhynchota including Jassoidea (now Cicadelloidea) in the Journal of Asiatic Society of Bengal, and drew attention of Homopterists to the large number of species of Cicadellidae awaiting examination in India. Other earlier works include Barlow (1886–1899), Buckton (1893–1898) and Cotes (1893).

Heteroptera

According to Sharp (1899), the total number of Hemiptera fauna of the World is about 18,000, of which about 12,000 species are Heteroptera. So far as Heteropteran insects of Indian Sub-continent are concerned, Fabricius (1775, 1790, 1794, 1803), Fieber (1844, 1851), Mayr (1853, 1863), Stal (1859–1868) made valuable contributions. Dohrn (1860) was the first who made significant contributions on Heteropteran insect fauna of Ceylon (now Sri Lanka).

ii) 1901-1947

Homoptera

Mishra (1921) and Singh (1931, 1932, 1940) contributed to the knowledge of Indian homopterans. Later Ayyar (1924), Hussain (1927), Mani (1935–1964) and Mathur (1975) made noteworthy contributions on the homopterans with special references to Psyllids. Also Distant (1904–1908, 1918) and Pruthi (1930–1936) made extensive studies on Indian Cicadelloidea.

Frunkhauser (1922, 1933), Chatterjee and Bose (1937) have studied Membracid fauna. Besides Distant's work (1902, 1910), Oltenbach (1928), Chatterjee (1936) and Fraser (1942) have contributed to our knowledge of Cicadidae.

Heteroptera

The studies on Indian hemipteran insects got momentum from 1900's, when Distant comprehensively studied the Hemipteran fauna of Indian and adjoining regions. The compilation of the work of Distnat (1902–1918) under seven volumes of 'Fauna of British India', reveals that about 2300 species occur in the Indian Sub-continent. Kirlaldy (1901) has worked on the Oriental heteropteran insects including some from India. Freunberg (1945) and later Freeman (1947) have revised the genus *Dysdercus*. Distant had recorded about 150 species of water bugs from Indian Sub-continent belonging to 8 families. Paiva (1918) had recorded some 33 species belonging to 5 families of water bugs from South Sun State (now Burma), of which 13 species were designated as new to science. Hafiz and Mathai (1938), Hafiz and Rebeiro (1939), and Hafiz and Pradhan (1947) have studied the Indian fauna of water bugs from different places. Hutchinson (1933) had studied the specimens of Notonectidae and Corixidae described by Distant and Paiva, to remove some anomalies regarding their true identity. Chatterjee (1936) recorded some Coreidae of sandal from India.

ii) 1948-1990

Homoptera

Significant contributions have been made by David and Subramanian (1966) on Aleurodidae; Raychaudhuri *et al.*, (1980) and Ghosh, A. K. (1982–1989) on Aphidoidea; Mathur (1975) on Psyllidae; Ananthasubramanian (1975–1981) on Membracidae; Dutta (1988) and Viraktamath (1976) on Cicadellidae; and Ali (1969–1974) and Varshney (1962–1990) on Coccoidea.

Heteroptera

Valuable contributions have been made by Ghauri (1972) and Muraleedharan (1975) on Anthocoridae; Kormilov (1953–1975) on Aradidae; Mitra, Sen and Muraleedharan (1977) on Pyrrhocoridae; Usinger (1966) and Bhatt (1974) on Cimicidae; Basu and Mitra (1977–1978) on Coreidae; Chopra (1972–1974), Dutta, Ghosh and Dhar (1985) on Pentatomidae; Livingstone (1972) on Tingidae; Brooks (1951) on Notonectidae; Pradhan (1950, 1976) and Gupta (1981) on Gerridae; Venkateshan (1980) on Belostomatidae; Mukhopadhyay (1988) on Lygaeidae; and Thirumalai (1986) on Gerridae and Notonectidae.

Estimation of Taxa

Homoptera

Superfamily Aleurodoidea

Family Aleurodidae : The aleurodids or white flies are serious pest of orchards. They infest the *Citrus* plant very badly. Butani (1970) published a bibliography of this group. A total of 117 species are known at present from India. Buckton (1903), Peal (1903); Quaintance and Baker (1917); Misra (1923); Dozeier (1928); Singh (1931, 1938, 1940, 1944); Ayyar (1923); Usman and Puttarudraiah (1955); David and Subramanian (1976); Rao (1958) and Nath (1970) have made valuable contributions.

Superfamily Aphidoidea

Family Adelgidae : Adelgids in general have short 2-5 segmented antennae, with 2 primary rhinaria in apterae and 3 in alatae; the wings are usually held roof-like in repose and the cubitus 1 and 2 remain separate in forewing. All adelgids are knwon to feed only on Coniferae and may have as many as 5 generations while leading a heteroceous life cycle.

In the Indian subregion, Stebbing (1904, 1910) was the first to study *Chermes* (now considered syn. of *Adelges*) alternating between *Picea* and *Abies* in North West Himalaya. Ayyar (1923) recorded serious damage by *Chermes* in Coonoor, South India. Schneider -Orelli and Schneider (1954) first described a holocyclic species from North West Himalaya. Ghani and Rao (1966) provided an excellent account of biology of two species in the Indian Subregion. Chacko (1973) recorded a *Pineus* species from Pipe in Shillong. The group is represented in the World over 46 species in 8 genera. In India only 6 species are known under 3 genera.

Family Aphididae : Aphids are one of the most important group of phytophagous insects. They are polymorphic and have complicated biology, besides processing and ability to transmit plant viral diseases. The aphid fauna of India and adjacent countries constitutes about 750 spcies, i.e. 10% of the World fauna comprising of 7500 species. It includes large number of rare and endemic (23%) species. The group is cosmopolitan in distribution.

Studies on Indian aphids were initiated with the work of Barlow (1896-1899), Buckton (1893-1898) and Cotes (1893). The first comprehensive account on regional fauna was published by Das (1918) who based his studies on aphids of Lahore (now in Pakistan). Later Fletcher (1914); van der Goot (1916-1917); George (1925-1928); Krishnamurthy (1928-1930); Deshpande (1930, 1937); Ayyar (1937) and Ghulamullah (1940) have worked on Indian aphids specially from Peninsular India. Studies on this group got a momentum from 1960 and many papers have been published as follows : David (1954-1958); Ghosh and Raychaudhuri (1958-1968)); Basu *et. al.* (1970-1989); Chakrabarti *et al.* (1970-1989); Ghosh, A. K. (1969-1989); Ghosh, L. K. (1969-1989); Ghosh, M. R. (1976-1989); Agarwala *et al.* (1977-1989); Raychaudhuri D. N. (1956-1983); Raychaudhuri, D. (1980-1989); Verma (1965-1989); Behura (1963-1965); Kulkarny (1980-1989) and Kurl (1980-1989).

Superfamily Cercopoidea

Family Cercopidae : The cercopids, known as frog hoppers or cuckoo spit bugs, are important from the economic point of view. The family consists of four subfamilies and nearly 2368 species from the World. Of these, about 10% are respesented in India. The notable Indian workers on this group are Distant (1908) and Dutta & Ghosh (1976).

Superfamily Cicadelloidea

Family Cicadellidae : Cicadellids, usually known as leaf hoppers, are reecognised as one of the most important groups of vectors associated with transmission of plant viruses and microplasms. In all 115 species of Cicadellids have been reported to transmit 86 plant pathogens. Atkinson (1885) was the first to undertake studies on this group in India. The notable workers are Distant (1908, 1916, 1918), Pruthi (1930, 1934, 1936, 1940), Ghauri (1963), Melichar (1900-1951), Dworakowska (1977), Dutta (1963-1989), Viraktamath (1976), Rao (1967-1989) and Ishihara (1989). A comparison of literature reveals that about 680 species of Cicadellids are known from India.

Family Membracidae : Commonly known as the tree hoppers, these are chiefly distinguished by the great development of the pronotum, particularly it's pronotal process; ocelli are placed between the eyes; antennae inserted in front of head and between the eyes; and pronotum prolonged backward. A little over 200 species are known from India, as against about 2300 species in the world. The pioneer works are by Distant (1908, 1916), Evans (1948), Mondal *et al.* (1958); Ananthasubramanian and Ananthakrishnan (1975); Dutta *et al.* (1978); and Ghosh *et al.* (1986).

Superfamily Cicadoidea

Family Cicadidae : These are forest insects and are well known for the shrill monotonous mating call of the males. From India 145 species are known so far. Notable contributions are made by Distant (1906, 1916); Oltenbach (1928); Fraser (1942); Bolivar (1964); Chatterjee (1936) and Mitra & Muraleedharan (1975, 1976).

Superfamily Coccoidea : Treated separately in this publication by R. K. Varshney.

Superfamily Fulgoroidea

Family Fulgoridae : Fulgoroids are ususally called lantern flies and pricipally characterised by reticulated anal area of the wing. The group is represented by nearly 430 species in India as against world fauna of 6521 species. The earlier works are by Distant (1908, 1916); Oltenbach (1929); Chatterjee and Bose (1934); and Pramanick & Dutta (1977).

Superfamily Psylloidea

Family Psyllidae : Psyllids or jumping plant lice are an economically important group. They are more common in forests. A few species attack fruit trees also. A little over 100 species are known from Indian subcontinent. The major contributions on this group are by Lethierry (1890); Buckton (1893, 1894); Kieffer (1905); Ayyar (1925); Hussain (1927); Mathur (1934, 1950, 1975) and Mani (1935–1964).

Heteroptera

Superfamily Cimicoidea

Family Cimicidae : In India this family includes only four species. All are blood sucking in habit. Usinger (1966) and Bhatt (1974) have worked on Indian species of the genus *Cimex*.

Family Anthocoridae : Anthocorids are important from the view point of biological control for their predatory habits. The main works on Indian Anthocoridae are those of Distant (1913), Ghauri (1972), Muraleedharan and Ananthakrishnan (1974) and Muraleedharan (1975). In all 45 species are known from India.

Superfamily Aradoidea

Family Aradidae : These are broad flattened insects adapted to live in the narrowest crevices under bark, skin of dead trees. So far about 30 species are known from India. Kormilov (1953-1975) has worked on Oriental fauna.

Superfamily Coreoidea

Family Coreidae : This family consists of some brightly coloured insects having four-jointed antennae inserted on the upper parts of the sides of the head. The coreids are vegetable feeders, a few are pests of rice and millets in the Orient. About 200 species are known so far from India. The notable works are by Distant (1902, 1908, 1918), Chopra (1969), and Basu & Mitra (1977, 1978).

Superfamily Lygaeoidea

Family Lygaeidae : Lygaeidae is the second largest family among Heteroptera. Being phytophagous they mostly occur on moss, rubbish, beneath stones or on low plants. It is an economically important family. The pioneer workers are Distant (1904, 1910, 1918); Chropra and Rastogi (1980); and Mukhopadhyay (1980, 1988). About 260 species are so far known from India.

Superfamily Pentatomoidea

Family Pentatomidae : These are known as shield bugs. Some are pests of vegetable crops. The most distinguishing feature of this family is the presence of large scutellum extending to the base of the membrane. The pioneer workers in this group are Distant (1902), Kirkaldy (1909), Power (1973), Datta and Chakrabarty (1977), Ahmed and Khan (1983), Ahmed and Afzal (1989), and Chopra (1972, 1980). More than 5000 species are known from the World and about 700 species are known from the Indian Subcontinent.

Superfamily Pyrrhocoroidea

Family Pyrrhocoridae : These are known as red cotton bugs and include the well known cotton pest *Dysdercus*. Nearly 50 species are known from India so far. The contributors are Distant (1904), Freunberg (1945), Freeman (1947), Van Doesberg (1958), and Mitra, Sen and Muraleedharan (1977).

Superfamily Reduvoidea

Family Reduviidae : These heteropteran insects known as assassin bugs are predaceous in habit. Some species are pathogenic. The species *Triotoma rubrofaciata* Deg. is responsible for Kalazar in Madagascar and South Asia. Nealy 450 species of Reduviidae are known from India. The notable contributions are by Distant (1906, 1910), Kirkaldy (1901), Miller (1949-1955) and Muraleedharan (1976).

Superfamily Tingoidea

Family Tingidae : The tingids are commonly known as lace bugs. These are pest of maize, sugar cane, cotton and fruit trees. Chopra (1971), Livingstone (1972), Mohansundaram (1973), Mohansudaram and Subba Rao (1973), Menon (1959), and Nagaraj (1955) have worked on this group. About 70 species are known from India.

Water bugs : Indian water bugs are comprising of 14 families, namely Nepidae, Notonectidae, Pleidae, Belostomatidae, Naucoridae, Corixidae, Gelastocoreidae, Ochtaridae, Hydrometridae, Veliidae, Mesoveliidae, Gerridae, Saldidae and Herbridae. Former 8 families belong to the Series-Cryptocerata, of which first 6 families are truly aquatic in habitat and other 2 families are shore dwelling; while the rest 6 families are semi-aquatic in habit either surface or shore dwelling, and belong to the Series-Gymnocerata. Water bugs are inhabiting any kind of water system, from lentic to lotic fresh water, brackish water to open ocean water. Mostly they are predaceous in nature, feeding on minute zooplankton to other sizeable organisms whatever they get in their habitat. Some members of water bugs are effectively performing the role of biological control of mosquito larvae and chironomous larvae which are harmful to the mankind. On the other hand, some members unfortunately destroy fish-fry, tadpoles etc. and render loss to the fish culture and frog culture. Water bugs are very important to study from the view point of water pollution.

About 200 species of watr bugs are so far recorded from Indian subcontinent. Dohrn's (1860) study on the Heteropteran fauna of Ceylon (now Sri Lanka) included a few aquatic bugs, but no other comprehensive studies on Indian water bugs were published until monumental work of Distant (1902, 1906, 1910) in 'Fauna of British India' Vols II, III & V. He reocrded about 150 species of water bugs from Indian Sub-Continent. Paiva (1918, 1919) worked on water bugs from Burma and India and recorded approximately 50 species. Hafiz *et al.* (1938, 1939, 1947) studied water bugs of Santhal Parganas, Bihar. He enumerated about 60 species of water bugs in his studies. Pradhan (1950) worked on Indian Gerridae and designated two new species. Brooks (1951) revised the genus *Anisops* worldwide belonging to the family Notonectidae, covering 96 species including 17 species from Indian fauna. Hungerford and Matsuda (1965) recorded 4 species of *Ptilomera* from India. Pradha (1976) reported genus *Ptilomera* for the first time from Andaman Islands. Venkateshan (1980) established a new species of Belostomatidae from South India, while Gupta (1981) designated a new species of Gerridae. Thirumalai (1986) studied the fauna of Silent Valley, Kerala consisting of 9 species of Gerridae, of which 5 were new, and two species of Notonectidae. On other families of Heteroptera no appreciable work has been done since the publication of 'fauna' volumes by Distant (1902-1918).

Current Studies

In Zoological Survey of India systematics and distribution of Hemipteran insects of West Bengal and Meghalaya are presently being studied, while that of Orissa has been published in 1989. The Hemipteran fauna of West Bengal, of families Aphididae, Membracidae, Cercopidae, Fulgoridae, Cicadellidae, Belostomatidae, Hydrometridae, Nepidae, Pleidae, Gerridae, Notonectidae, Mesovelidae, Velidae, Pentatomidae and Coccoidea are under publication. The work on remaining some families is likely to be submitted shortly for inclusion in the 'West Bengal State Fauna' sereis to be published by the Zoological Survey of India. The Hemiptera fauna of Namdapha, Arunachal Pradesh is also under publication. The revision of Indian species of *Aphis* Linn. (Family : Aphididae) has been published very recently in *Mem. zool. Surv. India* (1989). Since 1980, four volumes of 'Fauna of India' on Aphididae, have been published and more volumes are in progress and will be published shortly. Some works on Membracidae and Gerridae are being carried out at the Southrn Regional Station of Z.S.I. A Check list on Coccoidea of South Asia has been submitted for publication.

Outside Z.S.I., works on hemipteran group of insects are being carried out in a few centres, namely Calcutta University; Kalyani University; Tripura University, Agartala; Indian Agricultural Research Institute, New Delhi; Forst Research Institue, Dehra Dun; Central Potato Research Institute, Simla; Punjab Agricultural University, Ludhiana; Loyola College, Madras; M.M. (P.G.) College, Modinagar; etc. These studies are aimed at Taxonomy, Biology, Cytotaxonomy and Ecology of various hemipteran insects.

Expertise

INDIA

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HEMIPTERA : Coccoidea

Introduction

Our knowledge of the Indian scale insects and mealy bugs (Homoptera : Coccoidea) is at present inadequate. Whereas about 6000 species have already been described from all over the World, only 624 species (10.5%) have been reported from the Indian subcontinent (Varshney, 1985). Even these 6000 species amount to only 20–25% of the existing total species, when we consider the tropical areas of the world that need more intensive studies (Kosztarab, 1990).

This group of insects comprises some important pest species of fruit plants, (e.g. *Quadraspidiotus perniciosus, Hemiberlesia lataniae, Melanaspis glomerata, Nipaecoccus viridis, Chrysomphalus aonidum, Icerya purchasi, Drosicha mangiferae, Pseudaulacaspis pentagona, Aspidiotus destructor, Chloropulvinaria psidii,* etc.), as well as some beneficial insects like lac insect (*Kerria lacca*), Wax insect (*Ceroplastes ceriferus*), cochineal insect (*Dactylopius indicus*) and the lantana bug (*Orthezia insignis*). Hence, this insect group is of considerable economic importance. Its taxonomy is based on adult females.

Classification

The classification of Indian taxa, as understood at present, may be summarized as follows :

Superfamily Coccoidea

(i) Archaeococcoidea

(A) Margarodoids

1. Family Ortheziidae
2. Family Margarodidae
3. Family Monophlebidae

(ii) Neococcoidea

(A) Lecanoids

4. Family Pseudococcidae

4a. ? *Puto* Group

5. Family Aclerdidae
6. Family Coccidae
7. Family Dactylopiidae
8. Family Kermesidae
9. Family Eriococcidae
10. Family Tachardiidae
11. Family Beesoniidae
12. Family Asterolecaniidae
13. Family Lecanodiaspididae
14. Family Cerococcidae
15. Family Conchaspididae

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(B) Diaspidoids

16. Family Halimococcidae
17. Family Diaspididae

Basic Literature

Some selected world literature on the Coccids are indicated as follows :

1. Catalogue of the Coccidae [sensu lato] of World, By Fernald (1903).
2. Selected bibliography of Coccoidea, By Morrison and Renk (1957); First supplement By Morrison and Morrison (1965); Second supplement By Russell *et al.* (1974); and Third supplement by Kosztarab and Kosztarab (1988).
3. Annotated list of generic names, By Morrison and Morrison (1966); First supplement By Russell (1970); Second supplement By Kosztarab & Russell (1974); and third supplement By Kostarab *et al.* (1986).
4. Family groups names of the scale insects, By Williams (1969).
5. Atlas of scale insects of North America (in 7 vols.), By Ferris (1937–1955).
6. Catalogue of armoured scales of the World, By Borchsenius (1966).
7. Practical keys for identification of Coccoidea (In Russian), By Borchsenius (1963).
8. Coccidae, By MacGillivray (1921).
9. Mealybugs – Selected literature, By Ibekwe and Lawani (1977).
10. Lac Literature – A Bibliography of lac insects and shellac, By Varshney (1970).

Historical Resumé

i) Pre-1990

Perhaps the first coccid that attracted attention was the lac insect in South India. Father Tachard ion 1710 reported the occurrence of lac on trees, the species of which was named later as "*Coccus lacca* that produces lac in the Gangetic plains" (Kerr, 1782). In the same period Anderson (1787) discovered the cochineal insect *Dactylopius tomentosus*. The papers on both these insects were presented to the Royal Society of London. Anderson (1790) published a monograph from Madras, entitled "Monographia Cocci Ceriferi", which included account of wax producing coccids. Based on Anderson's work, Pearson (1794) published "Observations and experiments on a wax like substance, resembling the "pe–la" of the Chinese, collected at Madras by Anderson and called by him white lac", in the Philosophical Transactions of the Royal Society of London.

Atkinson (1886) was the first to list coccid insect pests. He published notes on economic entomology in 1889 and in the same year described a new genus and species, of Kermesidae, from Sikkim.

ii) 1990-1947

In the last decade of Nineteenth Century, Green, the greatest coccid taxonomist of Indian region, began publishing his studies. As he was based in Sri Lanka (then Ceylon) he made detailed studies on that country, starting with a catalogue in 1896, and with a monumental treatise, "*The Coccidae of Ceylon*" (1896–1922) in five volumes. His last paper was an annotated list of Coccidae (sensu lato) of Ceylon, published in Spolia Zeylanica.

Green started describing coccids from India in 1896, and published a catalogue of all the species hitherto recorded from the Indian subcontinent in 1908, recording 102 species. He worked on all families of coccids and prepared papers on many economically important species. In 1917–1919, he published a list of coccidae affecting various genera of plants. He studied the collections of coccids in Zoological Survey of India (Indian Museum) and also identified all the materials collected and reported by T. V. Ramakrishna Ayyar. With Mann, Green published in 1907 a memoir on the coccids attacking tea plant in Indian region.

Ayyar (1921) published a check list of the coccids of Indian region reporting 369 species. He published about 20 papers on this group of insects (1919–1941), many of them dealing with South Indian species. His two important contributions are : (i) A monograph on South Indian Coccidae, published in Bulletin of Agricultural Research Institute, Pusa, in 1930; and (ii) the Host plant index of Indo–Ceylonese Coccidae, authored with Ramachandran and published as a Miscellaneous Bulletin of I.C.A.R. in 1934. He is cited in references either as Ayyar, T.V.R. or Ramakrishna Ayyar, T. V. Both citations refer to the same person.

Rao initiated his studies on Coccids in 1939 when he described three new species from Baluchistan; discussed certain *Parlatoria* species in 1941; reported *Icerya purchasi* occurrence in 1943; and revised the genus *Pinnaspis* (Ferris and Rao 1947).

iii) 1948-1990

Rao (1951) made a detailed study of Iceryini of the Orient, revised the genera *Perissopneumon* (1947), *Unaspis* (1949), and *Andaspis* (Rao and Ferris, 1952). He was the only Indian worker who worked under world famous Coccidologist G. F. Ferris of U.S.A. In his career he was In–Charge of the Indian Station of the Commonwealth Institute of Biological Control, Bangalore. He published about 20 papers on the Coccids of Indian region (1939–1969). Rao and Kumar (1952) reported 20 little known species from the Indian region.

Kapur, in forties, has reported some coccid predating lady bird beetles. He also published a catalogue of lac insects in 1958, reporting 7 genera and 47 species from all over the World. Dutt (1948–1964) reported on Coccid pests of jute. Das (1948–1962) reported on Coccid pests of tea. Srivastava & Sinha (1965-1966) worked in detail on morphology of *Centrococcus insolitus*, Yadava (1966–1969) on *Saccharicoccus sacchari* and Singh (1970) on *Perissopneumon tectonae.*

Ali (1957–1975) published about 25 papers on Indian Coccids. His earlier works deal with sugarcane infesting mealy bugs. Later he made a detailed catalogue of Oriental Coccoidea, in five parts (1969–1974). Chacko (1976–1980) worked on the Coccids of Coffee in India. Srivastava (1972–1981) worked on mango mealy bug *Drosicha mangiferae.* Shukla and Tripathi (1979–1981) worked on sugarcane scale insece *Melanaspis glomerata.* Muthukrishnan and his coworkers at Madurai, and Nair and his coworkers at Trivandrum have recorded many Coccid pests from South India. Ghani and his associates reported the Coccids of Pakistan, with their host plants and insect parasites.

Varshney (1962–1990) has worked on taxonomic aspects of the Coccids of Indian region. His earlier work is on lac insects culminating in a monograph in 1977 describing all Oriental species. A synoptic world catalogue of this family was published in 1990. His detailed review of Indian Coccids (1985) reported 15 families, 208 genera and 624 species from the region. He discussed the biogeography of the Coccids of Indian subcontinent in a paper presented at the Fourth International Symposium of Scale Insect Studies (ISSIS-IV) held at Budapest in 1984. In recent times two reputed coccidologists, Williams of England on Pseudococcidae and Takagi of Japan on Diaspididae, have greatly enhanced our knowledge on Indian Coccoidea. Avasthi and Shafee (1976–1990) have published about 10 papers, particularly on Pseudococcidae and Coccidae. Z.S.I is publishing a check-list of scale insects and mealy bugs of South Asia (Varshney, *in press*).

Area-Wise Studies

The following areas of the Indian region have been explored for their Coccid fauna to more or less extant. The respective studies are mentioned against each, as follows :

INDIA

Catalogue from Indian continent, By Green (1908).

Indian check-list, By Ayyar (1921).

Indo-Ceylonese host plant Index, By Ramachandran and Ayyar (1934).

Iceryine Scales, By Rao (1951).

Diaspids collected from India, By Borchsenius (1964, 1967).

Catalogue of Oriental Coccoidea, By Ali (1969–1974).

Lac insects of India, By Varshney (1977).

Review of Indian Coccids, By Varshney (1985).

Indian Pseudococcidae, By Avasthi and Shafee (1987).

Faunal lists of :

South India, By Ayyar (1924, 1930, 1936).

Western India, By Kasargode (1914).

Goa, By Ali (1973).

Orissa, By Varshney and Moharana (1987).

West Bengal, By Ghose (1961) and Varshney (in press).

Bihar, By Ali (1968).

Pusa (IARI) Collections, By Misra (1924).

N. E. India (on tea), By Das & Ganguli (1962).

Tripura, By Ganguli and Ghosh (1954) and Agarwala and Varshney (1988).

BANGLADESH

Check-list, By Chowdhury and Ullah (1984, 1985).

NEPAL

Diaspid collections, By Takagi (1975, 1977).

PAKISTAN

Coccids and their parasites, By Ahmad and Ghani (1972) and Ghani and Muzaffar (1974).

SRI LANKA

First catalogue, By Green (1896).

Coccidae of Ceylon (5 vols.), By Green (1896–1922).

Indo-Ceylonese additions, By Ayyar (1926).

Annotated list, By Green (1937).

Other areas are virtually unexplored. No ecosystem-wise study has so far been made.

Genera and species recorded from Indian region

	Family/Subfamily/Tribe	*No. of genera*	*No. of sp./ssp.*
1.	Monophlebidae	3	5
2.	Margarodidae	13	41
3.	Ortheziidae	1	1
4.	Tachardiidae	3	26
5.	Eriococcidae	3	11
6.	Kermesidae	2	2
7	Dactylopiidae	1	4
8.	Beesoniidae	1	3
9.	Pseudococcidae :		
	Phenacoccini	16	28
	Pseudococcini	20	45
	Rhizoecini	3	7
	Sphaerococcini	3	8
10.	Aclerdidae	1	6
11.	Asterolecaniidae	5	29
12.	Cerococcidae	2	7
13.	Lecanodiaspididae	4	6
14.	Coccidae :		
	Ceroplastinae	2	9
	Coccinae :		
	Pulvinariini	6	18
	Coccini	20	73
	Filippinae	7	11
15.	Conchaspididae	1	1
16.	Halimococcidae	1	1
17.	Diaspididae :		
	Protodiaspidinae	1	1
	Parlatoriinae :		
	Kuwanaspidini	1	3
	Leucaspidini	6	11
	Parlatoriini	10	52
	Odonaspidinae :		
	Rugaspidiotini	2	2
	Odonaspidini	3	7
	Aspidiotinae	28	89
	Diaspidinae :		
	Lepidosaphedini	20	51
	Diaspidini	27	119
	Total	216	677

Classified Treatment

Margarodoids

Margarodidae, Monophlebidae and Ortheziidae are included here. Rao (1951) in two parts has dealt with Iceryine Coccids recorded from Orient. Genera *Icerya, Steatococcus* and *Crypticerya* are dealt with, with descriptions of new species (5 from India). Detailed diagnosis, a key and number of illustrations have been provided. *Drosicha* is well known pest on mango.

Ortheziidae is represented by only one species, *O. insignis*, in the region.

Orthezia is utilized for biological control of weed *Lantana*.

Pseudococcids (Mealybugs)

Ghose (1961) reported 11 species of economic importance from West Bengal. Ali (1968) reported six species of Pseudococcidae affecting fruit plants in Bihar. In another paper in the same year, he reported further five species (including one new) from Bihar. Nath (1972) has reported four citrus inhabiting spp. from Darjeeling.

Recently Avasthi and Shafee (1987) have revised Indian Pseudococcidae. A key to subfamilies, tribes and genera is given. Three subfamilies Pseudococcinae (with three tribes), Sphaerococcinae and Rhizoecinae, 31 genera and 48 species are included from India.

Muzaffar and Ahmad (1974) have reported seven species from Pakistan (including and Eriococcid) along with their insect parasites, predators and pathogen. Descriptions of Pseodococcid species are not included but host plants are mentioned in this work. Chowdhury and Ullah (1984 a, b) have reported *Saccharicoccus* and *Rastrococcus*, from Bangladesh.

Four tribes are recognized in the règion : Phenacoccini, Pseudococcini, Rhizoecini and Sphaerococciini. Some species are serious pests and cosmopolitan in distribution. *Brevennia rehi* on paddy, *Coccidohystrix insolita* on brinjal, *Nipaecoccus viridis* on coffee, etc. *Rastrococcus sacchari* on sugarcane, *Dysmicoccus brevipes* on pineapple, and *Antonina graminis* on bamboo are well known.

Coccids (sensu str.)

Soft scales are included in Coccidae. Three subfamilies are recognized : Ceroplastinae, Filippinae and Coccinae (which has two tribes Coccini and Pulvariini) known from the region. *Ceroplastes* contains wax scales and are polyphagous. *Coccus* contains many species, of which *C. hesperidum*, *C. longulus* and *C. viridis* are well known pests. *Eulecanium* and *Hemilecanium* also have well known pests. *Parthenolecanium* attacks coffee. Neem scale *Pulvinaria maxima* was monographed by Ayyar (1925). Avasthi and Shafee (1986) have dealt with Ceroplastinae, and (1989) given a key for Coccinae.

Diaspids (armoured scales)

The largest family of Coccids, Diaspididae contains some serious pests of orchards, throughout the World. Noteworthy genera are : *Aonidiella, Aspidiotus, Aulacaspis, Chrysomphalus, Diaspidiotus, Hemiberlesia, Lepidosaphes, Leucaspis, Lindingaspis, Odonaspis, Parlatoria, Pinnaspis, Quadraspidiotus, Temnaspidiotus*, etc.

Diaspids of Nepal have been studied sporadically by Takagi (1975, 1977, 1988). San Jose scale and related scales in India were studied by Rao and Chatterjee in 1950 (1948). It gives description and figures of 11 species. Borchsenius (1964, 1967) described some genera and species from India. These deal with *Lopholeucaspis* and *Andaspis* groups of taxa.

Other Families

Lac insects belonging to family Tachardiidae (syn. Lacciferidae) were catalogued by Kapur (1958), reporting two subfamilies and seven genera (three in Indian region). Ghosh (1963) reported four spp. of lac insects from West Bengal. Varshney (1977) has revised the family in detail and described all Oriental species with keys and figures. A total of three genera *Kerria, Metatachardia* and *Paratachardina* and 24 species and subspecies have been reported from the Indian region. A review of Family Tachardiidae in the Orient was published by Varshney in 1984. Recently he published (1990) a synoptic updated catalogue reporting two subfamilies, eight genera and 77 species from whole World [after which one more new species has been added from Yunnan, China].

Dactylopiidae has a single genus *Dactylopius* and its four species recorded from the region. They are well known as cochineal insects, on account of the cochineal (carmine) dye produced by them. Besides, they have been utilized for the biological control of noxious weed prickly pear (*Opuntia*).

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THYSANOPTERA

Introduction

The insects included under order Thysanoptera, popularly known as thrips or fringe-wings or bladder-footed insects, are one of the smallest of pterygote insects, ranging in size from 0.5 mm to 10 mm. They possess remarkable structural peculiarities having fringe-wings, asymmetrical feeding apparatus with right mandible vestigial and a protrusible bladder at the end of tarsi. The order Thysanoptera received little attention in the past by entomologists, possibly because of its minute size and unattractive colouration. In recent years however, thrips have assumed considerable importance as pests of variety of crops of agricultural and horticultural importance and some species are carriers of viral diseases to a few commercial and food crops. Most of them are phytophagous, remaining others are mycophagous feeding on spores and fungal hyphae, and a few are predaceous feeding on other thrips, mites, whiteflies and coccids.

Classification

Haliday (1836) raised Thysanoptera to an order level, which included two suborders Terebrantia and Tubulifera. In a most recent classification Mound, Heming & Palmer (1980) have recognised 8 families as follows:

Order	Thysanoptera
Suborder	Terebrantia
Family	Uzelothripidae
	Merothripidae
	Aeolothripidae
	Adiheterothripidae
	Fauriellidae
	Heterothripidae
	Thripidae
Suborder	Tubulifera
Family	Phlaeothripidae

Historical Resumé

i) Pre-1900

The first ever work on Indian Thysanoptera dates back to 1856 when Newman described two new species of Tubulifera, *Phlaeothrips anacardii* and *Idolothrips halidayi* from Mysore.

ii) 1901-1947

The studies on Indian Thysanoptera began rather late compared to other group of insects. The contributions of Bagnall (1913-1926), Hood (1919), Moulton (1927-1929) Ramakrishna Ayyar (1925-1935); Ramakrishna Ayyar & Margabandhu (1931-1939) and Shumsher (1942-1947) made

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the foundation of thrips studies in India, paving the way for extensive work later. Kieffer (1908) described one new gall forming species. Bagnall (1913a, 1913b, 1914, 1915, 1916, 1918a, 1918b, 1919, 1921a, 1921b, 1923, 1924a, 1924b and 1926) published a series of papers, mostly in *Ann. Mag. nat. Hist.* and added 35 new species. Vuillet (1914) described one new species. Williams (1915) described one new species, *Stenchaetothrips biformis* (Bagnall) [= *Thrips oryzae* Williams], considered to be a very serious pest of rice in whole of South East Asia. Hood (1919) described 5 new species. Karny (1926) published the first comprehensive account of Indian Thysanoptera and described 19 new species. Ramakrishna Ayyar is the pioneer worker on Indian Thysanoptera, who started exhaustive collection of thrips and used to send the material to specialists abroad for identification and thus, built up the first reference collection of thrips in India. Also he himself contributed a number of papers in (1925, 1932, 1934, 1935) and described 10 new species. Finally in (1928), he published the monograph of Indian Thysanoptera in which he has provided morphology, life history, key to genera and species, besides describing 26 new species, and thus recorded altogether 126 species from India. Moulton (1927, 1928, 1929a, 1929b) described 11 new species. Ramakrishna Ayyar and Margabandhu (1931, 1935, 1939a, 1939b) described 25 new species. Priesner (1935) described one new species. Ramakrishna Ayyar and Margabandhu (1940) compiled the catalogue of Indian Thysanoptera where 232 species under 94 genera have been recorded. Shumsher Singh (1942, 1944, 1947) described 5 species, and finally in 1945 published the monograph of the Suborder Terebrantia, where he has provided the key to the genera and species; described 2 new genera, 6 new species and recorded altogether 105 species.

iii) 1948-1990

The significant contributions on Indian Thysanoptera were made during this period. The knowledge on the group has been greatly enriched by the contributions of Ananthakrishnan (1949-1990) and Bhatti (1961-1990), the two very eminent authorities on this group. Priesner (1952) added 6 new species. Priesner and Seshadri (1952) added 3 new species. Margabandhu and Ananthakrishna (1953) in the supplement to the catalogue recorded 37 species (Thripidae 27 species; Phlaeothripidae - 10 species). Seshadri and Ananthakrishna (1954) described 7 new species.

Ananthakrishnan conducted intensive survey with special emphasis to South India, and built up a good reference collection of Indian and foreign species. Although Ananthakrishnan worked on the whole order in the beginning, subsequently he concentrated mostly on the suborder Tubulifera. Ananthakrishnan (1949-1990) published a large number of papers and altogether described 55 new genera and 179 new species, besides recording a number of species and genera for the first time from India. Ananthakrishnan and Jagadish (1966-1971) in a number of papers described 54 species. Ananthakrishnan and his other collaborators : Kudo (1974), Muraleedharan (1974), Swaminathan (1980), Varadarasan (1978), Viswanathan (1975) have brought to light another 14 species. Ananthakrishnan (1963) revised the Indo-Ceylonese Terebrantia and published the monograph of Indian Tubulifera (1964). He (1969) published the book, *Indian Thysanoptera*, in which he has dealt with morophology, bionomics, polymorphism and provided a key to genera & list of valid species.

Ananthakrishnan and Sen (1980) published a *Hand Book on Taxonomy of Indian Thysanoptera*, where they have provided the taxonomic criteria, keys to families, subfamilies, genera and species, analysis of distribution and host - plants of various species, and recorded altogether 248 genera and 647 species (Aeolothripidae - 18 species; Merothripidae - 3 species; Heterothripidae - 2 species; Thripidae - 237 species; Phlaeothripidae - 387 species).

Bhatti began his studies on thrips in the Zoological Survey of India, Desert Regional Station, and Central Regional Station at Jodhpur & Jabalpur, and after leaving ZSI he worked at Hans Raj College, Delhi. Bhatti concentrated his studies mostly on the suborder Terebrantia. He (1961-1990) published a number of papers and described altogether 29 genera and 90 species, besides studying a number of genera, the details of which were dealt in revisionary studies. Bhatti and Hatter (1974) described one new species, and Bhatti and Ananthakrishnan (1975, 1978) added 4 new species.

Stannard and Mitri (1962) described one new species and Stannard (1970) added one new species. Wilson (1972) added one; Pitkin (1976) added one; Okajima (1981, 1987) described four and Kulshrestha & Vijay Veer (1984) described two new species.

In the Zoological Survey of India, the studies of thrips were taken up by Sen and Muraleedharan who concentrated on thrips of North-Eastern India. Sen (1976, 1977, 1978), Sen & Muraleedharan (1977), Muraleedharan (1982), Muraleedharan & Sen (1978, 1981a, 1981b) described 2 new genera and 22 new species. Sen et al. (1988) compiled a monograph on Thysanoptera Fauna of North-Eastern India recording 105 species under 65 genera. Sen (1980) studied thrips from Andaman Islands and described two new species, and (1982) studied thrips fauna from Silent Valley, Kerala and added 2 new species. Sen, Pramanik & Sengupta have studied the Thysanoptera fauna of West Bengal, which is under publication.

Lakshminarayan (1962) studied thrips collection from Western and Southern India. Varshney (1970) studied thrips fauna of Shillong (Meghalaya). Thakur *et al.* (1973a, 1973b) studied thrips of Solan (Himachal Pradesh). Rao & Kamble (1975) studied thrips of Marathawade (Maharashtra). Jagadish & Ananthakrishnan (1972) studied the second instar larvae of some Indian Terebrantia and provided a key to genera. David and Ananthakrishnan (1973) studied the second instar larvae of Indian gall thrips and provided a key to genera.

Revisionary studies on a number of genera were under taken in this period the details of which are as follows : Bhatti (1964) studied the genus *Aeolothrips* (Family Aeolothripidae). Bhatti & Ananthakrishnan (1975) studied the genus *Merothrips* (Family Merothripidae). Under the family Thripidae, Sakimura & Ananthakrishnan (1962) have revised the Indian species of *Chaetanaphothrips*; Ananthakrishnan & Jagadish (1966, 1967a, 1967b) studied the genera *Thrips, Chloethrips*, and *Taeniothrips*; Bhatti (1968-1982) studied the genera *Helionothrips, Megalurothrips, Dendrothrips, Caliothrips, Ascirtothrips, Projectothrips, Caprithrips, Exothrips, Perissothrips, Sericothrips* and *Anaphothrips* of the Oriental Region; Mound (1976) studied *Dichromothrips* on old world Orchidaceae; Mound & Palmer (1981) studied pest species of *Scirtothrips*; Pitkin (1977) revised the genus *Chaetanaphothrips*; Wilson (1975) published the monograph of Panchaetothripinae of the world; Vijay Veer & Chauhan (1983) studied the genus *Arathrips*. Under the family Phlaeothripidae, Ananthakrishnan (1969-1976) studied the genera *Polyphemothrips, Leeuwenia, Nesothrips, Stigmothrips, Elaphrothrips, Mesothrips, Crotonothrips;* Ananthakrishnan & Kudo (1974) revised the genus *Xenothrips*; Ananthakrishnan & Muraleedharan (1974) studied the *Gynaikothrips - Liophlaeothrips - Liothrips* complex; Mound (1972, 1974) studied the genus *Allothrips* and spore feeding *Nesothrips* complex; Mound and Palmer (1983) studied the generic and tribal classification of spore-feeding Idolothripinae; Ritchie (1974) studied the genus *Podothrips;* Pitkin (1976) studied the Indian species of *Haplothrips, Antillothrips* and *Xylaplothrips*. Haga (1975) studied the genus *Pyrgothrips* and provided a key to species of world. Okajima (1979, 1987) studied the genera *Apelaunothrips* and old world species of *Holothrips*; Okajima (1981) revised the fungus feeding tribe Plectrothripini.

Studies from Different Environs

Mycophagous thrips : Ananthakrishnan (1969-1972) published the serial publication *Mycophagous Thysanoptera* Parts I-IV and gave a comprehensive account (1973) dealing with general ecology, intraspecific sex-limited diversity, patterns of oedymerism, besides provided keys to the genera and species and recorded 135 species.

Gall thrips : Ananthakrishnan & Jagadish (1969) have compiled the monograph of Indian gall thrips, where they have provided generic & specific keys and recorded 81 species. Subsequently Ananthakrishnan (1968, 1971, 1972) added another 19 species. Ananthakrishnan (1978) published the monograph *Thrips galls and Gall thrips*, where he dealt with the major gall types, morphology of thrips galls and provided keys to the genera of gall thrips of the world, along with list of gall thrips genera and alphabetical index of gall thrips species along with their hosts.

Ecology : The most significant work on different aspects of ecology of Indian thrips was undertaken by Ananthakrishnan and his associates in Entomology Research Institute, Loyola College, Madras and published a large number of papers. Ananthakrishnan (1984) published his monumental work *Bioecology of thrips* as an outcome of his intensive studies for a long period where he dealt at length the thrips communities, thrips and agroecosystem, reproductive strategies along with life cycles, ecology of gall and mycophagous thrips, thrips and natural control agents, thrips and host-plant interactions, etc. Kulshrestha & Srinivasan (1985), Kulshrestha, et. al. (1982, 1983) Srivastava *et. al.* (1983), Vijay Veer *et. al.* (1983) have studied the ecology of thrips of Doon Valley (U.P.).

Biology : Lal & Sinha (1968) studied the biology of *Thrips tabaci*. Dev (1964) studied the biology of *Scirtothrips dorsalis* on tea in Assam. Jagota (1961) studied the life history of *Microcephalothrips abdominalis*. Raizada (1965) studied the life history of *Scirtothrips dorsalis* with detailed external morphology of immature stages. Visalakshi & Joseph (1967) studied the biology of *Gynaikothris karnyi*. Srivastava & Vijay Veer (1983) studied the life history of *Lefroyothrips lefroyi*. Joshi (1974) studied the biology of *Stictothrips fimbriata*. Ananthakrishnan (1987, 1988a, 1988b, 1988c) studied the oocyte follicle cell dynamics in *Arrhenothrips ramakrishnae*. Ananthakrishnan et al. (1983) studied the reproductive strategies and behavioural attributes of some sporophagous Idolothripinae. Ananthakrishnan *et al.* (1984) studied ecological interactions, species dynamics and reproductive biology of some mycophagous thrips. Viswantahan & Ananthakrishnan (1973) studied the biology, ecology and behaviour of *Ecacanthothrips libialis* and in another paper (1973) studied the partial ovoviviparity in *Tiarothrips subramanii*.

Control : In recent years thrips have attracted the attention of agricultural and applied entomologists to work on the control aspects of thrips, due to their damage potential. Birat (1968), Lal & Sinha (1968), Pandey (1971), Patel & Patel (1967), Rathore *et. al.* (1970) Reddy & Jagadish (1980), Saxena (1975), Singh & Sidhu (1959) and Verma (1966) studied the control of cotton and onion thrips, *Thrips tabaci*. Other studies are : Rangarajan *et. al.* (1973), Reddy & Jagadish (1980) on chillies thrips, *Scirtothrips dorsalis*; N. R. Ananthakrishnan (1963) on biology and control of *Scirtothrips bispinosus*; Chaudhari & Ramjan (1971) on *Haplothrips ganglbaueri* on paddy; Lal & Pillay (1980) on *Retithrips syriacus* on Cassava; Muraleedharan and Kandaswamy (1980) on tea thrips; Pillai & Abraham (1978) on Cardamom thrips, *Sciothrips cardamomi*; Sandhu *et al.* (1974) on *Anaphothrips sudanensis* on maize; Santhanaraman (1965) on *Rhipiphorothrips cruentatus* on rose; Thimmaiah & Panchbhavi (1973) on *Heliothrips indicus* on groundnut.

Ananthakrishnan (1973 published a book *Thrips biology and control* where the has dealt in detail ecology, life cycles, feeding mechanisms and nature of injuries, major and minor thrips pests and their control, role of thrips in gall formation and plant disease transmission.

Surveys

Intensive survey of thrips fauna have been conducted in South India, West Bengal, Delhi and parts of Rajasthan, Madhya Pradesh, U.P., N.E. India and Himachal Pradesh. Our knowledge of thrips fauna of Western, Eastern, North Western and North Eastern India is meagre, and intensive surveys are needed in respect of mycophagous and gall inhabiting forms.

Estimation of Taxa

Mound, Heming & Palmer (1980) and Palmer et. al.(1989) have recognised eight families of Thysanoptera : Uzelothripidae, Merothripidae, Aeolothripidae, Adiheterothripidae, Fauriellidae, Heterothripidae, Thripidae, Phlaeothripidae, out of which five are represented in India leaving out three (Uzelothripidae, Faureillidae & Heterothripidae). Approximate 6000 species of thrips are known from the world, out of which 691 species under 250 genera are reported from India. The familywise break up is as follows :

Aeolothripidae	10 genera, 19 species
Merothripidae	2 genera, 3 species
Adiheterothripidae	1 genus, 2 species
Thripidae	97 genera, 248 species
Phlaeothripidae	140 genera, 419 species.

Current Studies

In the Zoological Survey of India, research on taxonomy of Thysanoptera of Meghalaya, revision and updating of Hand Book, and preparation of a bibliography of Indian Thysanoptera covering various aspects are in progress.

In the Entomological Research Institute, Loyola College, Madras a team of research workers under the guidance of Prof. T. N. Ananthakrishnan is engaged in studies on the aspects of ecobehaviour and bio-systematics, sensory perception and host location, biochemical parameters in relation to host-plant preference, thrips-crop-weed interactions relating to economically important crops; and cecidology and thrips and their role in pollination.

In Hans Raj College, Delhi, J. S. Bhatti is engaged in studies on systematics with special reference to taxonomic revisionary work and classification.

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NEUROPTERA

Introduction

The Order Neuroptera erected by Linnaeus (1758) was then represented by a heterogeneous group comprising Plecoptera, Isoptera, Embioptera, Corrodentia, Mallophaga, Mecoptera and Trichoptera besides true Neuroptera. The oldest fossil, described by Tillyard (1932) under the name *Permoberotha vilosa* (Family Permoberothidae), was discovered in the lower Permian rocks of Kansas in America. After a study of Permian Neuroptera and Megaloptera, Tillyard came to the conclusion that the family Berothidae is the oldest amongst the existing families of Neuroptera (*s. str.*).

The neuropterans are valuable allies of man.The order includes quite a large number of species which are predacious in their larval and adult stages. The larvae of the species belonging to families Hemerobiidae, Chrysopidae and Coniopterygidae are predacious on the various stages of small Hemiptera, Thysanoptera, Psocoptera, small Lepidoptera, Coleoptera, mites etc. These active predators destroy the agri-horticultural pests like aphids, coccids, thrips, moths and mites and thus, are beneficial to mankind. So, some neuropterans are being used in biological control of insects. Though in India this type of work has not received much attention but, a number of species have been used in other countries, e.g., *Chrysopa carnea* Stephens is successfully used in California in the control of Pear-Orchid pest, *Pseudococcus meritimus*. U.S. Department of Agriculture introduced a Palaearctic stock of *C. carnea* into the United States for control of alfalfa aphids. Besides being predators, some of the species of the family Mantispidae parasitize the egg capsules of spiders.

Classification

On the basis of morphological and biological features, subdivision of the order Neuroptera has been done by various authors. Imms (1925) and Tillyard (1926) considered two suborders, Megaloptera and Planipennia. Handlirsch (1925), Brues and Melander (1932) and Essig (1942) splitted Neuroptera into three orders, Megaloptera, Raphidoidea and Neuroptera (*s. str.*) (Planipennia). Tjeder (1957) retained Megaloptera and Planipennia as suborders. The order Neuroptera as conceived today consists of about twenty families, namely, Corydalidae, Sialidae, Raphididae, Inocellidae, Ithonidae*, Coniopterygidae, Dilaridae, Berothidae, Polystoechotidae*, Sisyridae, Hemerobiidae, Psychopsidae*, Osmylidae, Mantispidae, Chrysopidae, Myiodactylidae*, Nymphidae*, Nemopteridae, Ascalaphidae and Myrmeleontidae. Numerically, more than 5000 species are known from the whole world. However, some of the families (marked *) are not represented in India.

Historical Resumé

i) Pre-1900

Westwood (1848) made some contributions to the family Mantispidae and Ascalaphidae from India. Walker (1853) published a catalogue of the neuropterous insects in the collection of the British Museum, from which he described and referred to many species of Neuroptera belonging to different families from India. MacLachlan (1867) published new genera and species of insects and revised Walker's British Museum catalogue as far as the end of the genus *Myrmeleon*. In this revisionary work specially of the family Myrmeleontidae he tried to disassociated several species described under the genus *Myrmeleon* and new genera were established for the concerned species.

S. K. Ghosh, Zoological Survey of India, Calcutta.

MacLachlan (1869) worked on the genus *Chauliodes* and its allies with notes and descriptions and also gave description of some new species of the family Dilaridae and Osmylidae. His attempt to classify the family Ascalaphidae (1871) with generic descriptions as well as information on some of the Indian species is a valuable contribution.

ii) 1901-1947

This period may be regarded as the significant period in the history of Indian Neuropterology, as a large number of taxa were described during this period. At the Indian Museum, Calcutta, efforts were made to identify the collections lying in the Museum (Needham, 1909). Navas (1905-1935) discovered quite a large number of new genera and species belonging to different families. Banks (1910-1939) contributed a lot of information including the descriptions of new taxa of different families, namely, Coniopterygidae, Sisyridae, Chrysopidae, Mantispidae, Myrmeleontidae and Ascalaphidae from India. Dover (1921) published an account of the neuropteran insects of Barkuda Island. Fraser (1922) published on the Ascalaphidae in the collection of the Indian Museum. Withycombe (1925) contributed a monograph of Indian Coniopterygidae. Kimmins (1935-1943) published significant account on some of the Indian genera and species of the family Hemerobiidae and Osmylidae.

iii) 1948-1990

The period between 1943 to 1970 may be called as a period of stagnation in the field of Research on Indian Neuroptera. During this period only a few species were dealt with, by the scientists working outside India in their revisionary works. In this context, Kimmins (1949 and 1955), Nakahara (1960-1963), Holzel (1971-72) and Meinander (1972) may be referred to.

Ghosh (1968-1989) has published a number of papers on this subject, with descriptions of more than 20 new species and a new genus. Ghosh & Sen (1977) contributed a checklist of Indian Planipennia.

The specimens of Neuroptera collected from Himalayan ecosystem, Desert ecosystem, terrestrial ecosystem of Peninsular India and Insular ecosystem have been studied by Ghosh (1965 to date). Studies on the collections from Eastern India, i.e. Bihar, West Bengal, Orissa, Assam, Meghalaya, Nagaland, Manipur, Arunachal Pradesh and Sikkim have been undertaken and the accounts of the species belonging to the families Myrmeleontidae (1984), Ascalaphidae (1988) have been published and a paper on Chrysopidae is in press.

A check-list on Myrmeleontidae from Orissa was published (Ghosh, 1987) and another on West Bengal is in press. The studies on the Neuroptera of northern peninsular and north-western Himalayan parts of India, including Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Goa have been published (Ghosh, 1983), besides, that of Himachal Pradesh (1977), Rajasthan (1977), Andaman and Nicobar Islands (1980) and Laccadive Island (1981).

There is a need to further explore neuropteran fauna from different States and Union Territories including the Insular regions of India.

Estimation of Taxa

From a total of about twenty families known from the world, thirteen families are represented in India. The National Collections of Zoological Survey of India comprise material of two families of Megaloptera and eleven families of Planipennia. A total of 315 species are known from India. This includes about 25 species of Megaloptera and about 290 species of Planipennia.

The suborders and family-wise break up of Indian Neuroptera are as follows :

Suborder	*Family*	*Genera*	*Species*
Planipennia	Coniopterygidae	7	11
	Dilaridae	3	3
	Berothidae	3	3
	Mantispidae	4	12
	Osmylidae	7	11
	Sisyridae	2	4
	Hemerobiidae	10	20
	Chrysopidae	15	60
	Nemopteridae	4	6
	Myrmeleontidae	37	125
	Ascalaphidae	15	35
Megaloptera	Corydalidae	7	24
	Inocellidae	1	1
	Total	115	315

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COLEOPTERA

Introduction

Members of the order Coleoptera are commonly known as beetles. This is the largest group of comparable units among all animals. This is not only the largest order of Insecta, but has also been a very favourite group of the collectors for a long time, due to their versatile habits, marvellous colouration and sculpture, as well as for their economic importance. India being situated in tropics, is well known for her richness of Coleopterous fauna. The dense and evergreen forests of North-East India and Nilgiri hills are beetles paradise. The Himalaya down to the Nilgiri hills along with the Vindhyachal and Satpura Ranges gives us enormous variety of habitats and innumerable types of beetles. Beetles form a well characterised group, having hard integument, distinct gular region, modified forewing as elytra meeting mid-dorsally into a straight line, biting mouth parts and holometabolic life-cycle, which are ordinarily sufficient to distinguish them.

Beetles are of immense economic importance, some of them are beneficial, help in controlling many injurious insects. Importance of some Coccinellid species (*Rodolia*) in biological control is well know. On the other hand, damage caused by Coleoptera is colossal, although no definite statistical data is available. The major ecological impact of beetles results from their effects on green plants, their contribution to the breakdown of plant and animal debris and the formation of soil, and their predatory activities. Many species have economic importance often becoming injurious and some others also beneficial.

Many species of the order are markedly stenibiotic, with special ecological requirements for their continued existence. Occurrence of such species can be used as indicators of ecological conditions. Beetles provided suitable material for all types of studies on comparative biology. They also offer a classic example of evolutionary diversification.

Representatives of the following families of Coleoptera include majority of stored product insect pests.

	Family	*Number of species*	*Chief habitats*
1.	Tenebrionidae	100	Stored food products, flour, decaying vegetable matter in ware houses.
2.	Dermestidae	55	Animal skin, furs, woods, dried fish, dried vegetables.
3.	Lathridiidae	35	Ware houses and granaries, fungi & moulds.
4.	Curculionidae	30	Rice, seeds and nuts also attack twigs, leaves, buds and roots.
5.	Ptinidae	24	Stored products in Ware house and granaries.
6.	Bruchidae	20	Feed on leguminous plants, peas, beans, ware house, cargo ships
7.	Nitidulidae	16	Fruits, ware houses, carrions, fungi and flowers.

T. Sengupta, S. Biswas, P. Mukhopadhyay & C. R. Basu, Zoological Survey of India, Calcutta.

	Family	*Number of species*	*Chief habitats*
8.	Anobiidae	15	Drywood, dired animal matters, drugs, tobacco, stored products.
9.	Silvanidae	15	Grains, stored food products.
10.	Cleridae	10	Predacious, curried meat, cheese, seeds.
11.	Mycetophagidae	5	Stored food products.

Representative of following ten families of Coleoptera include majority of forest pests in India

	Family	*Number of species*	*Chief habitats*
1.	Cerambycidae	35	On tree, under and on bark, larvae make tunnel on dead and living trees.
2.	Cureulionidae	8	Flowers, buds, foliage under bark and wood borers.
3.	Scarabaeidae	8	Flowers, foliage, decaying wood, larvae live in soil or humus.
4.	Scolytidae	8	Roots and stems of herbaceous plants, dig galleries underneath the bark and sap-wood.
5.	Bostrychidae	7	Under bark, wood; larvae are wood borers.
6.	Chrysomelidae	6	Mainly foliage; larvae live in soil, sometime bore wood.
7	Platypodidae	6	Conifers and hardwood; larvae dig tunnels in wood.
8.	Buprestidae	5	Leaves and twigs, larvae live underbark, dried wood and sap-wood borer.
9.	Brenthidae	3	Under loose bark, larvae are wood borer.
10.	Meloidae	2	Flowers and foliage, larvae live in soil.

Classification

Classification of Coleoptera has been worked out from different angles by various workers, chiefly by Verhoeff (1893) on the abdomen; Sharp and Muir (1912) on the male genitalia, Forbes (1922 and 1926) on the wing venation and wing folding; Stickney (1923) on the head capsule;

Tanner (1927) on the female genitalia; Boving and Craighead (1931) on the larvae; Poel (1932) on the malpighian tubules; William (1938) on the mouth parts and Smith (1950) on Cytotaxonomy.

Crowson (1955) published an invaluable work on the natural classification of the families of Coleoptera, using external morphology and internal anatomy of both adult and larva, life histories, physiology, habitat and palaeontological evidences. He recognised 4 suborders, 6 series, 22 super families , 157 families, plus 3 families with uncertain systematic position. Since the work of Crowson (1955), more changes have been made specially in the super families Cantharoidea, Cleroidea, Cucujoidea and Dascilloidea. Some new families viz. Boganiidae, Cavognathidae, Phloeostichidae and Lamingtonidae have also been added recently to the order Coleoptera by Sengupta and Crowson (1966-70). The families of Coleoptera have been arranged in the following manner by Crowson (1981);

Suborder I Archostemata, Superfamily Cupedoidea.

Families

1. Ommadidae, 2. Tetraphabridae, 3. Cupedidae 4. Micromalthidae.

Suborder II Adephaga, Superfamily Caraboidea.

1. Rhysodidae, 2. Paussidae, 3. Cicindelidae, 4. Carabidae, 5. Trachypachydae, 6. Haliplidae, 7. Amphizoidae, 8. Hygrobiidae, 9. Noteridae, 10. Dytiscidae, 11. Gyrinidae.

Suborder III Myxophaga; Superfamily Sphaerioidea.

Families

1. Lepiceridae, 2. Torridincolidae, 3. Hydroscaphidae 4. Sphaeriidae

Suborder IV. Polyphaga, Superfamily : Hydrophiloidea.

1. Hydraenidae, 2. Spercheidae, 3. Hydrochidae, 4. Georyssidae, 5. Hydrophilidae

Superfamily Histeroidea

Families

1. Sphaeritidae, 2. Syntelidae, 3. Histeridae

Superfamily Staphylinoidea

Families

1. Ptiilidae, 2. Empelidae, 3. Liodidae, 4. Scydmaenidae, 5. Silphidae, 6. Micropeplidae, 7. Dasyceridae, 8. Staphylinidae, 9. Pselaphidae.

Superfamily Eucinetoidea

Families

1. Clambidae, 2. Eucinetidae, 3. Helodidae

Superfamily Dascilloidea

Families

1. Dascillidae, 2. Karumidae, 3. Rhipiceridae

Superfamily Scarabaeoidea

Families

1. Lucanidae, 2. Trogidae, 3. Acanthoceridae, 4. Passalidae, 5. Pleocomidae, 6. Geotrupidae, 7. Ochodaeidae, 8. Hybosoridae, 9. Glaphyridae, 10. Scarabaeidae.

Superfamily Byrrhoidea

Families

1. Byrrhidae

Superfamily Dryopoidea

Families

1. Eulichadidae, 2. Ptilodactylidae, 3. Chelonariidae, 4. Psephenidae, 5. Elmidae, 6. Lutrochidae, 7. Dryopidae, 8. Limnichidae, 9. Heteroceridae

Superfamily Buprestoidea

Families

1. Buprestidae

Superfamily Artematopoidea

Families

1. Artematopidae, 2. Callirhidpidae, 3. Brachypsectridae

Superfamily Elateroidea

Families

1. Cebrionidae, 2. Elateridae, 3. Throscidae, 4. Eucnemidae

Superfamily Cantharoidea

Families

1. Gneoglossidae, 2. Plastoceridae, 3. Homalisidae, 4. Lycidae, 5. Drilidae, 6. Phengodidae, 7. Telegeusidae, 8. Lampyridae, 9. Omethidae, 10. Cantharidae

Superfamily Dermestoidea

Families

1. Derodontidae, 2. Nosodendridae, 3. Dermestidae, 4. Thorictidae, 5. Jacobsonidae

Superfamily Bostrychoidea

Families

1. Bostrychidae, 2. Lyctidae, 3. Anobiidae, 4. Ptinidae

Superfamily Cleroidea

Families

1. Phloiophilidae, 2. Peltidae, 3. Lophocateridae, 4. Trossitidae, 5. Chaetosomatidae, 6. Cleridae, 7. Acanthoenemidae, 8. Phycosecidae, 9. Melyridae

Superfamily Lymexyloidea

Families

1. Lymexylidae, 2. Stylopidae

Superfamily Cucujoidea

Section (I) Clavicornia

Families

1. Nitidulidae, 2. Rhizophagidae, 3. Boganidae, 4. Phalacridae, 5. Protocucujidae, 6. Sphindidae, 7. Hobartiidae, 8. Cucujidae, 9. Passandridae, 10. Phloeostichidae, 11. Silvanidae, 12. Cavognathidae, 13. Cryptophagidae, 14. Helotidae, 15. Byturidae, 16. Biphyllidae, 17. Lamingtoniidae, 18. Languriidae, 19. Erotylidae, 20. Cryptophilidae, 21. Cerylonidae, 22. Corylophidae, 23. Sphaerosomatidae, 24. Endomychidae, 25. Coccinellidae, 26. Discolomidae, 27. Merophysiidae, 28. Lathridiidae.

Section (II) Heteromera

Families

1. Merycidae, 2. Colydiidae, 3. Prostomidae, 4. Mycetophagidae, 5. Cisidae, 6. Pterogeniidae, 7. Tetratomidae, 8. Melandryidae, 9. Mordellidae, 10. Rhipiphoridae, 11. Synchroidae, 12. Cephaloidae, 13. Oedemeridae, 14. Pythidae, 15. Trictenotomidae, 16. Pyrochroidae, 17. Anthicidae, 18. Aderidae, 19. Meloidae, 20. Scraptiidae, 21. Cononotidae, 22. Othnidae, 23. Salpingidae, 24. Inopeplidae, 25. Myctoridae, 26. Monommidae, 27. Zopheridae, 28. Lagriidae, 29. Tenebrionidae, 30. Alleculidae.

Superfamily Chrysomeloidea

Families

1. Disteniidae, 2. Cerambycidae, 3. Megalopodidae, 4. Bruchidae, 5. Chrysomelidae

Superfamily Curculionoidea

Families

1. Nemonychidae, 2. Anthribidae, 3. Belidae, 4. Oxycorynidae, 5. Aglycyderidae, 6. Allocorynidae, 7. Attelabidae, 8. Apionidae, 9. Brenthidae, 10. Curculionidae, 11. Scolytidae, 12. Platypodidae

Historical Resumé

i) Pre-1900

Indian Coleoptera have been dealt and described by various workers, as early as 1792 by Fabricius, who described a longhorn beetles (Cerambycidae) based on single specimen from Tranquebar. some other early workers are Wiedemann (1823) who described 200 new species from Bengal, Petry (1831) who in his D.Sc thesis included 1500 species of Coleoptera from Oriental region; Westwood (1832) published a book on Indian Insects with many colour illustrations, Hope (1837) on Himalayan Insects, and Bates (1864) recorded 5000 species from India.

ii) 1901-1947

At the beginning of twentieth century, most important work published on Coleoptera is *Coleopterorum Catalogus* (1910-1940) in 31 volumes, 170 pars, edited by S. Schenkling and published by W. Junk (The Netherlands), other important works published are: Lefroy (1906 and 1909) on 'Indian Insect Pests'; Stebbing (1914) on 'Ecology and control of Indian forest insects. In the 'Fauna of British India' series contributions were made by C. J. Gahan (1906) on Cerambycidae (Prioninae, Disteniinae, Lepturinae, and Cerambycinae); by M. Jacoby (1908) on Chrysomelidae (Sagrinae, Danacinae, Criocerinae, Zugophorinae, Orsodaeninae, Megalopodinae, Clytrinae, Cryptocephalinae, Chlamisinae, Lamprosomatinae, Eumolpinae); by G. J. Arrow (1910) on Scarabaeidae (Cetoninae, Dynestinae); by W. W. Fowler (1912) on Cicindelidae, Rhysodidae and Paussidae; by G. A. K. Marshall (1916) on Curculionidae (Brachyderinae and Otiorhynchinae): by G. J. Arrow (1917) on Scarabaeidae (Rutelinae, Desmomycinae & Euchirinae); by S. Maulik (1919) on Chrysomelidae (Hispinae & Cassidinae); by G. J. Arrow (1925) on Erotylidae, Languriidae & Endomychidae); by S. Maulik (1926) on Chrysomelidae (Chrysomelinae & Halticinae); H. E. Andrewes (1929) on Carabidae (Carabinae); by M. Cameron (1930) on Staphylinidae (Micropeplinae, Oxytelinae, Oxyporinae, Megalopodinae, Steninae & Enaesthetinae); by G. J. Arrow (1931) on Scarabaeidae (Coprinae); M. Cameron (1931) on Staphylinidae (Paederinae); by M. Cameron (1932) on Staphylinidae (Staphylininae, Trichophyinae, Termitodiscinae, Phgosteninae & Trachyphorinae); by H. E. Andrewes (1935) on Carabidae (Harpalinae); by S. Maulik (1936) by Chrysomelidae (Galerucinae); and by M. Cameron (1939) on Staphylinidae (Pseudoperenthinae & Aleocharinae). Catalogue of Indian insects were published by Government of India (1924-1931) on the families Carabidae (H. E. Andrews 1930), Lycidae (R. Kleine 1931), Palpicornia (d' Orchymont 1928), Cicindelidae (M. H. Heynes-Wood and C. Dover 1928), Nitidulidae (S. N. Chatterjee 1924) and Brenthidae (R. Kleine 1926).

iii) 1948-1990

Since Independance (1947) two major work published are 'Fauna of India' vols. by G. J. Arrow (1949) Lueanidae and Passalidae; other Indian Coleopterists of this period, who worked in Z.S.I., are A. P. Kapur on Coccinellidae, T. G. Vazirani on Dytiscidae, Gyrinidae and Haliplidae, R. K. Kacker on Cytotaxonomy of Coleoptera, K. Rai on Bostrychidae, G. N. Saha on Meloidae, C. R. Basu on Chrysomelidae, S. Biswas on Scarabaeidae, Dytiscidae and other aquatic families, S. K. Saha on Carabidae, Cicindelidae and Rhysodidae, P. K. Maiti on Cerambycidae, Scolytidae and Platypodidae, A. K. Mukherjee on Languriidae and Dytiscidae, P. Mukhopadhyay on Cucujidae and Curculionidae, T. K. Pal on Silvanidae and Passalidae, A. R. Bhaumik on Coccinellidae, R. Sewak on genitalia of Scarabaeidae, N. Saha on Scolytidae, D. N. Bisws on Staphylinidae, G. N. Saha & B. N. Das on Tenebrionidae, S. K. Chatterjee on Scarabaeidae, T. Sengupta, P. Mukhopadhyay, R. Sengupta & P. K. Basak on Stored product beetles, T. Sengupta & Mrs. M. Dey on Beetles of Wetland, T. Sengupta & C. K. Sengupta on Cerambycidae, T. Sengupta on higher classification of Clavicornia, and on Languriidae, Cryptophagidae, Erotylidae, Cerylonidae, Byturidae, Merophysidae, Othnidae, Inopeplidae, Rhizophagidae, Propalticidae and Lathridiidae. In other Institutions, the following worked : V. V. Ramamurthy & S. Ghai on Curculionidae, G. L. Arora on Bruchidae, H. Pajni on Curculionidae and K. P. Jaiswal on Hydrophilidae.

Foreign workers in the recent times (1975-83) published several papers on various families of Coleoptera from Indian and its adjoining countries, which enriched present knowledge on Indian beetles. These workers are : S. Kimoto, H. Takizawa, I. Lopatin, M. Daccordi and M. Wurmli (Chrysomelidae), R. Bielawski (Coccinellidae), E. Colonnelli (Curculionidae), P. Morvan, K. Mandl, M. Schmid, A. Casale, R. Heinertz, W. Heinz and T. Deave (Carabidae), M. Sato (Georyssidae, Hydraenidae, Hydrophilidae and Ptilodactylidae), S. Breuning and C. Holzschuh (Cerambycidae), M. Chujo (Erotylidae, Languriidae & Helotidae), R. Dajoz and S. A. Slipinsky (Colydiidae & Cerylonidae), H. Franz (Scydmaenidae); G. Fray, R. Petrovitz and G. Sahatinelli (Scarabaeidae), Z. Kaszab (Tenebrionidae), F. Angetini & L. Marzo and M. O. Lisle (Lucanidae), V. Puthz, H. Coiffait and G. M. Rougemout (Staphylinidae), C. Reyes (Passalidae), E. Schedl (Scolytidae and Platypodidae), J. Theorond (Histeridae), G. Wewalka (Dytiscidae), W. Wittmer (Cantharidae), J. Jelinck (Nitidulidae), W. Schawaller (Silphidae), V. Svihla (Oedemeridae), M. Brancui (Cantharidae and Dytiscidae), B. Klausnitzer (Helotidae), R. Friesa (Anthribidae), G. Liberti (Dasytidae), S. Bily (Buprestidae), H. Coiffait and L. Harmann (Staphylinidae).

Sengupta *et al.* (1984) published an important account on major beetle pests on stored products, Basak & Sengupta (1989-90) published a number of papers on stored product beetles, and Basak (1989) reported 84 species under 22 families of Coleoptera associated with stored products in Calcutta. Kacker (1963-1988) published a series of papers on cytotaxonomy of beetles, wherein he proposed a hypothetical classification of Coleoptera based on his chromosomal studies. Recently, Biswas and Mukhopadhyay (in press) hae completed a study on beetles of Lakshadweep Islands.

Estimation of Taxa

Out of the four suborders of Coleoptera, two major suborders, namely, Adephaga and Polyphaga, are represented in India. Members of other two suborders, Archostemata and Myxophaga are yet to be discovered. Against an estimated total of 179 families of Coleoptera known from the world, about 103 families are recorded from India. Out of about 3,50,000 described species from all over the world, 15,000 species under 2000 genera are known from India. The National Zoological Collections in the Zoological Survey of India contain 86 families covering about 8000 species, collected from different localities in India and adjacent countries. Some species from different parts of the world are also represented in the collection.

Our knowledge of the Indian Coleoptera at present is far from complete. Leaving aside the case of little known groups, new taxa of specific or generic level are constantly discovered. The family wise break up of Indian and world Coleoptera is as given below :

Suborder	*No. of families in World*	*No. of families in India*
Archostemata	3	—
Myxophaga	4	—
Adephaga	7	7
Polyphaga	165	96

Terrestrial Coleoptera

Of the four suborders of the order Coleoptera, the members of Archostemata are terrestrial, whereas numbers of families of Adephaga are divided into terrestrial and aquatic forms, Myxophaga are predominantly aquatic and major families of Polyphaga are terrestrial in habit, although about half a dozen Polyphagan families are aquatic. Some members of the families Chrysomelidae (Donaciinae), Curculionidae (Ceuthorthynchinae, Boganinii) and Lampyridae (Luciolinae in part) have secondarily gone into water. An approximate estiamte of different categories is given below :

Suborder	*Families*	*Genera*	*Species*
Archostemata	—	—	—
Adephaga	5	300	2500
Polyphaga	155	1600	12000

Aquatic Coleoptera

Out of 8054 species of aquatic beetles known from the world, 588 species are represented in India. An approximate break up of different taxa is given below :

Suborder	*Families*	*Genera*	*Species*
Myxophaga	—	—	—
Adephaga	5	52	411
Polyphaga	9	57	177

Among freshwater Coleoptera, there are certain Zoogeographically interesting groups *e.g.* out of five species of Amphizoidae known from the world, one species is recorded from Kashmir in India. Family Psephenidae is known from North America and Tibet. In recent surveys specimens have been collected from torrential rivers and streams of Arunachal Pradesh and Uttar Pradesh.

Classified Treatment

Suborder I Archostemata

This suborder is not represented in India proper; Fowler (1912) recorded a species, *Cupes clathratus* Solsky, from Ruby mines, Burma.

Suborder II Adephaga

Superfamily Caraboidea

Super family Caraboidea includes 11 familes, namely Rhysodidae, Paussidae, Cicindelidae, Carabidae, Trachypachydae, Haliplidae, Amphizoidae, Hygrobiidae, Noteridae, Dytiscidae and Gyrinidae. Fowler (1912) published an account of Indian Rhysodidae, Paussidae and Cicindelidae in a volume of 'Fauna of British India' series, whereas Andrews (1929, 1935) contributed accounts of Indian Carabinae in two other volumes of 'Fauna' Recently, T. G. Vazirani (1953-1984) published a series of papers on aquatic beetles of India, of which most important review of the subfamilies Noterinae, Laccophilinae, Hydroporinae, Colymbetinae and Dytiscinae. He (1977) also published a catalogue of Oriental Dytiscidae. his other contributions are discovery of Amphizoidae for first time from India and a volume of 'Fauna' on Gyrinidae and Haliplidae (1984). Saha (1978-86) has published a number of papers on Indian Carabidae, where he has added 12 new species. Presently he is studying Carabidae fauna of West Bengal and a revision of Indian Chlaeniinae. Saha with Biswas, Sengupta and Halder (1978-86) published a number of papers on Cicindelidae and Rhysodidae Biswas and Rynth (1987) published Cicindelidae of Meghalaya. Sengupta, Dey & Bhuiya (1989) published an account on wetland fauna of W. Bengal, and Dey (1990) recorded 28 spp. of aquatic beetles associated with wetland around Calcutta. Mukherjee and Sengupta (1986) discovered a new species of Dytiscidae from Silent valley. Biswas, Saha & Mukhopadhyay recently completed a study on Dytiscidae, Gyrinidae & Haliplidae of West Bengal and dealt with 71 species. Saha, Halder and Biswas have taken a project on Indian Cicindelidae.

Suborder III Myxophaga

This suborder contains 4 families. Family Lepiceridae is represented with single genus *Lepicerus* and two species, Torridincollidae with 6 genera and 25 species, Sphaeriidae with single genus *Sphaerius* and 18 species and Hydroscaphidae with 3 genera and 13 species from the world. So far, these families are not reported from India.

Suborder IV Polyphaga

This suborder contains large number of taxa and divided into 19 superfamilies and 145 families. Workers differ intheir opinion regarding definition and limit of some of the families included. however, classification is based on the biology of Coleoptera by Crowson (1981).

Superfamily Hydrophiloidea

D'Orchymont (1919-1929) and Sharp (1874-1890) dealt with Indian fauna. Orchymont (1928) published a check list of the species recorded from India and ajoining areas. Hydrophilidae is the dominant family and other four smaller families namely Hydaenidae, Hydrochidae and Sperchidae are often treated as subfamilies of Hydrophilidae. Champion (1920-1923) has described a few species of Georyssidae and recently deo Sato described a number of species from Darjeeling area. A study on Hydrophilidae of Orissa by Biswas & Mukhopadhyay is in press, and work on Hydrophilidae of West Bengal is also completed, where they dealt with 79 spp under 21 genera with several new records. Biswas and Mukhopadhyay have also studied Indian Georyssidae.

Superfamily Histeroidea

Of the three families, Histeridae, Sphaeritidae and Syntelidae, Sphaeritidae does not occur in India, while Syntelidae is represented by single species *Syntelia indica* from India. Histeridae fauna was studied chiefly by Erichson (1834), Wiedemann (1821), Redtenbacher (1847), Thomson (1862), Bickhardt (1913-1921), Marseul (1853-1879), Lewis (1888-1910), Cooman (1932-47), Therond (1970-78) and Mazur (1978-85). Recently, Biswas and Pal (1984) have published Histeridae of Namdapha (Arunachal Pradesh) adding one new species. Chakraborty and Biswas have worked on Histeridae of West Bengal where they have dealt with 40 species.

Superfamily Staphylinoidea

Nine families are included in this superfamily, of which little work has been done in India on 8 families, namely, Ptiliidae, Empelidae, Liodidae, Scydmaenidae, Dasyceridae, Pselaphidae and Silphidae, though about 9700 species and 1072 genera are known these families from all over the world. The remaining family is Staphylinidae, of which about 30,000 species and 1500 genera are knwn from the world. The Indian fauna of Staphylinidae has been studied by early workers like Motschulsky (1844-1861), Krattz (1853-1863) and Fauvel (1862-1908). Later Cameron (1930-1939) published four volumes of 'Fauna of British India including Ceylon and Burma' Recently harmann (1970-1986) and Hamond (1973-1975) have added knowledge to Indian Staphylinidae. D. N. Biswas (1977-89) published a series of papers on Indian Staphylinidae, including a monograph with Sengupta where they have added 14 new species and a new genus. They also revised genus *Bledius* Leach reporting 8 new species. Angelini and De Marzo (1983-86) published a number of papers on Indian Leiodidae and added 31 new species from Himalaya and South India.

Superfamily Eucinetoidea

This superfamily contains 3 families, 40 genera and 680 species from the world, but very little is known about the group from India.

Superfamily Dascilloidea

This group contains 3 families, 20 genera and 130 species from the world, but little informations available on these groups from India. Van Emden (1926) published results of his studies on the Sandalidae (= Rhipiceridae) of Indian Museum Collection and reported the larva of *Sandalus* as a parasite of Cicadas.

Superfamily Scarabaeoidea

This is one of the distinct group of Coleoptera. The species are usually fossorial. Many species are of economic importance. Some species of Melolonthinae, Rutelinae, Dynastinae and Cetoniinae are defamed for their destructive habit. Coprophagus species of several subfamilies of Scarabaeidae are useful scavangers. In India subfamily Coprinae plays an important role in clearing the animal faeces. They also enrich the soil by taking valuable nutrients into it. About 2200 genera and 27,500 species are known of this group from the world. In India, Gravely (1914) published a monograph on Indian Passalidae. Lucanidae was monographed by Arrow (1949) in 'Fauna of British India' series and he also updated our knowledge on Indian Passalidae in the same volume. of the remaining families, only Scarabaeidae has received serious attention both by Indian and foreign workers due mainly to its economic importance. Arrow (1910, 1917, 1931) published three volumes dealing with part of the family but economically very important subfamily Melolonthinae is yet to be worked out. Biswas (1978); made important contribution on Indian Coprinae of Meghalaya. Biswas & Chatterjee (1977-87) published a series of papers on Scarabaeidae of Arunachal Pradesh, Silent Valley (Kerala), Palamau Tiger reserve (Bihar), Orissa, West Bengal, Meghalaya, Tripura and Andaman Islands, where they have dealt with hundreds of species, adding 12 new species. Recently, Pal (1990) published an account of Passalidae of Arunachal Pradesh.

Superfamily Byrrhoidea

This superfamily contains a single family Byrrhidae, which includes 300 species under 28 genera from the world, but little is known from India.

Superfamily Dryopoidea

The superfamily Dryopoidea contains 9 families, which are mostly subaquatic. Not much is known of these beetles in India. Only some species of Heteroceridae, Dryopidae, Elmidae and Psephenidae have been reecorded from India. The last named family is interesting for its geographical distribution, being known from N. America, Tibet and Himalaya.

Superfamily Buprestoidea

This superfamily contains a single family Buprestidae, which includes about 15,000 species under 400 genera from the world. The family is essentially tropical in distribution. Some species are brilliantly coloured and owing to the splendour of their metallic lustre are used in embroidery and jewellery. Beeson (1919), Gardner (1929), Kalshoven (1929), Stebbing (1914) and Thery (1928) have worked on various aspects of the group, but no comprehensive taxonomic account is available from India.

Superfamily Artemetopoidea

The superfamily contains only 3 small families with about 2000 species known from the world. Van Emden (1926, 1936) contributed some informations on Indian Callirhipidae and since then no other information is available.

Superfamily Elateroidea

This superfamily contains 4 families, of which Elateridae is the largest. The adult beetles are capable of leaping when lying on their back. Some members possess photogenic organs like those of Lampyridae. The larvae of Elaterinae are elongate and cylindrical and very tough skinned. Some larvae are root feeders and extremely destructive. Altogether about 10,470 species under 600 genera are known from the world. Inspite of their economic importance, little attention has been paid to this group in India. Chatterjee and Fleutiaux (1933) and Gardner (1930) studied some species but no comprehensive work is available. If properly explored, many new taxa are likely to be discovered from the country.

Superfamily Cantharoidea

The superfamily contains 12 families. Their soft integument and loosely articulated body parts are characteristic of the group. Fire flies of the family Lampyridae belong to this superfamily. Some larvae of this group prey on snails. About 10,500 species under 430 genera are known from the world. No comprehensive taxonomic account is available of any of the families from India, but Austin (1924), Paiva (1919) and Mehata (1932) have worked on biology of few species of Indian Lampyridae. Wittmer (1980–86) published a number of papers on Indian Malachiidae, describing 27 species mostly from foothills of Himalaya. He also published (1983-86) descriptions of 20 new species of Cantharidae from Himalaya.

Superfamily Dermestoidea

This superfamily contains 5 families, of which Dermestidae is the largest. It includes some of the most injurious pest species of store products, specially fur, wool, skin and hide. No comprehensive taxonomic account of Indian fauna is available. About 925 species under 51 genera are known from the world. Barnes and Grove (1916), Fletcher and Ghosh (1919) and Hussain (1921) have worked on Indian species.

Superfamily Bostrychoidea

This superamily includes 4 families. Majority of species are associated with wood or wooden furniture, bamboo and other materials of plant origin. *Lasioderma serricorne* of the family Anobiidae is a serious pest in Cigar and Cigarette factories everywhere. This species infects dry fish also. About 2750 species under 270 genera are known from the world. Pic (1937), Gardner (1937), Garthwaite (1940), Atkinston (1933), Beeson and Bhatia (1937) and Beeson (1919–1935) have dealt with the group. Rai has published some papers on Bostrychidae.

Superfamily Cleroidea

This superfamily includes 9 families. Majority of species are predatory in nature, at least in larval stage. The group is predominantly distributed in tropics. A few species (*Necrobia, Corynotes*) occur within carcases and skin. In the larval stage they are predacious and feed upon wood and bark boring Coleoptera. About 9609 species under 410 species genera are genera from the world. In India, Beeson (1926), Corporaal (1926, 1939) and Gardner (1937) have contributed to our knowledge.

Superfamily Lymexyloidea

The superfamily Lymexyloidea contains a single family Lymexylidae, of which 50 species under 6 genera are known from the world. They can bore into hard wood, sometimes doing serious damage by drilling cylindrical holes. Two genera *Attractocerus* and *Melittoma* occur in India, which have been dealt by Gardner (1926). The group needs more attention.

Superfamily Cucujoidea

Superfamily Cucujoidea is divisible into two sections, namely Clavicornia and Heteromera. The Clavicorn beetles pose some difficult problem in the classification of the families, particularly in the characterisation and constitution of the group. Different authorities still vary greatly in their treatment of vast number of species assembled in this superfamily. Usually 28 families are recognized in the section Clavicornia and 30 families in Heteromera. Sengupta & Crowson (1966-73) published a series of papers on higher classification of Clavicornia, where they established 4 new families, and reviewed Languriidae, Cerylonidae and Sphindidae. Sengupta (1967–88) published many papers on tribe Loberini, Cladoxenine and Thallisellini of Languriidae; reviewed the world genera of Rhizophagidae; discovered the families Propalticidae and Byturidae for the first time from India region; proposed a new classification fo the family Erotylidae: and revised Lathridiinae of India. Recently, he has completed a study of Indian Cryptophagidae where about 50 new species are discovered. Sengupta & Pal (1977–84) worked on Indian Silvanidae, Merophysiidae, Cerylonidae, Sphindidae and published a number of papers. A volume of 'Fauna' on Silvanidae by them is in press. Sengupta and Mukhopadhyay (1976–85) published many papers on Indian Cucujidae and a volume of 'Fauna' is under preparation, which will include 24 new species. Sengupta & Dey (1990) revised Indian *Rhizophagus* (Rhizophagidae) where they established 7 new species. Mukherjee published a number of papers on Indian Languriidae.

Kapur (1946–72) published a series of valuable papers on Indian Coccinellidae, of which important ones are: Revision of genus *Jauravia*, Tribe Aspidimerini, genus *Stethorus, Rodalia* and *Tetrabrachys*. Amongst other important works contributed by Kapur on Coccinellidae are fauna of Manipur, Nepal, Andaman, Goa and Mount Everest region. Recently, Chakraborty and Biswas completed a study of Coccinellidae of West Bengal, where they have dealt with 95 spp.; Ghosh, Biswas and Lahiri (1977) published a list of Coccinellidae of Meghalaya. Mukhopadhyay has studied Indian Passandridae and Prostomidae, adding 4 new species. Sengupta, Pal and Mukhopadhyay (1977–1980) have published a number of papers on small families of Heteromera mainly Inopeplidae and Elacatidae. Saha (1972–1990) published a series of papers and a monograph on Indian Meloidae, dealing with about 100 species and reporting 28 new species and one new genus. Saha has also prepared a catalogue on Oriental Tenebrionidea and published (1984–90) a few papers besides jointly working with Das on Tenebrionidae of West Bengal.

Superfamily Chrysomeloidea

This superfamily contains 5 families 6560 genera and 71,500 species from the world. Out of the 5 families, Disteniidae is often included in Cerambycidae and Megalopodinae in Chrysomelidae. All members of this group are phytophagus and cause considerable damage to the foliage, timber, forest trees and stored products, specially seeds and pods of various leguminous plants. Due to its economic importance, the group has attracted attention from the early times and one of the first volume of 'Fauna' was published on a part of Cerambycidae by Gahan (1906). Jacoby (1908) published a volume on a part of Chrysomelidae, and remaining parts were dealt with in three separate volumes of 'Fauna' by Maulik (1919, 1926, 1936). Recently Scherer (1969) published a monograph on Indian Alticinae (Chrysomelidae). In Z.S.I. Basu (1977–87) published a series of papers on Indian Chrysomelidae where he dealt with hundreds of species, added one new genus, 30 new species and several new records. Recently he completed a study on Chrysomelidae of West Bengal, where he has dealt with 374 species including 4 new species. He has published papers jointly with Sengupta, Bhowmick and Halder on Chrysomelidae of Tripura and other states. Anand (1978–89) published a number of papers on Chrysomelid species of economic importance. Arora (1977–78) published two important monographs on Taxonomy of Bruchidae of North West India. C. K. Sengupta & T. Sengupta (1981) has dealt with Cerambycidae of Arunachal Pradesh: Maiti, Khan & Mitra (1981–88) published a series of papers on biology & ecology of Cerambycidae beetles. Maiti & Mitra are studying Cerambycidae of Anaman & Nicobar Islands. Biswas, Basak & Mukhopadhyay are dealing with Cerambycidae of West Bengal, Meghalaya and Tripura.

Superfamily Curculionoidea

Superfamily Curculionoidea includes 10 families, about 5311 genera and 59,9520 species from the whole world. Curculionidae alone contains 50,000 species and 4,500 genera distributed over 75 subfamilies. The members of this group are phytophagus and include some serious pests of forest trees, agricultural crops and stored grain. Ambrosia (members of Platypodidae and Scolytidae) are notorious due to their relationship with a deadly fungal disease, which causes heavy damage to forest trees. Out of the families included in this superfamily, considerable work has been done on biology of economically importance species, but no comprehensive taxonomic account is available. Stebbing (1914), Beeson (1941), Voss (1935), Ayyar (1922) and Gardner (1934), have done useful work, and Marshall (1916) has published a monograph on a part of Curculionidae as a volume in 'Fauna of British India' series. Recently, Pajni (in press) has completed work on another 'Fauna' volume on Eremninae : Curculionidae. Ghai, Supare and Rammurthy (1988–90) have revised genera *Tanymecus* and *Myllocerus* and added a new species in genus *Derelomorphus* Mukhopadhyay (1984) has dealt with Indian Brachyderinae, adding a new species. Mukhopadhyay and Biswas are now engaged on studies of Rhynchophorinae : Curculionidae of West Bengal and Meghalaya. Maiti and Saha (1990–89) published a series of papers including two monographs on Indian Scolytidae, dealing with 150 species, particularly from the Bay Islands, West Bengal and North–east India. Maiti and Nandi are now engaged on Indian Platypodidae, recording 89 species so far.

Expertise

INDIA

In ZSI

T. Sengupta, [Rhizophagidae, Languriidae, Cerylonidae, Erotylidae, Cucujidae, Silvanidae, Cryptophagidae, Lathridiidae, Nitidulidae, Elacatidae, Propalticidae]. Kuldip Rai, [Bostrychidae]. P. K. Maiti, [Bark and Timber beetles (Cerambycidae, Scolytidae and Platypodidae)]. S. Biswas, [Aquatic Coleoptera, Scarabaeidae, Histeridae, Coccinelidae, Bruchidae, Cerambycidae, Curculionidae]. G. N. Saha, [Meloidae, Tenebrionidae]. S. K. Saha, [Carabidae, Cicindellidae, Rhysodidae]. P. Mukhopadhyay, [Cucujidae, Stored grain pest, Cerambycidae, Curculionidae]. C. R. Basu, [Chrysomelidae]. S. K. Chatterjee, [Scarabaeidae, esp. Cetoniinae Dynastinae]. D. N. Biswas, [Staphylinidae]. S. K. Chakraborty. [Histeridae, Coccinellidae] and N. Saha, [Scolytidae], all of ZSI, M-Block, New Alipur, Calcutta 700 053.

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Elsewhere

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G. L. Arora, Punjab University, Chandigarh. [Bruchidae].

G. K. Veeresh, Agricultural University, Bangalore. [Scarabaeidae, esp. Melolonthinae].

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Michel Brancucci, Museum d' Histoire Naturelle, Entomologie, Augustinergasse 2, CH-4001 Bale. [Dytiscidae, Cantharidae].

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Takizawa, H., Biological Research Centre, Japan Tabacco Inc., 23, Nagoki Kanagawa 257 (Japan). [Chrysomelidae].

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STREPSIPTERA

Introduction

Strepsiptera, popularly called as the Stylops or twisted-winged insects, was considered by some authorities as closely related to the order Coleoptera. These strange insects have also had few changes in nomenclature until they were placed in the order Strepsiptera by Kirby (1913). They were regarded as Rhipidoptera in the order Diptera Lamarck 1816; Rhipiptera Latreille 1817; Strepsata Billberg 1820; Rhipidoptera Burmeister 1829; Stylopites Newman 1834 and Stylopida Haeckel 1896. In view of the similarities in the larvae and metamorphosis, the stylopids were included with Coleoptera, but the peculiar characters of the stylopids justified their separation as an independent order, Strepsiptera.

The strepsipterans are small insects and the males are about 1.5-4 mm in length. They are distinguished by the marked sexual dimorphism. They are parasites of Hymenoptera (bees and wasps), Homoptera and also Orthoptera. The development of both the sexes are different. All the stages of development of females take place within the body of the host where the adult female remains, whereas the adult male flies off leaving the host.

They are of little or of no economic importance to man, as their role in biological control of pest species is very much limited. However, Tillyard (1926) indicated that the species which parasitize Homoptera are to be regarded as highly beneficial, the effects of their parasitism being severe to destroy the host or to render it infertile.

Classification

Bohart (1941) classified Strepsiptera into six families, namely, Mengeidae (parasites of Lepismatidae), Myrmecolacidae (Parasites of Formicidae Male or of Orthopteroids Female, Callipharixenidae (parasites of Heteroptera), Stylopidae (parasites of Aculeate Hymenoptera), Elenchidae (parasites of Delphacidae) and Halictophagidae (parasites of Homoptera:Auchenorrhynca and of Orthoptera :Tridactylidae).

The family Mengeidae is the most primitive family of the order. The oldest known species of the order is *Menges tertiaria* (Menga), which is a Tertiary insect taken from the Eocene in German Baltic Amber. The order is composed of some 35 genera and subgenera and approximately 300 species from the whole world, of which 8 species are hitherto known from India.

According to Bohart, three genera of Orthoptera, 45 genera of Homoptera, three genera of Heteroptera and 41 genera of Hymenoptera are recorded as the hosts of stylops.

Historial Resumé

The first male of Strepsiptera namely, *Xenos vesparum* was recorded from Europe by Rossius in 1793 and it was taken from a wasp, *Polistes gallicus* Linnaeus. Information on the Indian species of this interesting group is restricted to the contribution of Pierce (1909, 1911 & 1918) and Subramanian (1922, 1927 & 1932). Through their works, only three species belonging to three genera are known. After these works on Indian Strepsiptera, no study was undertaken until Chaudhuri, Dasgupta & Chatterjee, Sinha Roy (1977, 1978) published the account of four new species. The majority of 300 species known from all over the world are from the Holarctic region though the order is represented in remaining Zoogeographical regions also.

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Studies from Different Environs

It may be pointed out that since very few works have been published from India, so there is sufficient scope for exploration and determination of Strepsiptera from different environs of India.

Estimation of Taxa

Only a total of eight species distributed over seven genera and three families are known from India.

Expertise

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MECOPTERA

Introduction

Mecoptera, in which the males carry the terminal abdominal segments upturned in the manner of scorpions, are generally called scorpion-flies. They have beak-like prolongation of head and often maculated wings. The adults are smaller or medium sized insects. They have two pairs of large wings, a pair of antennae and a pair of large compound eyes. Legs are slender, but in few families they may be long and spidery. Mouth parts present at the snout like elongated head, are chewing type. Larvae are grub-like or caterpillar-like in appearance.

One of the main evolutionary line of the Endopterygota is called as the *'Panorpoid group'* Besides Mecoptera it includes four more insect orders, namely Lepidoptera, Trichoptera, Diptera and Siphonaptera. It is postulated that the common ancestor of these group of insects might have been as primitive living Mecoptera (Merope: Meropidae).

Adults are omnivorous and feed on small insects, nector, pollen, petals, fruits, mosses etc. The winged forms are active fliers. The female lays eggs on ground either singly or in clusters of hundred or more. Larvae are found in mosses, rotten wood, mud and humus.

Mecoptera represents relatively a smaller insect order. These insects are rather scanty in nature both qualitatively and quantitatively. The order is relatively more Palearctic in distribution and prefers vegetations in montane and submontane zones, though families Bittacidae and Panorpidae are cosmopolitan in distribution. Both these families have their representatives in India.

In habit, both larvae and adults are carnivorous, but the extent to which members of family Panorpidae prey upon other animals is doubtful. *Bittacus* remains suspended from grass or twigs by its fore-legs and preys upon small dipterans, whereas members of the genus *Boreus* live among mosses or beneath stones in autumn or early winter, appearing occasionally on the surface of snow. Sometimes they are observed feeding upon vegetable matter.

Mecoptera includes a little more than 350 species from the world, which are referred to seven families viz., Bittacidae, Boreidae, Panorpidae, Notiothanmidae, Meropidae, Choristidae and Nannocharistidae under two suborders, Protomecoptera and Eumecoptera. The families Panorpidae and Bittacidae are relatively more common. In India this order is represented by 15 species only belonging to genera *Bittacus* (Family Bittacidae), *Panorpa* and *Neopanorpa* (Family Panorpidae).

Historical Resumé

1900–1990

No significant work has come across of early period on this order except Needham (1909), worked out the Mecoptera collections present in Indian Museum, Calcutta.

Cheng Fung Ying (1952-1954) described 3 new Mecopteran species one of which was from India (Darjeeling). Penny (1970) described a new species *Bittacus taraiensis* of the family Bittacidae. Contribution on Indian Mecoptera also included the family Panorpidae (*Panorpa* -7 species, *Neopanorpa* 6 species). Imms (1957) formulated keys of Mecoptera, based on evolutionary studies by Tillyard (1935)). Byers (1965 and 1966) published the Mecoptera fauna of Indo-China, Borneo and Taiwan Islands.

Estimation of Taxa

Mecoptera is a small order, in which approximately 350 species are reported from all over

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world. Out of its 7 families, only two viz. Panorpidae and Bittacidae are represented in the Indian region.

Very little is known about Mecoptera of India. Altogether 15 species belonging to three genera *Bittacus, Panorpa* and *Neopanorpa* are reported from India. Majority of these species occur in North-Eastern hill ranges, i.e. Darjeeling(West Bengal), Sikkim, Assam and Meghalaya, while one species each is reported from Pant Nagar (U.P) and Bombay (Maharashtra).

Classified Treatment

Suborder Eumecoptera

This suborder of Mecoptera is represented in the world by 5 families, of which 2 families, namely *Bittacidae* and *Panorpidae* occur in India.

Family Bittacidae has a cosmopolitan distribution, except the northern portion of Holarctic region. Indian component of this family, is represented by a single species under genus *Bittacus*. The member of this genus are very slender *Tipula*-like insects having prehensile tarsi and very prominent bulbous swelling of male abdominal end.

Family Panorpidae is having relatively more Indian representation. It is represented by two genera viz., *Panorpa* and *Neopanorpa*. The former has 7 species (*P.appendiculata* West, *P. chinensis* Chang, *P. fenestrata* Needham, *P.sordida* Needham). The genus *Neopanorpa* is represented by 6 species viz., *N. borensis* Chang, *N. contracta* Chan, *N. cornata* Esbenand Peterson, *N. flava*, Esb. and Pet., *N. salai* Navas and *N.zebrata* Esb. and Pet.

The other suborder *Protomecoptea* does not occur in Indian region.

Expertise

ABROAD

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G. W. Byers, Department of Entomology, University of Kansas (U.S.A.)

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SIPHONAPTERA

Introduction

The order Siphonaptera (*siphon* = tube, *aptera* = without wings) includes secondarily wingless insects known as fleas. They are most closely related to orders Mecoptera and Diptera. The larvae of fleas resemble those of dipterous type but more generalised. They are believed to have common origin with the superfamily Staphylinioidea (Coleoptera).

The Siphonaptera are small, wingless insects, body strongly compressed laterally and generally heavily selerotized. Eyes present, sometimes vestigial or absent. Antennae short and stout, when at rest lying within the antennal fossae. Mouth parts adapted for piercing and sucking. Thoracic segments distinct, free and not fused, legs well developed, coxae large and tarsi five-jointed. Abdomen large. Metamorphosis complete. Adults ectoparasitic on warm blooded animals. Sexes almost alike but female larger in size having a less abruptly tip-tilted tail and without coiled internal horny attachments of the genital organs which are present in the male.

The fleas are facultive rather than obligatory blood sucking ectoparasites on warm blooded animals. They are brown insects with their body size varying 1.00 to 5.6 mm. in length. The characteristic shape of the body, covered with backwardly directed spines and bristles, makes fleas very well adapted for gliding among hair and fur of mammals and feathers of birds, which are their common hosts. They also live in the nests of these hosts. They usually walk but can jump up to 20 cm. high with a horizontal range of about 30 cm. On the average they live from three to four months but females may live up to two years. The pupal stage varies in its duration from 5-7days to 354-450 days in some European species. Human flea can live without food for months or even as long as a year. The female must feed on the blood of its normal host before it can lay fertile eggs. They like warmth, therefore, they leave the host soon after it dies and becomes cold.

They are most abundant in the tropics but also occur in the temperate and even in the polar regions. In the most recent times, they have been carried into Sahara Desert and many Pacific Islands where they were unknown untill the advent of civilized man. Though they occur as ectoparasites on warm blooded animals, but indoor fleas hide in the cracks and crevices of buildings or in the litter found in the grain godowns etc.

Economic Importance

The Siphonaptera are of considerable economic importance as they are vectors of the most important bacterial disease caused by them, the bubonic plague. This is a disease primarily of rodents and has its ancestral home in the plains of Africa and Asia. The disease became distributed ever more widely even into both Americas and now there are reservoirs from which it might break out into epidemics at any time. In Europe, from 1347-1350 about 25 million persons lost lives due to epidemic called Black Death. Also, towards the end of the 19th Century, smaller epidemics suddenly struck in several parts of the world, the worst in India, where in course of about 20 years some 10 million persons died. Even today this disease, whenever occurs, takes thousands of victims annually in tropical countries. The Indian rat flea, *Xenopsylla cheopsis* (Rothschild) is the chief transmitter of *Bacillus* (*Pasteurella*) *pestis* which causes human bubonic plague. After a large number of rats die with this disease, it is only then that the disease spreads to man through flea bite. *Pulex irritans* Linnaeus is another human flea but it also attacks cats, dogs and horses. It is a cosmopolitan species but its favourite host is the pig. *Ctenocephalides felis* (Bouché) and *C. canis* (Curtis) are cat and dog fleas and their larvae consume eggs of the dog tapeworm, *Dipylidium caninum*, which is occasionally found in human being, particularly in children. *Echidnophaga gallinacea* (Westwood) is an important pest of poultry.

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Estimation of Taxa

There are more than 2,000 species and subspecies known from the World distributed over 150 genera and 17 families belonging to two superfamilies, *viz.*, Pulicoidea and Ceratophylloidea. Pulicoidea are characterised by the outer internal ridge of mid-coxa being absent, the hind-tibia without an apical tooth on outside and sensilliun with 8 or 14 pits on each side. On the other hand, Ceratophylloidea include majority of the families and have the outer internal ridge of mid-coxa usually present, hind-tibia usually with pointed external apical tooth and sensillium with 14, more often 16 or even more pits on each side. Fifty two species and subspecies, comprising only a little over 2% of the total Siphonaptera (known from the world), are so far recorded from India, which belong to 27 genera, eight families and two superfamilies.

Historical Resumé

i) Pre-1900

Linnaeus (1758) placed fleas along with other apterous insects in the order Aptera. De Geer (1778) established a new order Suctoria for fleas by excluding them from the special sectionof the order Aptera. Retzius (1783) treated Suctoria in the Saltatoria or jumping insects but Latreille (1796) adopted Suctoria as a group for the fleas. Leach (1815) included fleas in the Aptera in Suctoria, to which he designated Century Medamoptera and referred to them Suctoria of Latreille. Samoulle (1819) followed Linnaeus and Lamarck in recognizing the order Aptera and considered Suctoria of Latreille as its synonym. Latreille (1825) erected order Siphonaptera and Kirby (1826) also established order Aphaniptera for the fleas. Kirby (1826) synonymised Aptera of Linnaeus and Lamarck, Rhynchota of Fabricius and Suctoria of Latreille to Aphaniptera. Stephens (1829) treated fleas in the order Aphaniptera Kirby, but erected the family Pediculidae for them. Other names were given to these insects by several workers e.g. Burmeister (1829) called them 'Pulicina', Walker (1851) referred to them as 'Suctoria' where as Haeckal (1896) mentioned them 'Pulicida' But the name of the order 'Siphonaptera' as designated by Latreille (1825) is widely accepted and followed which has precedence over the name 'Aphaniptera' of Kirby (1826) which is also sometimes used.

ii) 1901-1947

During the first decade of the century, Baker (1904 and 1905) contributed two important works, 'A revision of American Siphonaptera, or fleas, together with a complete list and bibliography of the group' and 'The classification of the American Siphonaptera' Taxonomic contributions including manuals and monographs were owing to Jordan & Rothschild (1908), Rothschild (1915), Essig (1926, 1931), Ewing (1929), Sharif (1930), Jordan (1933), Wagner (1934), Iyenger (1935), Ioff (1936), Fox (1940), Ewing & Fox (1943) and Costa Lima & Hathaway (1946). Among these, Iyenger (*loc. cit.*) provided identification of rat fleas of India.

Works on the morphology of Siphonaptera were mainly by Perfilgew (1926), Wagner (1932), Sharif (1935, 1937b), and Snodgrass (1946). Minchin (1915) studied anatomy of the fleas. Knowledge on the biology of Siphonaptera was due to Beier (1936) and Sharif (1937a).

Observations on bionomics of fleas were made by Mitzmain (1910) whereas larvae were studied by Bacot and Ridewood (1914) and Sikes (1930). Schroeder (1926) discovered fossils of Siphonaptera of genera *Palaeopsylla* Wagner in Baltaic amber and *Pulex* (?) in Lower Oligocene of Aix, France.

iii) 1948-1990

During this period, significant contributions were made on the studies of Siphonaptera. Jordan (1948) dealt with fleas as *Suctoria* in Smart's 'Insects of Medical Importance' Brumpt (1949) studied parasitological aspects of the fleas. Weidner (1953) and Wenk (1953) worked out their biology and anatomy, respectively. Works of Munshi (1960) and Chandra (1971) refer to histology and anatomy of rat fleas, *X. cheopsis* and *X. astia*. The emphasis on the studies of plague and effects of insecticides (DDT, BHC, dieldrin, Organophosphorus etc.) on these fleas is evident in the works of Mohan (1960, 1962), Seal (1960), Sharma & Joshi (1961), Krishnamurthy & Joshi (1962), Mohan *et al.* (1962), Krishnamurthy *et al.* (1966) and Joshi *et al.* (1967). Seal & Bhattacharjee (1961) and Chandra (1971) studied bionomics and seasonal prevalence of certain fleas from Calcutta and Kollar (Karnataka). Bai (1972), Prasad (1972, 1973, 1976) and Bai & Prasad (1976) worked on host-relationship, histochemistry, egg yolk and influence of sex hormones of host on the fecundity of two species. Yurgenson (1982) estimated the physiological age of the fleas.

Reike (1970) recorded two fossils fleas from the Lower Cretaceous of Gyppsland (Australia), of which one resembles *Echidnophaga* of family Pulicidae and other is quite unusual having long antennae.

Faunistic works on fleas of Canada, Centra America and Mexico, and Japan, were due to Holland (1949), Traub (1950) and Sakaguti & Jameson (1962). Smirnova (1950) worked on the systematics of the larval stages of some species of fleas. Hopkins (1951, 1952 and 1958) contributed towards the scientific names, notes on synonymy and also on Order-group and family-group names for these fleas. Monographs and handbooks on Siphonaptera were due to Smit (1954) and Ioff & Scalon (1954). Rothschild & Hopkins (1953-1966) classified the order Siphonaptera into 17 families under two superfamilies, *viz.*, Pulicoidea and Ceratophylloidea. 'An illustrated Catalogue of the Rothschild Collection of fleas (Siphonaptera) in the British Museum' by Hopkins & Rothschild (1952-1971) running into five volumes, was a monumental work. Other important contributions on fleas from different parts of the world were by Hubbard (1940-1967), Ahn & Soh (1973), Haig (1978), Keifer (1979), Okereke *et al.* (1980), Morris (1981), White & White (1981), Edwards *et al.* (1982), Arnett (1983), Beaucournu & Fain (1983), Rothschild & Haddow (1983) and Darskaya & Suvorova (1984).

Taxonomic works on Siphonaptera from India and adjoining countries were mainly by Traub (1966), Traub & Evans (1967), Lewis (1968, 1970, 1972, 1973), Kulkarni & Bhatt (1972), Lewis *et al.* (1972), Iyenger (1973), Smit & Rosick (1973), Kulkarni *et al.* (1974), Smit (1974, 1977) and Michel & Dick (1978). Of these, works by Iyenger and Kulkarni *et al.*, (*loc. cit.*) reported more than 50 species and subspecies including new records and new species of fleas from India. Singh (1980) referred to the collection and preservation of the fleas.

Studies from Different Environs

The Siphonaptera of India has been poorly studied. Species are known from States of Arunachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Manipur, Punjab, Sikkim, Tamil Nadu and West Bengal. There are also certain reports on their occurrence in temperate parts and western Himalaya in India.

Considering the richness of hosts, i.e. species of mammals and birds, and the diversity of the climatic and geographic conditions in India, there is a possibility of existence of a very large number of species of Siphonaptera. It is therefore, expected that future collecing from the unexplored parts of India particularly those harbouring mammalian and avian fauna, will reveal the Siphonaptera fauna more than known at present.

Classified Treatment

Rothschild & Hopkins (1953-1966) classified the order Siphonaptera into 17 families under two superfamilies, namely Pulicoidea and Ceratophylloidea. Majority of the families belong to superfamily Ceratophylloidea. Iyenger (1973) and Kulkarni *et al.* (1974) reported 52 species and species and subspecies belonging to 27 genera and 8 families (9 subfamilies) so far known from India. Classification upto subfamilies is given below :

Superfamily Pulicoidea

1. Family Tungidae
2. Family Pulicidae
   - (i) Subfamily Pulicinae
   - (ii) Subfamily Archaeopsyllinae
   - (iii) Subfamily Xenopsyllinae

Superfamily Ceratophylloidea

1. Family Vermipsyllidae
2. Family Pygiopsyllidae
3. Family Hystricopsyllidae
   - (i) Subfamily Rhadinopsyllinae
   - (ii) Subfamily Neopsyllinae
   - (iii) Subfamily Doratopsyllinae
   - (iv) Subfamily Ctenophthalminae
4. Family Ischnopsyllidae
   - (i) Subfamily Thaumapsyllinae
   - (ii) Subfamily Ischnopsyllinae
5. Family Ceratophyllidae
6. Family Leptopsyllidae

Expertise

INDIA

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DIPTERA

Introduction

The Diptera comprising mosquitoes, midges and flies are among the most highly specialized members of the Class Insecta. It is the Permian period that gave birth to modern orders of insects and it is thought that the Diptera evolved from the Mecopterous ancestors. The order Diptera is classified into three suborders : Nematocera (primitive forms), Brachycera (intermediate forms) and Cyclorrhapha (advanced forms). An earlier classification into two suborders : Orthorrhapha (Nematocera and Brachycera together) and Cyclorrhapha, is rarely adopted now-a-days. There are about 130 families of Diptera containing more than hundred thousand species in the world.

With the most adaptive capability the Diptera have accommodated themselves nearly to every situation for breeding and colonization. The majority of adult Diptera frequent flowers causing pollination and feed chiefly on nectar and plant sap or on liquids exudated from rotting organic matter. Some prey upon various insects but there are a few having developed the habit of sucking blood and on this account a number of species take an important role in transmitting certain dreaded diseases, *viz.*, malaria, trypanosomiasis, leishmaniasis, filariasis, yellow fever, dengue fever, encephalitis and several other viral infections of man and animals. The dipterous larvae are close behind adults in economic importance. Majority of them live in water, in rotting flesh, in decaying fruits or other organic materials. There are some others living inside live plant tissues or animal tissues. The most serious damage to animal tissues by infestation of larvae is called myiasis.

Historical Resumé

Love for nature was the prime source of collecting and gathering insects in old days. Many-a king, emperor and naturalist supported collectors during their expeditions and voyages to acquire knowledge on natural resources of different countries of the world. In such an instance, Joseph Banks of England and Daniel Solander of Sweden went on their expedition round the world with the famous navigator Captain James Cook abroad the "Endeavour" in June, 1768, and collected numerous insects including Diptera. Niels Tonder Lund and Count Ove Sehestedt held high posts in the Civil Service, through which they were able to contact officials sent out to the Danish colonies like Tranquebar (Tamil Nadu) and certain other parts of India to obtain collections of insects, including Diptera, which Fabricius studied and published as a first account on the Indian insect fauna.

i) Pre-1900

Long before the establishment of the Asiatic Society of Bengal (1784), the Indian Museum (1814), the Calcutta School of Tropical Medicine (1914), the Zoological Survey of India (1916) or any other Research Institutes in India, collecting, and describing species of Diptera from India was initiated by naturalists from abroad. Among them, Fabricius (1775, 1781-1805), Leach (1817), Meigen (1818), Wiedemann (1819-1830), Schummel (1829), Robineau-Desvoidy (1830), Macquart (1834-1855), Guérin-Méneville (1834-1844), Westwood (1834-1849), Staeger (1840), Saunders (1841), Walker (1848-1864), Schiner (1868), Bigot (1877-1892), Becher (1885), Wulp (1885, 1894), Karsch (1886), Wood-Mason (1889), Brauer and Bergenstamm (1889-1893), Cotes (1893), Rübsaamen (1894), Skuse (1895), Kertész (1897), Coquillett (1898), Giles (1899), Grassi (1899), Speiser (1900) and Wasmann (1900) are notable.

J. C. Fabricius, a naturalist by birth, published a number of treatises on his observations on

M. Datta and P. Parui, Zoological Survey of India, Calcutta.

insects. Of these, *Systema Entomologiae* in 1775, *Species Insectorum* in 1781, Mantissa Insectorum in 1787, *Entomologia Systematica* in 1794, *Supplementum Entomologiae Systematicae* in 1798 and *Systema Antliatorum* in 1805 concern Diptera from India. These were based on collections mainly by Rohr, Banks, and Solander; Smidt, Richard, Bosc, Palisot de Beauvois, Pflug and Yeats. These collections are now deposited mainly in the Copenhagen Museum, British Museum, Paris Museum and Vienna Museum.

C.R.W. Wiedemann, who was primarily a medical practitioner, became interested in the study of Diptera by the strong influence of the great master J.W. Meigen, and studied the collections of the Berlin Museum, Leyden Museum and Copenhagen Museum, as well as of other persons, mainly Westermann, a Danish collector who visited India sometime before 1817. The Indian Diptera were dealt with in an article entitled "Beschreibung neuer Zweifluegler aus Ostinden und Afrika" in 1819 and in *Diptera Exotica* (1821), *Analecta Entomologica* (1824), and *Aussereuropaische zweiflügelige Insekten* (1828, 1830).

J. B. Robineau-Desvoidy of France worked in Paris for his treatise "Essai sur les Diptéres" (1830) that includes many Indian species deposited in the Paris Museum. P. J. M. Macquart, a French Commander began his studies on Diptera under the influence of the great masters J.W. Meigen and P.A. Latreille and published his "Histoire Naturalle des Insectes : Diptères" (1834-1835) on collections of the Paris Museum and of several private owners. In the following years (1838-1855) he published on exotic species brought by French expeditions around the globe including India. F. É. Guérin-Méneville studied the collections by Lesson and Duperrey during the cruise of La Coquille and several others of the Paris Museum in 1834-1844.

J. O. Westwood, a lawyer by profession, who was later actively associated with the Entomological Society of London, published five articles including that on Diptera from India during 1834-1849. F. Walker, son of a naturalist and himself an extensive collector, worked on the collections of the British Museum (Nat. Hist.) and published "List of the specimens of Dipterous Insects in the collection of the British Museum" in series from 1848. In the succeeding years, he also began to publish *Insecta Saudersiana* from 1851 and "Characters of undescribed Diptera in the Collection of W.W. Saunders" from 1857. An Austrian Dipterist, I.R. Schiner published his famous treatise "Reise der österreischischen Fregatte Novara um die Erde" in 1868 on Diptera collected also from India.

J. M. F. Bigot, a French Dipterist published a series of articles mainly entitled "Diptères nouveaux ou peu connus" in the Annales Société Entomologique de France during 1877-1892 containing Diptera from India. A few other workers (mentioned above) about whom meagre information is available, studied the Indian Diptera represented in various museums and private collections of Europe. Beginning from Fabricius, the entire period was aimed at collecting with keen interest, maintaining with tremendous care and describing species with the utmost capability within the then limited scope.

ii) 1901-1947

The Indian Museum/Zoological Survey of India, Calcutta and the then Central Research Institute, Kasauli, in India, and the British Museum (Natural History), London during this period played a significant role in studying the Indian Diptera fauna. The period is remarkable for the precious contributions of the great workers like Ricardo (1902-1927), Brunetti (1907-1928), Kieffer (1909-1913), Christophers (1911-1933), Edwards (1915-1934), Senior-White (1922-1940), Patton (1922-1937); Barraud (1923-1934), Sinton (1923-1933), Puri (1929-1933), Mani (1934-1974), Emden (1965) etc.

G. Ricardo, while working in the British Museum (Nat. Hist.), published a series of papers on the Indian Asilidae and Tabanidae mainly based on the collections of this Museum and the Indian Museum. E. Brunetti (1912) published his first volume in "The Fauna of British India" series on the families : Bibionidae, Simuliidae, Psychodidae (incl. Phlebotomidae), Dixidae, Tipulidae and

Anisopodidae (Rhyphidae), comprising 425 species. Brunetti's (1920) second volume included the following families : Stratiomyidae, Rhagionidae (Leptidae), Nemestrinidae, Acroceridae (Cyrtidae), Bombyliidae, Therevidae, Scenopinidae, Mydidae (Mydaidae), Empididae (Empidae), Lonchopteridae and Platypezidae, dealing with 327 species. His third volume (1923) dealt with the families : Pipunculidae, Syrphidae (including Microdontidae), Conopidae and Oestridae, comprising 319 species. The bulk material for these valuable contributions to the Dipterology was collected by T. N. Annandale, S. W. Kemp, J. T. Jenkins, E. E. Green and C. Paiva of the Indian Museum; some by F. M. Howlett and T.B. Fletcher of the then Imperial Agricultural Research Institute, Pusa and a few by F. H. Gravely, H. T. Pease, R. E. Lloyd, A.D. Imms, G. C. Chatterjee and J. W. Yerbury of other organisations in the then India and Ceylon. In the meantime, J. J. Kieffer, a French worker, contributed substantially by over 230 species to the Indian Chironomidae (including Ceratopogonidae) and Cecidomyiidae.

The discoveries of the causation of malaria due to mosquitoes by Ronald Ross in 1898 and of other mosquito-borne diseases in India and abroad led to the concerted effort to work out the species involved. "Fauna of British India" fourth volume dealing with the Anophelini (43 species and 10 varieties) by S. R. Christophers of the then Central Research Institute, Kasauli and the fifth volume on the Megarhinini and Culicini (245 species) by P. J. Barraud on the then Malaria Survey of India, Kasauli, were published respectively in 1933 and 1934. Indeed, F. W. Edwards of the British Museum (Nat. Hist.), London, had to do much for these works. Edwards himself as an eminent entomologist, published a lot of papers not only on the Culicidae but also on several other families during 1915-1934.

R. Senior-White, working at times in the British museum (Nat. Hist.) London, on many families was transferred to the Indian Medical Service, and for once in the then Malaria Institute of India, Madras. He in collaboration with D. Aubertin and J. Smart of the British Museum (Nat. Hist.) published the sixth "Fauna of British India" volume on the Calliphoridae comprising 214 species in 1940. The seventh "Fauna of India" volume dealing with the Muscidae (Muscinae, Stomoxydinae and Phaoniinae) comprising 294 species, by F. I. van Emden of the Commonwealth Institute of Entomology, housed in the British Museum (Nat. Hist.), London, was due to be published long before, but could be brought out only in 1965. The type-specimens of the species treated in these "Fauna" series are deposited mainly in the British Museum (Nat. Hist.) and the Zoological Survey of India. The collections considered for these volumes were mainly made by T. N. Annandale, E. E. Green, J. T. Jenkins and E. Brunetti of the Indian Museum; T. B. Fletcher and Shobha Ram of the then Pusa Agricultural Research Institute; S. R. Christophers of the then Kasauli Central Research Institute; P. J. Barraud and J. A. Sinton of the then Malaria Survey of India; W.S. Patton and F. H. Gravely of the Pasteur Institute of Southern India, Coonoor and R. Senior-White, M.O.T. Iyenger and Khazan Chand of the then Malaria Institute of India.

A series of works on the Muscidae, Calliphoridae, Oestridae and Gasterophilidae by W.S. Patton, sometimes with R. Senior-White or F.W. Cragg of the then Central Research Institute, Kasauli, during 1922-1937 are certainly in themselves a mine of information. As a member of the Kala-azar Commission, J.A. Sinton's works (1923-1933) on the Psychodidae (Phlebotomidae) are ever remembered in India. I.M. Puri of the then Central Research Institute contributed a number of papers on the Culicidae and Simuliidae, during 1929-1933 from his own collections that are mainly housed in the National Institute of Communicable Diseases, Delhi. He was too particular to imply a modern concept of taxonomical works, especially of the Simuliidae. Lastly, the works by M.S. Mani from the St. John's College, Agra, since 1934 have enriched our knowledge on the cecidomyiid fauna.

Apart from these contributions, several others referred to as under each family below, are equally invaluable to the students of Dipterology. This period witnessed the Indian Dipterology to expand at a prodigious rate. There were many reasons supplemented each other to this end, *e.g.*, (1) Devastating outbreaks of diseases of man and his animals by dipterans occurred periodically; (2)

Arousing widespread interest in collecting throughout the country and maintaining the collections in institutional museums were provided by the European assistance; and (3) Demand for trained personnel brought about teaching of entomology/dipterology in colleges and universities.

iii) 1948-1990

Research on Diptera during this period in the Zoological Survey of India was initiated by A. N. T. Joseph as the Officer-in-Charge of the newly organised Diptera Section of the Entomology Division at the end of 1964. He began his work sometimes in collaboration with his colleagues on Syrphidae (Joseph, 1967, 1968, 1970; Joseph and Sharma, 1976; Joseph and Parui, 1979) and thereafter became interested mainly in the Tipulidae and the Asilidae (excluded here). In the meanwhile, he published papers also on the Coenomyiidae (Joseph, 1970), Muscidae (Joseph and Parui, 1972), Lonchopteridae (Joseph and Parui, 1976, 1979, 1981), Celyphidae (Joseph and Parui, 1978), Phlebotomidae (Joseph, 1979, 1981; Joseph and Parui, 1980; Joseph and Ninan, 1981) and the Diptera fauna in general of Arunachal Pradesh and adjoining areas of Assam (Joseph and Rao, 1972; Joseph and Parui, 1973, 1977; Joseph and Ray, 1976), of Chotanagpur, Bihar (Joseph and Parui, 1977) and of the Silent valley, Kerala (Joseph and Parui, 1986). Joseph and Parui (1980) also made some behavioural studies on the filth inhabiting flies of the Calcutta city. He was succeeded by P.T. Cherian who had been working on Chloropidae (excluded here). During this period, D.K. Guha and B.C. Nandi, of this Section worked on the Chironomidae (in collaboration with the Zoology Dept. of the Burdwan University) and the Sarcophagidae, respectively. M. Datta, the present Officer-in-charge of the Section, came into prominence on his contributions towards the taxonomy, distribution, ecology and bionomics of the Simuliidae (excluded here), some in collaboration with others (Datta, 1973-1988; Datta and Dasgupta, 1972-1977; Datta and Das, 1975; Datta and Pal, 1975, Datta, Dey and Paul, 1975; Datta, Dey, Paul and Pal, 1975, 1976; Datta, Chaudhury and Dasgupta, 1984). Alongside, in collaboration with his colleagues, he published on the Tabanidae (Datta, 1979-1981, 1985, 1986; Datta and Biswas, 1977; Datta and Das, 1978; Datta and Chakraborti 1985), Syrphidae (Datta and Chakraborti, 1983, 1986), Diopsidae (Datta and Biswas, 1985), Celyphidae (Datta, 1986, 1987), Gasterophilidae (Datta and Pal, 1985), Oestridae (Pal and Datta, 1989) and also on the Diptera fauna in general of the Namdapha Biosphere Reserve, Arunachal Pradesh (Datta and Chakraborti, 1985), and of Orissa state (Parui and Datta, 1987). Lastly, on joining the Section, T.K. Pal studied Culicidae (Pal, 1989; Pal and Ghosh, 1988) and Bibionidae (Pal, 1989). Works on Streblidae by Vazirani *et al.* (1976, 1981), Cecidomyiidae by Sharma *et al.* (1983-1988) and Tephritidae (excluded here) by Radhakrishnan (1984) are also worth-mentioning.

The School of Entomology in the St. John's College, Agra, had been in the forefront of dipterological research under the guidance of M. S. Mani. The main field of research was on the high altitude Diptera (especially Blepharoceridae : Kaul, 1971, 1976, 1984), and Cecidomyiidae (Mani, 1934-1974) and Agromyzidae (excluded here). The family Cecidomyiidae was also extensively studied by S. N. Rao and his collaborators (1950-1978) in the Marathwada University and by P. Grover and her collaborators (1961-1986) in the Allahabad University. Studies on the Drosophilidae were undertaken under the leadership of J. P. Gupta (1968-1989) from the Banaras Hindu University and of N. B. Krishnamurthy (1968-1989) from the Mysore University. P. K. Chaudhuri of the Burdwan University built up an effective school of Dipterology and made significant contributions on the Chironomidae, Sciaridae and Ceratopogonidae. The Chironomidae were also studied by A. K. Kulshrestha (1979) in the Garhwal University and by J. R. B. Alfred (1973-1975, 1990) in the North-Eastern Hill University. The Ceratopogonidae were initially studied by S. K. Das Gupta in the Presidency College, Calcutta and Darjeeling Government College, where Dasgupta B. led a team of workers on various aspects of the Simuliidae, Muscidae, Calliphoridae and Sarcophagidae. Under the guidance of V. C. Kapoor in the Punjab Agricultural University, several family-groups, such as, Bombyliidae, Tephritidae and Pipunculidae were worked out in detail. In the University of Agricultural Sciences, Bangalore, K.D. Ghorpade contributed a lot on the families Syrphidae, Scenopinidae, Sciomyzidae and Tachinidae. M. Zaka-ur-Rab studied Tephritidae in the Aligarh Muslim University, and at Govt. Agric. College, Sopore (J. & K.).

In other Research Institutes, B.L. Wattal, N.L. Kalra and others worked on the Culicidae at the National Institute of Communicable Diseases, Delhi; H.R. Bhat and others worked on the haematophagous Diptera at the National Institute of Virology, Pune; P.K. Rajagopalan, R. Reuben and others worked on the Culicidae at the Vector Control Research Centre, Pondicherry; A.K. Hati, N. Tandon and others worked on the Culicidae and the Phlebotomidae at the Calcutta School of Tropical Medicine; K.M. Rao, P.R. Malhotra and others worked on the Simuliidae and the Culicidae at the R & D organization, Tezpur; and M.L. Srivastava worked on the Muscidae at the Indian Agricultural Research Institute, New Delhi. They mainly worked on the bionomical aspects of pest and vector species of Diptera. Besides, there are also a few works done in certain colleges, universities and institutes, which have been cited under the family account below.

Studies from Different Environs

Capturing Diptera in India began long after the middle of the eighteenth century (*ca.* 1769) by the European naturalists who initially did it from south India, Assam and Bengal, and thereafter from other parts of India. Most of these collections were mainly studied by workers like Fabricius (1775), Speiser (1900) and Wasmann (1900). Earlier workers of the current century studied collections made nearly throughout India, especially the Himalayan belt, Assam hills and the rest of east India and the south. These were incorporated in publications since 1907 and subsequently in the "Fauna of British India" series since 1912.

In the later part of this century, most of the workers were near selective to the field of investigation, irrespective of ecosystems. Consequently, it was evident that certain groups had thoroughly been worked out, while some others had not been. Joseph and his collaborators (1972, 1973, 1976, 1977) studied the Diptera fauna of Arunachal Pradesh and adjoining areas of Assam. Parui and Datta (1987) worked out the Diptera fauna of Orissa. On the other hand, Edwards (1922, 1927, 1934), Alexander (1927-1965), Tonnoir (1930, 1932), Hora (1931), Schmid (1958, 1970), Cutten and Kevan (1970), Kaul (1971, 1976, 1984), Datta (1973-1988) and Datta *et al.* (1972-1976) studied the eutorrenticolous families in the Himalaya. The references from Annandale (1908) to Chaudhuri *et al.* (1988) on the wetland fauna are worth-mentioning. These were the contributions based on nematocerans breeding in the truly aquatic situations. But the majority of the family-groups are associated either with grassland, herbage, woods, etc. or with other animals occasionally as parasites predominantly in the larval stage and do not need as much water as those mentioned above. They mostly belong to the Brachycera and the Cyclorrhapha. The former category includes works of Edwards (1923-1924); Séguy (1928, 1956), Cresson (1929-1948), Parent (1929-1941), Mani (1934-1974), Rao (1950-1953), Hardy (1948-1965), Steyskal (1952-1971), McAlpine (1956, 1964), Grover (1961-1986), Crosskey (1967-1974), Nagatomi and Saigusa (1970), Kapoor (1970-1985), Krishnamurthy *et al.* (1973-1986), Kapoor *et al.* (1977-1987), Datta and Chakraborti (1983-1986), Zaitzev (1987-1988), and Alam, Das Gupta and Chaudhuri (1988). The latter comprises works of Patton (1920-1937), Senior-White (1922-1930), Smith (1958), Schlinger (1959), Disney (1981, 1988) and Papp (1982).

Broadly speaking, the Diptera fauna is known from all the easily accessible habitats in India, but those that predominantly inhabit high mountains, deep forests, plateaux, deserts, costal belts and oceanic islands, are less-known because extensive collecting from these areas have not so far been made. In this context, dipterologists should bear in mind that taxonomy of a species remains incomplete until the biological or ecological information and evidence furnished by immature stages are taken into consideration. It is, therefore, imperative to emphasize investigation on the immatures so as to have complete knowledge on the environs where a species does actually occur.

Estimation of Taxa

The order Diptera comprises 3502 species under 801 genera of 138 subfamilies belonging to 81 families (excluding 6 families : Tipulidae, Simuliidae, Asilidae, Tephritidae, Agromyzidae and Chloropidae) and 25 superfamilies in India.

Of these, the suborder Nematocera includes 1342 species under 184 genera of 28 subfamilies belonging to 20 families (excluding Tipulidae and Simuliidae) and 6 superfamilies. The Brachycera comprise 674 species under 142 genera of 38 subfamilies belonging to 14 families (excluding Asilidae) and 3 superfamilies, and the rest numbering 1486 species under 475 genera of 72 subfamilies belonging to 47 families (excluding Tephritidae, Agromyzidae and Chloropidae) and 16 superfamilies constitute the suborder Cyclorrhapha.

Classified Treatment

Suborder Nematocera

Family Trichoceridae

The Trichoceridae or "winter crane flies", the adults of which resemble those of the Tipulidae, are represented by 20 species under 2 genera of the subfamily Trichocerinae in India. Adults are found to swarm mainly in winter at high altitudes. Larvae that resemble those of the Anisopodidae develop commonly in humus and are saprophagous in habit.

Contributions from : Brunetti (1911, 1912); Karandikar (1931); Alexander (1935, 1959-1961).

Family Tipulidae (Given separately)

Family Tanyderidae

The Tanyderidae are regarded as the most primitive of all living Diptera and are known in India by all 3 Oriental species under the genus *Protanyderus* Handlirsch. Larvae are aquatic and pupae generally develop in the sandy soil along the stream margin.

Contributions from : Alexander (1927, 1930, 1959, 1960).

Family Psychodidae

The Psychodidae, commonly known as "moth flies", are represented by 41 species under 8 genera of 2 subfamilies in India. Adults are found on vegetation in the vicinity of shady moist or wet places where they breed especially in freshwater marginal habitats, marshes, tree holes, water accumulated in leaf bases, pitchers, etc. Larvae are predominantly saprophagous.

Contributions from : Annandale (1908, 1910); Brunetti (1908, 1911-1913); Senior-White (1922); Tonnoir (1933); Quate (1962); Kaul (1971); Duckhouse (1987).

Family Phlebotomidae

The phlebotomids or "sand flies" as they are popularly called, comprise 38 species under 2 genera in India. Adults occur in close proximity to the larval habitat in dark or shaded damp situations. Females suck the blood of vertebrates including man and cause much irritation. Certain species are notorious vectors of leishmaniasis (Kala-azar and Oriental sore) and sand fever in India.

Contributions from : Annandale (1908, 1910, 1911); Sinton (1923, 1924, 1926, 1929-1933); Adler and Theodor (1927); Young and Chalam (1927); Theodor (1931); Mitra and Roy (1952-1954); Mitra (1953); Lewis and Lane (1976); Lewis (1978, 1982, 1987); Lane and Rahman (1980); Joseph (1981; Joseph and Ninan (1981); Kaul and Modi (1982); Kumar, Rahman, Nim, Chirwatkar and Kalra (1983); Addy, Mitra, Ghosh and Hati (1983); Pandya (1983, 1985);

Mukhopadhyay, Kumar and Rahman (1986, 1987); Lewis and Kaul (1987); Saxena (1987).

Family Ptychopteridae

The Ptychopteridae, commonly known as "phantom crane flies" comprise 4 species under a single genus *Ptychoptera* Meigen in India. Adults are found at the edges of streams, pools, etc. and larvae are aquatic or semi-aquatic living in mud saturated in decaying organic matter and are saprophagous.

Contributions from : Brunetti (1911); Alexander (1927, 1959, 1965).

Family Nymphomyiidae

This is a very small family known only by a single monotypic genus endemic to India. The species *Felicitomyia brundini* Kevan is known only from its type locality "Darjiling" in West Bengal. Larvae occur in small fast-flowing cold streams at high altitudes where adults are sometimes seen to swarm in subdued light.

Contribution from : Cutten and Kevan (1970).

Family Blephariceridae

The Blephariceridae or "net-winged midges" are represented by 23 species under 6 genera of 2 subfamilies in India. The genus *Manaliella* Kaul is endemic to India. Larvae and pupae are highly resistant to the most rapid streams, cascades, falls and cataracts in mountainous regions where they inhabit. Adults are found to frequent banks of streams or on vegetation along these watercourses.

Contributions from : Brunetti (1911); Agharkar (1914); Tonnoir (1930, 1932); Hora (1931); Alexander (1958); Kaul (1971, 1976, 1984);Zwick (1991).

Family Deuterophlebiidae

This is a very small family, discovered from Kashmir in India and studied by Edwards (1922). So far two species under the genus *Deuterophlebia* Edwards are known from India. These midges occur in the same situations as the blepharicerids do.

Contribution from : Edwards (1922).

Family Dixidae

The Dixidae are closely related to the Culicidae with which they were previously treated. There is a single genus *Dixa* Meigen with 11 species in India. Adults are usually seen to swarm in places like streams, rivers, pools etc. where females breed. Larvae feed upon unicellular plants and pupae attach themselves to floating substrata.

Contributions from : Brunetti (1911); Senior-White (1924); Edwards (1934); Freeman (1948); Alexander (1959).

Family Chaoboridae

A small family also closely related to the Culicidae is represented by only 2 species under the genus *Chaoborus* Lichtenstein of the subfamily Chaoborinae in India. Adults are rarely seen in the vicinity of their breeding places like streams, pools, ditches, etc. where larvae and pupae occur.

Contribution from : Giles (1901, 1904).

Family Culicidae

The Culicidae or "mosquitoes" are represented by 300 species under 15 genera of 3 subfamilies in India. Females feed on blood and on this account are important vectors of certain dreaded diseases of man and animals, *viz.*, malaria, filariasis, dengue fever, Japanese encephalitis, etc. They oviposit in all kinds of water, with preference to stagnant water-bodies. Both larvae and pupae are highly motile, and larvae and pupae are phytophagous or carnivorous. Because of their medical importance, enormous works have been done in India.

Contributions from : Wiedemann (1820); Skuse (1895); Grassi (1899); Giles (1899-1902, 1904); Liston (1901); Theobald (1901-1903, 1905, 1907, 1908, 1910); James (1902, 1903, 1911); Cogill (1903); Rothwell (1907); James and Liston (1911); Christophers (1911, 1912, 1924, 1933); Edwards (1915, 1916, 1920-1923, 1932, 1934); Mello (1918); Prasad (1918); Barraud (1923, 1924, 1926-1929, 1931, 1932, 1934); Iyengar (1924); Covell (1927); Young and Majid (1928); Choudhury (1929); Puri (1929, 1930); Christophers and Puri (1931); Strickland and Choudhury (1931); Sweet and Rao (1937); Senior-White (1937); Russel and Jacob (1942); Menon (1944, 1950); Qutubuddin (1947, 1951); Mattingly (1954, 1957, 1958); Wattal, Phatia and Kalra (1958, 1965, 1966); Wattal and Kalra (1965); Wattal, Kalra and Krishnan (1966); Reuben (1967, 1980); Rahman, Wattal and Sharma (1973); Bhat (1975); Hati (1976); Hati, Tandon and Mukhopadhyay (1978); Tandon, Hati and Mukhopadhyay (1978); Rajagopalan and Panicker (1978); Hati, Ghosh and Das (1980); Hati and Mukhopadhyay (1980); Ghosh and Hati (1980); Rao (1984); Rajput and Singh (1987); Pal (1989).

Family Thaumaleidae

The Thaumaleidae comprise 14 species under a single genus *Thaumalea* Ruthe in India. Larvae are found on wet rocks of cold streams and feed mainly on diatoms. Pupae are found in wet moss or leaves or buried in mud. Adults may be found on vegetation or flowers not far from the larval habitat.

Contributions from : Schmid (1958, 1970).

Family Ceratopogonidae

The Ceratopogonidae or commonly called "biting midges"are represented by 220 species under 21 genera of 4 subfamilies in India. The genus *Haasiella* Kieffer with a single species is endemic to India. Adults may be found on vegetation or flowers. Some are predaceous on smaller insects, some are ectoparasites on larger insects and some are notorious pests of man and animals. A few act as vectors of malaria in animals in India. Larvae and pupae may be terrestrial under bark or in damp wood or may be aquatic or semi-aquatic in mud or sand of stream margins, pools, marshes, tree-holes etc. or in decomposing plant material in banana stalks, pine apple axils etc.

Contributions from : Meigen (1818); Kieffer (1910-1911, 1913, 1914, 1918, 1919); Brunetti (1912); Annandale (1913); Patton (1913); Edwards (1924, 1932); Senior-White (1929); Smith (1929); Mukherji (1931); Macfie (1932, 1936); Smith and Swaminath (1932); Das Gupta and Ghosh (1956,.1957, 1961); Sen and Das Gupta (1958, 1959, 1968); Ghosh and Das Gupta (1962); Das Gupta (1962-1964); Das Gupta and Wirth (1968, 1970); Das Gupta, Chaudhuri and Sanyal (1971); Chaudhuri, Das Gupta and Sinharay (1974, 1976); Chaudhuri and Sinharay (1976); Dasgupta and Pal (1976); Chaudhuri and Ghosh (1980); Wirth, Chaudhuri and Das Gupta (1985); Ray and Choudhury (1986, 1988); Wirth and Hubert (1989).

Family Chironomidae

The Chironomidae or "midges" are known by over 165 species under 25 genera of 4 subfamilies in India. the genus *Himatendipes* Tokunaga with a single species is endemic to India. Adults occur abundantly in the vicinity of lakes, pools, ponds, streams etc. and are seen to swarm in the air. Females lay their eggs in masses enveloped by a transparent gelatin secreted by the female. Larvae usually inhabit slow streams, pools, ponds, water trough, etc. but they have high range of temperature tolerance by which they can live in glacier fed rivulets to hot (42°C) spring water. They significantly serve as fish food.

Contributions from : Walker (1850); Kieffer (1910-1914, 1918); Edwards (1932); Pagast (1947); Singh (1958); Tokunaga (1959); Singh and Kulshrestha (1975, 1977); Sinharay, Chaudhuri and Choudhuri (1978); Kulshrestha (1979); Chaudhuri, Sinharay and Das Gupta (1979); Chaudhuri and Ghosh (1980, 1982); Chaudhuri, Guha and Das Gupta (1981); Guha and Chaudhuri (1981, 1982, 1984, 1985, 1987); Chaudhuri (1982); Ghosh and Chaudhuri (1982); Chaudhuri and Debnath (1983); Chaudhuri, Guha and Ghosh (1984); Guha, Das, Chaudhuri and Choudhuri (1985); Chaudhuri, Bhattacharyay and Dutta (1985, 1989); Maheshwari (1986, 1987); Halvorsen and Saether (1987); Chaudhuri and Guha (1987); Coffman, Yurasits and Rosa (1988); Chaudhuri, Nandi and Ghosh (1988).

Family Simuliidae (Given separately)

Family Anisopodidae

A small family of "window gnats" comprising only 8 species under the genus *Sylvicola* Harris of the subfamily Anisopodinae in India is akin to the Tipulidae. Adults are commonly found in swarms, preferably near trees and larvae live in decaying vegetable matter or manure.

Contributions from : Van der Wulp (1885); Brunetti (1911); Edwards (1923, 1928).

Family Bibionidae

The family of "march flies" comprises 39 species under 4 genera of 2 subfamilies in India. Adults often enormously frequent meadows, grassy hillsides or decaying vegetation and predominantly feed on decaying vegetable matter. Larvae are known to feed gregariously on roots and tubers of a wide variety of crops.

Contributions from : Fabricius (1775, 1781); Guérin-Méneville (1838); Bigot (1890); de Meijere (1904); Brunetti (1911-1913, 1917, 1925); Fletcher (1919); Hardy (1948, 1949, 1953, 1965); Strenzke (1951); Pal (1989).

Family Mycetophilidae

The Mycetophilidae or "fungus gnats" are represented by 77 species under 22 genera of 3 subfamilies in India. Adults are mostly nocturnal and so they are commonly met with in damp, dark places, especially among forest undergrowth during the day. Larvae prefer to feed on fungi to any other organic matter, often living there. Several species exhibit luminosity.

Contributions from : Lehmann (1822); Walker (1848, 1856); Brunetti (1912, 1917); Senior-White (1922); Edwards (1924); Coher (1988).

Family Sciaridae

The sciarids resemble the mycetophilids in most habits and so were once treated together. Larvae feed on fungus, animal excrement or decaying plant material. There are over 61 species under 8 genera in India. The genus *Psilomegalosphys* Enderlein is endemic to India.

Contributions from : Walker (1856); Rübsaamen (1894); Enderlein (1911); Brunetti (1912); Senior-White (1921); Roy (1983); Alam, Das Gupta and Chaudhuri (1988).

Family Scatopsidae

This is a small family containing only 3 species each under a genus of 3 subfamilies in India. Adults are generally encountered in grasslands and larvae usually live in decaying plant matter.

Contributions from : Brunetti (1911, 1925); Cook (1956).

Family Cecidomyiidae

The Cecidomyiidae or "gall midges" as they are commonly called, are represented in India by

310 species under 60 genera of 3 subfamilies of which some 18 genera are endemic to India. Adults are inconspicuous fragile flies and are entirely saprophagous. Larvae exhibit a wide range of habits: some are predacious on mites and small insects; some feed on decomposing organic matter and the great majority feed in or on tissues of leaves or stems of plants, form galls and affect nearly all parts of plants.

Contributions from : Schiner (1868); Wood-Mason (1889); Anonymous (1903); Kieffer (1905, 1909, 1910, 1912, 1913); Kieffer and Cecconi (1906); Felt (1916, 1917, 1920-1922, 1926, 1927); Senior-White (1922); Mani (1934-1938, 1942, 1943, 1946,1947, 1953, 1954, 1963, 1964, 1973, 1974); Barnes (1936); Nayar (1944, 1949, 1953); Rao (1950-1953, 1956, 1957, 1960); Agarwal (1956); Rao and Saksena (1959); Rao and Grover (1959, 1960); Grover (1961-1970, 1972, 1975, 1979, 1981); Grover and Prasad (1966, 1981), Rao and Sharma (1977, 1978); Grover and Bakshi (1977-78); Sharma and Rao (1977-1978); Gangwar (1982); Prasad and Grover (1982); Sharma, Dev Roy and Das (1983); Sharma (1983-1988); Sharma and Das (1984); Sharma, Dev Roy, Mitra and Das (1984); Sharma and Dev Roy (1985); Kashyap (1986); Kashyap and Grover (1986).

Suborder Brachycera

Family Coenomyiidae

The Coenomyiidae are primitive brachycerans comprising 4 genera of which *Coenomyia* Latreille with 2 species occur in the Himalaya. Adult frequent woods, and larvae live in the soil or decaying wood and are carnivorous.

Contributions from : Enderlein (1921); Nagatomi and Saigusa (1970).

Family Rachiceridae

The Rachiceridae are known in India by 4 species only under a single genus *Rachicerus* Walker. They are closely related to the coenomyiids and have the same habit and habitat.

Contributions from : Brunetti (1920); Nagatomi (1970).

Family Solvidae

The family contains 13 Indian species under 2 genera : *Coenomyiodes* Brunetti and *Solva* Walker. They are related to both coenomyiids and rachicerids and have similar habits and habitats.

Contributions from : Brunetti (1920, 1923); Enderlein (1921); Séguy (1956).

Family Stratiomyidae

The Stratiomyidae, commonly known as "soldier flies" are often colourful. In India, 73 species belonging to 34 genera under 6 subfamilies are known. Adults are commonly encountered in woods, dense vegetation and grass meadows near water or around garbage or decaying plants. Many are flower-visitors too. Larvae are either terrestrial or aquatic and carnivorous or saprophagous. A few species damage plant tissues. Pupae remain enclosed in the larval skin and differ from those of other brachycerans.

Contributions from : Fabricius (1794, 1805); Wiedemann (1819, 1824); Macquart (1838, 1846); Walker (1851, 1854); Schiner (1868); Bigot (1879); de Meijere (1904, 1911), Kertész (1906, 1923); Brunetti (1907, 1912, 1913, 1920, 1923, 1925); Enderlein (1914, 1921); Séguy (1934); Lindner (1937); Das, Sharma & Dev Roy (1984).

Family Tabanidae

The Tabanidae, comprising "horse flies" and "deer flies" are represented in India by nearly 200 species of 12 genera under 3 subfamilies. The genus *Melissomorpha* Ricardo with a single species is endemic, hitherto known only from Rangaroom (alt. 1500 m) in the eastern Himalaya (West Bengal). Adults are usually swift-fliers and are found in forests, vegetation and meadows in the vicinity of water. Larvae live in aquatic and semi-aquatic situations. Females of most species are blood-sucking pests and a few are mechanical carriers of *Trypanosoma* causing surra in equines in India and for this reason the group has been much studied in respect of habit, habitat, behaviour and prophylaxis (Datta, 1985).

Contributions from : Fabricius (1798, 1805); Wiedemann (1821, 1824); Macquart (1838, 1846, 1850, 1855), Saunders (1841); Walker (1848, 1850, 1854); Schiner (1868); Bigot (1891, 1892); Ricardo (1902, 1906, 1909, 1911, 1913, 1914, 1917); Brunetti (1912); Surcouf (1921); Austen (1922); Senior-White (1922, 1924, 1927), Enderlein (1925), Szilády (1926), Schuurmans Stekhoven (1926, 1932); Kröber (1930); Basu, Menon and Sen Gupta (1952); Philip (1959, 1960, 1962, 1970, 1972); Philip and Mackerras (1960); Mackerras (1962); Sen and Fletcher (1962); Chvála (1969); Stone and Phlip (1974); Datta and Biswas (1977); Datta and Das (1978); Datta (1980, 1981, 1986); Datta and Chakraborti (1985).

Family Rhagionidae

The family of "snipe flies" comprises 30 species under 5 genera in India. Adults are found in open woods and meadows in the vicinity of water or marshy places, and are predacious upon other insects. Larvae live in streams, damp soil or wet decaying wood.

Contributions from : Schiner (1868); Brunetti (1909, 1912, 1920); Szilády (1934).

Family Therevidae

The Therevidae are represented by 16 species under 3 genera in India. Adults frequent vegetation and grass-meadows near water, and are predacious upon other insects. Larvae inhabit the soil in leaf-mould, fungi, decaying wood etc. and are carnivorous.

Contributions from : Wiedemann (1824); Walker (1848, 1852); Bigot (1889); Kröber (1912); Brunetti (1912, 1917, 1920).

Family Scenopinidae

The scenopinids or "window flies" are poorly known in India and are represented by 2 species under *Seguyella* Kelsey and *Scenopinus* Latreille out of over 300 species in the world. Adults are found on windows or about stables and outbuildings. Larvae are predaceous on the larvae of wood-boring beetles, fleas and lice, stored food pests, household pests and on termites.

Contributions from : Brunetti (1920); Kelsey (1969, 1973); Ghorpade (1981).

Family Mydidae

The family Mydidae of "mydas flies" contains 5 species from India. The subfamilies Mydinae and Syllegomydinae with at least 3 genera are supposed to accommodate these species. Adults are flower-visitors and are believed to be predaceous on other insects. Larvae feed on Coleopterous larvae.

Contributions from : Wiedemann (1824); Brunetti (1912, 1913); Séguy (1928).

Family Asilidae (Given seperately)

Family Nemestrinidae

The Nemestrinidae are represented in India by only 6 species under 2 genera of 2 subfamilies occurring mainly in hot and arid regions. Adults frequent flowers and larvae are believed to be internal parasites such as of grasshoppers.

Contribution from : Lichtwardt (1910).

Family Acroceridae

The acrocerids, often called "small-headed flies" or "swollen-bodied flies" are internal spider parasitoids. Adults having functional mouth-parts visit flowers. The pupae of this family are remarkable for the great size of their thorax that is exceptional in Diptera. There are 14 species under 8 genera of 2 subfamilies so far known in India.

Contributions from : Walker (1852); Litchwardt (1909); Brunetti (1912, 1920, 1926); Schlinger (1959).

Family Bombyliidae

The bombyliids, the so-called "bee flies" are represented in India by 118 species under 24 genera of 10 subfamilies and are abundant in arid and semi-arid areas favoured by them. Adults are nectar - and pollen-feeders and larvae are parasitic on those of other endoptergote insects.

Contributions from : Fabricius (1775, 1781, 1787, 1794, 1805); Wiedemann (1824, 1828); Macquart (1840); Westwood (1842, 1849); Guérin-Méneville (1844); Walker (1849, 1852); van der Wulp (1885); Bigot (1892); Brunetti (1909, 1912, 1917, 1920); Nurse (1922); Enderlein (1926); Aldrich (1928); Bowden (1964); François (1967, 1968); Kapoor, Agrawal and Grewal (1978); Evenhuis (1979); Grewal and Kapoor (1987); Zaitzev (1987, 1988).

Family Empididae

The Empididae, commonly known as "dance flies" are observed in aerial dances for mating. They prey chiefly upon small Diptera or other soft insects and may be found on flowers, in woods and over pools and streams. Larvae are found in soil, decaying wood, dung or in water. The Indian fauna comprises 57 species under 19 genera of 5 subfamilies best represented in the Himalaya.

Contributions from : Walker (1849); Bigot (1889); Bezzi (1904); Brunetti (1913, 1917, 1920); Collin (1960).

Family Dolichopodidae

The Dolichopodidae or "long-legged flies" are represented in India by 134 species under 27 genera of 8 subfamilies. Adults are commonly found on foliage and mud in moist situations. Larvae generally live beneath the ground, in decaying wood and among humus, and some others are aquatic. Both adults and larvae are carnivorous. Adults of many species are also known to feed on nectar.

Contributions from : Fabricius (1805); Macquart (1842, 1846); Walker (1849); Schiner (1868); Becker (1922); Lamb (1924); Parent (1929, 1932, 1934, 1937, 1941); Robinson (1971).

Suborder Cyclorrhapha

Division Aschiza

Family Lonchopteridae

The family is poorly represented in India only by 3 species under a single genus *Lonchoptera* Meigen. Adults are found resting or running on herbage, dead leaves or wet stones near shady streams in damp forests. Larvae are believed to be semi-aquatic.

Contributions from : Panzer (1809); Joseph and Parui (1976, 1979, 1981).

Family Phoridae

The Phoridae, the "scuttle flies" as they are commonly called, are represented by 48 species under 18 genera of 4 subfamilies hitherto known in India. The 2 genera, *viz.*, *Assmutherium* Schmitz and *Indoxenia* Schmitz are endemic to India. Adults are frequently seen in decaying vegetation, or in nests of ants and termites. Larvae live in decaying vegetable matter and dead animals. Some are parasitic, while others have symbiotic relation with ants.

Contributions from : Schiner (1868); Bigot (1890); Wasmann (1900, 1902, 1913); Brues (1905, 1907); Brunetti (1912, 1914); Schmitz (1912-1915, 1924, 1926, 1938); Senior-White (1922, 1924); Colyer (1961); Rao (1961); Borgmeier (1967); Disney (1981, 1988); Papp (1982).

Family Platypezidae

The platypezids, commonly known as "flat-footed flies" are known in India by 3 species only under a single genus *Plesioclythia* Kessel & Maggioncalda in the subfamily Platypezinae. Adults frequent shady woods. Eggs are laid on fungi on which larvae feed.

Contributions from : de Meijere (1907); Brunetti (1912); Kessel and Clopton (1969).

Family Pipunculidae

The pipunculids or "big-headed flies" are represented in India by 25 species under 4 genera of 2 subfamilies known. Adults are found hovering on flowers or herbage and larvae are parasitic on Homopterous insects.

Contributions from : Brunetti (1912, 1915, 1923); Hardy (1972); Kapoor (1985); Kapoor, Grewal and Sharma (1987).

Family Syrphidae

The Syrphidae popularly known as "hover flies" or "flower flies" are represented by 256 species under 62 genera of 2 subfamilies so far known in India. The genus *Ischyrosyrphus* Bigot is endemic to India. Adults are mainly flower-visitors and are of great value in pollination. Larvae of many Syrphinae are natural enemies of aphids, scale insects and other soft-bodied insects. Larvae of Milesiinae are habitually saprophagous and a few of *Eristalis* Latreille occasionally cause myiasis in humans, and a few other damage bulbs of cultivated plants.

Contributions from : Fabricius (1781, 1787, 1794, 1798, 1805); Wiedemann (1819, 1824, 1830); Guérin-Méneville (1834); Saunders (1841); Macquart (1842, 1846); Walker (1849, 1852, 1857); Schiner (1868); Bigot (1880, 1882-1885); Kertész (1901); de Meijere (1904, 1908); Brunetti (1907, 1908, 1913, 1915, 1917, 1923, 1925); Hervé-Bazin (1914, 1922-24); Shannon (1926); Sack (1928); Curran (1929, 1933); Bhatia (1933, 1939); Bhatia and Shaffi (1933); Hull (1941, 1942, 1944, 1950); Deoras (1942); Greene (1949); Coe (1964); Joseph (1967, 1968, 1970); Nayar (1968); Ghorpade (1973, 1981); Roy and Basu (1977); Agarwala, Ghosh and Raychaudhuri (1982); Datta and Chakraborti (1983, 1986); Singh, Sodhi and Gupta (1985, 1986); Chander (1988); Mahalingam (1988).

Family Microdontidae

This is originally a subfamily of the Syrphidae given the status of a family recently by Thompson (1972) to accommodate 16 species under 4 genera. While adults frequent flowers, larvae are exclusively scavengers in the nests of ants.

Contributions from : Wiedemann (1824); Macquart (1834); Walker (1849); de Meijere (1904); Brunetti (1907, 1908, 1915, 1923, 1925).

Family Conopidae

The Conopidae are parasitic flies on aculeate Hymenoptera, cockroaches and calyptrate Diptera represented by 48 species under 11 genera of 3 subfamilies so far known in India.

Contributions from : Fabricius (1794); Macquart (1843); Walker (1852); Bigot (1887); Brunetti (1912, 1923, 1925); Kröber (1915, 1916, 1940); Smith (1958); Nayar (1968).

Suborder Cyclorrhapha

Division Schizophora

Section Acalyptratae

Family Neriidae

The Neriidae or long-legged flies are closely related to the Micropezidae and are represented by 4 species under 2 genera of 2 subfamilies in India. Adults are seen in rotten wood where larvae are believed to inhabit.

Contributions from : Schiner (1868); Brunetti (1913); Hennig (1937); Steyskal (1966).

Family Micropezidae

The micropezids, popularly known as "stilt-legged flies" are represented by 10 species under 3 genera of 2 subfamilies in India. Larvae are saprophytic to the habitat where adults are found.

Contributions from : Wiedemann (1830); Schiner (1868); Brunetti (1913); Enderlein (1922); Steyskal (1952); Frey (1958).

Family Psilidae

The family Psilidae is poorly known in India and contains a single species *Chyliza cylindrica* (Walker) in the subfamily Chylizinae. Larvae are phytophagous. Adults usually remain hidden in dense vegetation on high lands or mountains.

Contributions from : Walker (1852); Frey (1955).

Family Megamerinidae

This family is also poorly represented in India and contains a single species *Texara dioctrioides* Walker. They are also highland flies and larvae are found under barks.

Contributions from : Walker (1860); de Meijere (1914); Enderlein (1920); Hennig (1941, 1952, 1958).

Family Nothybidae

This is another poorly represented family with a single species *Nothybus kempi* Brunetti from India.

Contributions from : Brunetti (1913), Aczél (1955).

Family Diopsidae

The diopsids or "stalk-eyed flies" are represented by 8 species under 5 genera of the Diopsinae in India. Adults are found on herbage about streams or pools, sometimes in large numbers and larvae are saprophagous or phytophagous.

Contributions from : Wiedemann (1830); Westwood (1837, 1838, 1845); Walker (1856); Bigot (1880); Brunetti (1907); Curran (1936); Shillito (1971); Steyskal (1972); Datta and Biswas (1985).

Family Pyrogotidae

The pyrgotids are parasitic in their larval stage on adult scarabaeid beetles. Adults are mainly nocturnal and females oviposit when the beetle is in flight. the family comprises 15 species under

6 genera in the nominate subfamily in India. The genus *Tylotrypes* Bezzi is endemic.

Contributions from : Walker (1852, 1861); Bezzi (1914); Hendel (1914, 1934); Aldrich (1928); Enderlein (1942); Hardy (1959).

Family Tephritidae (Given separately)

Family Platystomatidae

The Platistomatidae are known by 36 species under 10 genera of 3 subfamilies in India and are predominantly tropical in distribution. Adults are found to be attracted by flowers, decaying fruits, human sweat, faeces, decaying snails, etc. Larvae are found on fresh or decaying vegetables, human corpses, humus, etc.

Contributions from : Wiedemann (1830); Walker (1849, 1852); Kertész (1897); Coquillett (1904); de Meijere (1904); Enderlein (1912, 1924); Brunetti (1913); Hendel (1914); Steyskal (1965, 1971); McAlpine (1973).

Family Otitidae

The family is known in India only by 2 species under the genus *Physiophora* Fallén of the subfamily Ulidinae. Adults are commonly found on vegetation and larvae are believed to be saprophagous.

Contributions from : Fabricius (1794); Walker (1849, 1852, 1858); Steyskal (1952).

Family Sciomyzidae

This family includes 10 species under 4 genera of the subfamily Sciomyzinae in India. Adults frequent rice fields or other damp situations and larvae are predators or parasitoids of snails or slugs.

Contributions from : Wiedemann (1824); Walker (1858); Hendel (1912); Brunetti (1917).

Family Dryomyzidae

The family is known in India by a single species *Dryomyza formosa* (Wiedemann). Adults are associated with excrement or decaying fungi and larvae are believed to be saprophagous.

Contributions from : Macquart (1851); Steyskal (1957).

Family Sepsidae

The sepsids are known by 17 species under 8 genera of 2 subfamilies in India. Adults are abundantly encountered on herbage, excrement, dung or other decaying matter and larvae are coprophagous.

Contributions from : Wiedemann (1824); Walker (1852); de Meijere (1906, 1913); Brunetti (1909); Senior-White (1924); Duda (1926); Zuska (1974); Iwasa (1982).

Family Lauxaniidae

The Lauxaniidae comprise 30 species under 12 genera of 2 subfamilies in India. Adults remain in shady undergrowth and larvae live in leaf litter and plant debris etc. and are saprophagous.

Contributions from : Wiedemann (1824, 1830); Macquart (1843); Walker (1852); Schiner (1868); Kertész (1904); Brunetti (1913); Malloch (1929).

Family Celyphidae

The Celyphidae, commonly known as "beetle flies" are represented by 12 species under 2 genera in India. Adults are found in moist situations along streams, ponds or rivers and in grassy areas and larvae are known to live in decaying vegetation.

Contributions from : Dalman (1818); Wiedemann (1830); Macquart (1851); Sen (1921); Malloch (1929); Vanschuytbroeck (1952); Tenorio (1972); Joseph and Parui (1978); Datta (1986).

Family Chamaemyiidae

The Chamaemyiids are known in India only by 7 species under the genus *Leucopis* Meigen of the subfamily Chamaemyiinae. Larvae are predaceous upon aphids, adelgids and coccids (Homoptera).

Contributions from : Malloch (1924); Tanasijtshuk (1968); McAlpine (1971); Das, Poddar and Ray Chaudhuri (1981).

Family Lonchaeidae

The Lonchaeidae or "lance flies" are represented by only 8 species under 3 genera of the subfamily Lonchaeinae in India. Adults are found in forests where males congregate in swarms. Larvae generally live under bark of decaying trees or in fruits or vegetables.

Contributions from : Brunetti (1913); Senior-White (1924); Bezzi (1920); McAlpine (1956, 1964).

Family Piophilidae

The family is represented in India by only 2 species under the genus *Piophila* Fallén. Larvae are saprophagous and the well-known "Cheese skipper" may do much damage to cheese and other fatty foods.

Contributions from : Brunetti (1909); Zumpt (1965).

Family Aulacigastridae

This small family is often associated with the Drosophilidae and comprises only 4 species under 2 genera in India. Adults are attracted to the exudation from wounds on trees where larvae are believed to live.

Contributions from : Sabrosky (1956, 1965); Hennig (1971).

Family Asteiidae

This is also a small family often associated with the Drosophilidae and is represented by 3 species, one in each of 3 genera in India. Adults are found in shady places near water where larvae are believed to live.

Contributions from : Sabrosky (1956); Papp (1974).

Family Agromyzidae (Given separately)

Family Milichiidae

The family is represented by 6 species under 3 genera of 2 subfamilies in India. Adults of *Desmometopa* Loew live on sucking body-fluids of bugs, spiders etc. and of *Phyllomyza* Loew are associated with ants, and others live in birds' nests. Larvae are saprophagous or coprophagous and inhabit manure, decaying plants or other vegetative materials.

Contributions from : Brunetti (1924); Hennig (1937).

Family Carnidae

This is a very small family generally associated with the milichiids and contains a single species *Carnus hemapterus* Nitzsch from India which is an avain blood-sucking ectoparasite.

Contributions from : Nitzsch (1818); Hennig (1937, 1972); Bequaert (1942).

Family Chloropidae (Given separately)

Family Ephydridae

The Ephydridae, commonly known as "shore flies" inhabit marshy places, damp meadows, etc. and are important food sources for wildlife. Adults rest on mud or water or vegetation near water whereabout larvae are abundantly encountered. Some are leaf - or stem-miners. The family comprises 45 species under 24 genera of 4 subfamilies in India.

Contributions from : Wiedemann (1824); Fraunfeld (1867); Schiner (1868); Cresson (1929, 1934, 1945, 1948); Wirth (1964); Clausen (1977); Mathis and Zatwarnicki (1988).

Family Drosophilidae

The Drosophilidae, the "pomace flies" (erroneously fruit flies) are represented by 102 species under 11 genera of 2 subfamilies in India and are abundant in all situations containing decaying fruits or vegetable matter. These flies are extensively used in cytogenetic researches.

Contributions from : Walker (1864); Schiner (1868); de Meijere (1906); Brunetti (1923); Duda (1924); Malloch (1924, 1929); Chaudhuri and Mukherjee (1941); Parshad and Paika (1964); Parshad and Duggal (1966); Reddy and Krishnamurthy (1968, 1970, 1973, 1974); Gupta (1969-1974); Gupta and Ray-Chaudhuri 1970); Sajjan and Krishnamurthy (1973, 1975); Vaidya and Godbole (1973, 1976); Singh and Gupta (1974); Sajjan and Reddy (1975); Singh (1976); Singh and Gupta (1977); Gupta and Singh (1978), Prakash and Reddy (1977, 1978); Dwivedi, Singh and Gupta (1979); Gupta and Dwivedi (1980); Muniyappa and Reddy (1980); Muniyappa, Reddy and Krishnamurthy (1981); Dwivedi (1981); Muniyappa, Reddy and Prakash (1982); Gai and Krishnamurthy (1982, 1986); Gupta and Panigrahy (1982, 1986); Panigrahy and Gupta (1983); Kumar and Gupta (1988, 1989).

Family Heleomyzidae

The Heleomyzidae are known in India only by 2 species under the genus *Suillia* Robineau-Desvoidy of the subfamily Suillinae. Larvae are mainly scavengers in fungi, excrement etc. where adults are found.

Contributions from : Czerny (1932); Deeming (1966).

Family Canaceidae

The canaceids or "beach flies" closely resemble the Ephydridae in appearance and habits. They are found in salt marshes. Larvae live on algae on wave-splashed rocks or sandy beaches. The family is known in India by a single species *Xanthocanace orientalis* (Hendel).

Contributions from : Hendel (1913); Wirth (1951); Mathis (1982).

Family Sphaeroceridae

The Sphaeroceridae comprise 28 species under 16 genera of 3 subfamilies from India. Adults are saprophagous and frequent decaying animal or vegetable matter in which they breed. Larvae are also habitually saprophagous. A few species are apterous.

Contributions from : Wiedemann (1824); Meigen (1830); Haliday (1833); Zetterstedt (1847); Stenhammar (1854); Rondani (1880); Brunetti (1913, 1924); Duda (1923, 1925); Hackman (1965, 1969); Deeming (1969); Papp (1978, 1981, 1984, 1988, 1989); Opava and Papp (1988).

Section Calyptratae

Family Hippoboscidae

The family comprises 23 species under 11 genera of 3 subfamilies in India. Adults of both sexes are haematophagous and are obligatory ectoparasites of birds and certain mammals. Females reproduce by pseudoplacental viviparity and prepupae are dropped to the ground.

Contributions from : Leach (1817); Macquart (1843); Bigot (1885); Ormerod (1895); Austen (1930); Bequaert (1953); Maa (1963, 1965, 1969); Rao, Hiregaudar and Alwar (1964).

Family Nycteribiidae

The Nycteribiidae or "bat flies" are represented by 29 species under 7 genera of 2 subfamilies in India. Adults are apterous and spider-like, and both sexes are obligatory blood-sucking ectoparasites of bats. The prepupae are found adhered to the perches where the hosts occur.

Contributions from : Westwood (1834); Speiser (1907); Scott (1914, 1925); Theodor (1956, 1967); Hiregaudar and Bal (1956); Choudhuri and Mitra (1965); Maa (1968, 1975).

Family Streblidae

The streblids are known in India by 10 species under 4 genera of 2 subfamilies. Adults of both sexes are obligatory blood-sucking ectoparasites of bats. The prepupae remain attached to the wall in the vicinity of roosts of bats.

Contributions from : Speiser (1900); Hiregaudar and Bal (1956); Vazirani and Advani (1976); Advani and Vazirani (1981).

Family Scathophagidae

The family is represented in India by 2 species in the genus *Scathophaga* Meigen of the subfamily Scathophaginae. Larvae live in dung and are saprophagous whereas adults are believed to be predatory on small insects.

Contributions from : Coquillett (1898); Cotterell (1920); Malloch (1935); Séguy (1952).

Family Anthomyiidae

The Anthomyiidae bear a general resemblance to the Muscidae for which they were previously treated under the latter. There are 19 species under 11 genera in India. Adults are usually found in woods or moist situations. Adults are generally saprophagous and larvae are saprophagous or phytophagous as a serious pest in agriculture.

Contributions from : Rondani (1866); Walker (1852, 1856); Malloch (1921, 1924), Séguy (1923); Brunetti (1924); Karl (1935); Auckland (1967, 1968, 1987).

Family Fanniidae

The family, once treated under the Muscidae, contains only 5 species under the genus *Fannia* Rob-Desv. in India. Adults are found on vegetation and larvae live in excrements and decaying organic matter.

Contributions from : Stein (1918); Chillcott (1961); Pont (1965).

Family Muscidae

The Muscidae or the "common true flies" occur in all zoogeographical regions and are represented by over 253 species under 39 genera of 6 subfamilies in India. Adults are found almost everywhere and are generally saprophagous. Some species have biting habit and carry disease germs and some other species carry germs from filth to food. A few species are extremely detrimental to human beings. Larvae have varied habits being saprophagous, parasitic or phytophagous as leaf-miners.

Contributions from : Fabricius (1794); Wiedemann (1824, 1830); Robineau-Desvoidy (1830);

Macquart (1843, 1855); Walker (1849, 1852, 1861); Schiner (1868); Bigot (1888); Bezzi (1907); Brunetti (1907, 1910, 1913); Picard (1908); Austen (1909, 1910); Stein (1910, 1918); Patton and Cragg (1912, 1913); Awati (1916, 1918); Malloch (1921-1923, 1925, 1928); Patton (1922, 1933); Patton and Senior-White (1924); Aubertin (1933); Enderlein (1934); Zimin (1947); Crosskey (1962); Emden (1965); Steyskal (1966); Shinonaga (1970); Vockeroth (1972); Joseph and Parui (1972); Pont (1972, 1973); Zumpt (1973); Srivastava (1985).

Family Eginiidae

The family is closely related to the Muscidae and so it was once included in the latter family. It contains only 2 species, each under a genus of which one under the genus *Magma* Albuquerque is endemic to India.

Contributions from : Malloch (1921); Albuquerque (1949).

Family Calliphoridae

The Calliphoridae, commonly known as "blow flies", "blue bottle flies" or "green bottle flies" are represented by 97 species under 26 genera of 4 subfamilies in India. Adults often frequent vegetation, flowers, excrement, decaying plant or animal matter. Larvae are scavengers or parasites on insects, earthworms, snails, and other animals. Some species are notorious in causing myiasis in man and animals.

Contributions from : Fabricius (1787, 1794, 1805); Wiedemann (1819, 1824); Robineau-Desvoidy (1830); Macquart (1835, 1843, 1847); Walker (1849, 1852, 1858); Schiner (1868); Bigot (1874, 1877, 1878, 1887); Bezzi (1913); Surcouf (1914); Townsend (1917, 1937); Patton (1920-1922); Senior-White (1922, 1923, 1930); Séguy (1928, 1946, 1949); Patton and Evans (1929); Aldrich (1930); Malloch (1931); Aubertin (1931); Rao and Pillay (1936); Baranov (1938); Roy and Siddons (1939); Senior-White, Aubertin and Smart (1940); Strickland and Roy (1940, 1941); Peris (1951, 1952); Crosskey (1965); Kurahashi (1970); James (1970); Roy and Dasgupta (1971, 1975, 1980, 1982); Joseph and Rao (1972); Das, Roy and Dasgupta (1978, 1979, 1981); Das and Dasgupta (1982).

Family Sarcophagidae

The Sarcophagidae or "flesh flies" as they are often called, comprise over 65 species under 26 genera of 3 subfamilies in India. Adults are generally found on vegetation, flowers, excrement or decaying plant and animal material. Larvae are saprophagous or coprophagous and live in decaying plant or animal matter or are parasites of insects and other animals.

Contributions from : Fabricius (1794); Fallén (1816), Meigen (1826); Wiedemann (1830); Robineau-Desvoidy (1830); Böettcher (1912, 1913); Sinton (1921); Patton (1922); Parker (1923); Senior-White (1924), Hardy (1927); Rao (1929); Patton and Evans (1929); Baranov (1931, 1934, 1938); Ho (1934); Senior-White, Aubertin and Smart (1940); Strickland and Roy (1941); Lopes (1961); Lopes and Kano (1969); Shinonaga and Lopes (1975); Roy and Dasgupta (1977); Nandi (1976-1979, 1982, 1988, 1989); Nandi and Roy (1982); Verves (1988).

Family Rhinophoridae

The family is closely related to the Calliphoridae or the Tachinidae. It is known by *Termitoloemus marshalli* Baranov only that is endemic to India. The species is predacious on termites.

Contributions from : Baranov (1936); Crosskey (1976).

Family Tachinidae

The Tachinidae or "tachina flies" are represented by 207 species under 111 genera of 5 subfamilies in India. The two genera *Isochaetina* Mesnil and *Thelairodrino* Mesnil with a single species in each are endemic to India. Adults are generally found on flowers or leaves or vegetation and larvae are all endoparasites mainly in insects. Many species are employed in biological control against a number of insect pests. They are well-known to create a problem in sericulture in India.

Contributions from : Fabricius (1794); Wiedemann (1819, 1824, 1830); Robineau-Desvoidy (1830); Macquart (1843, 1851); Walker (1849, 1852, 1858); Egger (1860); Bigot (1889); Brauer and Bergenstamm (1893); van der Wulp (1894); Lichtwardt (1909); Tothill (1918); Malloch (1924); Curran (1929, 1933); Baranov (1932, 1934, 1936, 1938); Villeneuve (1937); Gardner (1940); Mesnil (1950-1953, 1957, 1968, 1970); Crosskey (1967, 1976); Ghorpade (1986); Patil and Govindan (1986); Venkatesh, Srinivas and Rani (1987).

Family Gasterophilidae

The Gasterophilidae or "bot flies" as adults are scarcely encountered but larvae are frequently found to live as parasites in the alimentary tracts of equines and elephants. All the 6 species under 3 genera of 2 subfamilies of the Oriental region occur in India.

Contributions from : Macquart (1843); Patton (1920-1922, 1924, 1937); Brunetti (1923); Cross (1926); Datta and Pal (1985).

Family Oestridae

The Oestridae, commonly known as "warble flies", are also frequent in the larval stage that lives as a subcutaneous parasite in the bodies of mammals. The family contains 8 species under 7 genera of 2 subfamilies in India.

Contributions from : Steel (1887); Patton (1920-1923, 1936, 1937); Cross and Patel (1921); Brunetti (1923); Cross (1926); Rao (1929); Malkani (1931); Sen (1934); Bhatia (1934); Handa (1936); Soni (1938-1942); Chadha and Soni (1939); Soni and Khan (1942, 1944); Grunin (1949); Ghosh (1950); Pal and Datta (1989).

Current Research

The Zoological Survey of India is the premier institute where a maximum number of family-groups are under investigation, primarily on systematics. The family-groups, *viz.*, Simuliidae, Tabanidae, Asilidae and Syrphidae are being currently studied in the Headquarters at Calcutta; the Asilidae and Chloropidae at Madras, and the Cecidomyiidae at Poona. Alongside, all the other family-groups collected from Maghalaya and Tripura are currently under study at the Headquarters. Besides, taxonomical researches on some other family-groups are also done in certain Colleges and Universities as indicated in the following title. There are some other institutes, such as, the National Institute of Virology at Pune, the Vector Control Research Centre at Pondicherry, the National Institute of Communicable Diseases/National Malaria Eradication Programme at Delhi, the School of Tropical Medicine, Calcutta, the Indian Veterinary Research Institute at Izatnagar and the R and D Organization at Tezpur, where various aspects of bionomical studies on dipterans of medical and veterinary importance are carried out.

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DIPTERA : Tipulidae

Introduction

The family Tipulidae, popularly known as crane flies or daddy long-legs, is the largest in order Diptera as presently known. The adults are free living. Their larvae live among decaying vegetation, grass, roots, etc., or are aquatic. The larva of *Dicranota* lives in ponds and streams and preys upon the worm *Tubifex*. The larvae of Cylindrotomina group are acquatic or terrestrial and feed upon mosses or angiosperms. Among Limnobiinae the larvae of some *Limnobia* are fungivorous. A species of *Dicranomyia* is leaf mining in Hawaiian Islands, and that of *Tipula oleracea*. L. is a serious pest in meadows in Europe.

Members of the family Tipulidae can be recognised by the long six or more segmented antennae, absence of ocelli, mosotergum with a V-shaped transverse suture, long and slender legs, presence of discal cell, and valvular, horny ovipositor. The tipulids include some of the largest species of Nematocera.

Historical Resumé

Till the early part of 20th century, Tipulidae was considered as a family with three subfamilies under it, *viz.*, Ptychopterinae, Tipulinae and Limnobiinae. The division was mainly based on palpi. This system was followed by Brunetti (1912) in his volume in the *Fauna of British India*, Diptera Nematocera. He described 235 species of crane flies from India and adjoining countries. Alexander (1961) gave the detailed synonymy of the species described by Brunetti. Out of these, the types of 216 species are available in the National Zoological Collections of the Zoological Survey of India, Calcutta, which were redescribed by Joseph (1971-1979).

Alexander was the outstanding worker of world Tipulidae, who had worked for more than half a century on the family. He had contributed over 1000 papers and described over 10,000 species. His long series of papers in the *Annals and Magazine of Natural History*, London and *Philippine Journal of Science*, Manila, are unparalleled in the history of Tipulidae taxonomy. Alexander and Alexander (1973) catalogued the crane flies from the Orient, which is a landmark in the taxonomy of these flies.

Distribution

Tipulids are well distributed in all the major faunal regions and subregions, with the largest number occurring in the Oriental and Neotropical regions. The species are abundant in tropical and temperate areas at moderate altitudes. The highest altitude at which crane flies have been collected is at about 5000 m. in Bolivian Andes, by Alexander (1962), with a wide variety of species distributed at altitudes lower than that, for example from Sikkim in India.

Estimation of Taxa

About 14,000 species of tipulids are known from the world. Alexander and Alexander (1973) recorded over 1300 species under 60 genera from India in 'A Catalogue of Diptera from the Oriental Region.' Subsequently some more additions have been made.

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Animal Resources of India : 399–402 : 1991

DIPTERA : Simuliidae

Introduction

The Simuliidae or black flies as they are popularly known, belong to the suborder Nematocera of the order Diptera. They constitute one of the most homogeneous families of the superfamily Culicoidea. The superfamily comprises both the mosquitoes and their relatives (Culicidae, Chaoboridae and Dixidae), and the midges and their relatives (Chironomidae, Ceratopogonidae, Simuliidae, Thaumaleidae, Blephariceridae and Deuterophlebiidae). The Simuliidae are haematophagous like mosquitoes, but alongside the Ceratopogonidae having similar nature of feeding devices they are likely to be more close to the primitive stock than the non-biting members of the Culicoidea. The earliest fossil records of these flies are from Oligocene ambers of the Baltic coast in Germany.

Earlier workers including Linnaeus (1758), Fabricius (1787) and Meigen (1800, 1803, 1804) described species of the Simuliidae under genera of various families. The type-genus *Simulium* was erected by Latreille (1802) and was first recognized by Meigen (1818) as a clearly defined group of Diptera, which was later designated a family, the Simuliidae (as Simuliites), with this single genus by Newman (1834). Roubaud (1906) proposed subgeneric division. Surcouf and Gonzalez-Rincones (1911), Malloch (1914), Enderlein (1921-1937), Tonnoir (1925), Baranov (1926-1938), Dyar and Shannon (1927), Edwards (1931, 1934), Rubtzov (1937, 1940) and Smart (1945) advanced various suggestions for the classification of the family, resulting in the creation of a large number of genus-group names as respective subfamilies and tribes. Nearly after two decades, there were two different approaches to the suprageneric classification of the family: one of Stone (1964), and the other of Rubtzov(1959-1964). Stone divided the world fauna into five tribes: Gymnopaidini, Parasimuliini and Prosimuliini under the subfamily Prosimuliinae, and Cnephini, Simuliini under subfamily Simuliinae. Rubtozv recognised only two sub-families : Gymnopoaidinae and Simuliinae, without any tribes. The most recent classification advocated by Crosskey (1981) and elaborated and elucidated in 1987 is simple and reasonable. He recognized two subfamilies : Parasimuliinae and Simuliinae. The Simuliinae contain two tribes : Prosimuliini and Simuliini, of which only the tribe Simuliini is represented in the Orient. There are two genera in the tribe, but only the type-genus *Simulium* with eight subgenera *viz., Nevermannia* Enderlein, *Montisimulium* Rubtozov, *Eusimulium* Roubaud, *Wilhelmia* Enderlein, *Gomphostilbia* Enderlein, *Himalayum* Lewis, *Tetisimulium* Rubtzov and *Simulium* Latreille (nominate) occurs in India.

The most remarkable biological fact about black flies is that the immature stages almost always inhabit the clear flowing water and for this reason they occur abundantly in the trickles, streams, cascades and rivers of hilly regions or meagrely in artificial water-courses like irrigation channels in plateaux and plains.

Black flies are one of the groups of insects of medical and veterinary importance. As blood-sucking pests, they produce an allergic reaction that may be very serious in man and results in the death of cattle, horses and other domestic animals. They cause annoyance by getting into eyes, ears or nostrils even when they do not bite. As vectors, they transmit Onchocerciasis, a serious filarial disease in man resulting in blindness, in parts of tropical Africa and Central America. They also transmit Leucocytozoonosis of ducks and turkeys and certain viral infections of animals causing serious losses in some parts of the globe. However, there are no such reports in India.

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Historical Resumé

Several expeditions were conducted mainly in the north-east India shortly before the first species *Simulium indicum* was described by Becher in 1885 (*vide* Needham, 1886; MacGregor, 1886; Woodthorpe, 1889, 1890). In the beginning of the twentieth century, Brunetti (1911) described seven species from certain parts of India that had been included in the 'Fauna of British India' by Brunetti (1912). Senior-White (1922) described three species from south India, one of which was later found by Puri (1932) to be conspecific with one described from Sri Lanka by Brunetti (1912). In the meanwhile, Brunetti (1917, 1920) recorded three species from Himachal Pradesh. Edwards (1927) described two species from Kashmir, one of which had been synonymized by Lewis (1973) with *indicum* Becher. Subsequently, Puri (1932-1933) described nineteen species, and re-described and recorded some species from various parts of India. Lewis (1973), while dealing with the Simuliidae of Pakistan, recorded one species from Himachal Pradesh also. In 1974, he supplemented invaluable information of two species from the north-east India. Datta (1973-1978, 1983-1988) described seventeen species and unknown stages of certain species mainly from the Himalaya, and extended knowledge on the distribution of several species in India. Datta and Pal (1975), and Datta *et al.*, (1975) described another species and immature stages of certain unnamed species from the Darjiling area.

Field observations on *indicum* were made by an anonymous worker (1950-1960), Jacob (1957), and Perti and Lopez (1962) in Arunachal Pradesh. Datta and Dasgupta (1972-1977, 1984), while studying black flies of the Darjiling area, paid attention to several aspects of behaviour of six species. Simultaneously, Datta and Das (1975) evaluated statistically the incidence of females of these six species in their different internal conditions. Datta *et al.*, (1975, 1976) worked on the ecology of sixteen species of black flies from the Darjiling area. A comprehensive account of the ecology of the only autogenic widespread species *aureohirtum* Brunetti was given by Datta (1981) based on observations made in the north-east India.

Apart from these works, certain other approaches are also evident on this important group of flies. Das Gupta *et al.*, (1969) and Datta and Dasgupta (1975) recorded the biting activities of some species of the Darjiling area. Cytogenetic works onsix species of black flies by Dey and Fumafartosok (1984) in the same area are the first of its kind in India. Besides, experimental observations on certain behavioural expressions with the application of insecticides and repellents in Arunachal Pradesh were made by Bhuyan et al (1974); Saxena *et al.*, (1974); Das *et al.*, (1981, 1984) and Kumar *et al.*, (1984).

Estimation of Taxa

Of nearly 1500 species, under 57 subgenera of 24 genera, belonging to 2 tribes and 2 subfamilies in the world fauna, only 52 species under 8 subgenera of *Simulium* are known from India. There are 184 species under 11 subgenera of *Simulium*, known from the Orient.

Classified Treatment

The first species *indicum* Becher (1885) is the only species in the subgenus *Himalayum* erected by Lewis (1973), who also described the male, pupa and larva for the first time. In the following year (1974) he redescribed the female and reviewed the species in detail. The only species *aureum* Fries (1824) from India belonging to subgenus *Eusimulium* Roubaud, was recorded by Puri (1933). Simultaneously, he recorded another species *pseudequinum* Séguy (1921) (= *equinum* var. *mediterraneum* Puri, 1925) of subgenus *Wilhelmia* Enderlein from India. Edwards (1927)'s extant species *stevensoni* is the sole example of subgenus *Tetisimulium* Rubtzov in India. The subgenus *Gomphostilbia* Enderlein includes 8 species, *viz.*, *metatarsale* Brunetti (1911), *pattoni* Senior-White (1922), *tenuistylum* Datta (1973), *darjeelingense* Datta (1973), *bucolicum* Datta (1975), *litoreum* Datta (1975), *unum* Datta (1975) and *fidum* Datta (1975). The two species *nemorivagum* Datta (1973) and *ghoomense* Datta (1975) described from the eastern Himalaya are assignable to the subgenus *Montisimulium* Rubtzov. The subgenus *Nevermannia* Enderlein is known to contain 7 species, *viz.*, *rufithorax* Brunetti (1911), *aureohirtum* Brunetti (1911), *senile* Brunetti (1911), *praelargum* Datta (1973), *gracile* Datta (1973), *purii* Datta (1973) and *dasguptai* Datta (1974). The largest subgenus of the simuliid fauna in India is *Simulium* (nominate), representing 31 species as follows : *grisescens* Brunetti (1911), *griseifrons* Crunetti (1911), *rufibasis* Brunetti (1911), *striatum* Brunetti (1912), *gurneyae* Senior-White (1922), *himalayense* Puri (1932), *nilgiricum* Puri (1932), *ramosum* Puri (1932), *christophersi* Puri (1932), *nitidithorax* Puri (1932), *novolineatum* Puri (1932), *barraudi* Puri (1932), *digitatum* Puri (1932), *dentatum* Puri (1932), *howletti* Puri (1932), *hirtipannus* Puri (1932), *lineothorax* Puri (1932), *palmatum* Puri (1932), *consimile* Puri (1932), *pallidum* Puri (1932), *gravelyi* Puri (1933), *palniense* Puri (1933), *tenuitarsus* Puri (1933), *nodosum* Puri (1933), *rashidi* Lewis (1973), *nigrifacies* Datta (1974), *biforaminiferum* Datta (1974), *singtamense* Datta and Pal, 1975, *kapuri* Datta (1975), *adventicium* Datta (1985) and *asishi* Datta (1988).

In addition, Datta (1974) described heretofore unknown larval stages of *grisescens* Brunetti, *rufibasis* Brunetti, *himalayense* Puri, *ramosum* Puri and *dentatum* Puri. It may be mentioned that adults and pupal stages of almost all the species are well-known, but knowledge on larval stages of several species is far from satisfactory.

Current Research

The Zoological Survey of India is the only centre in the country where taxonomic and ecological works on the Simuliidae are carried out. At present the faunas of Meghalaya and Tripura states are being studied. The workers of the Field Laboratory of Research and Development Organization, Ministry of Defence, at Tezpur are engaged in controlling these flies in Arunachal Pradcsh.

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Animal Resources of India : 403–405 : 1991

DIPTERA : Asilidae

Introduction

The Asilidae, or robber flies, comprises one of the largest and abundant families of Diptera. Their adults and larvae are predaceous, feeding on other insects, especially on phytophagous insects, and thus help to maintain the natural balance of insect populations. They, therefore, have considerable potential in biological control.

The asilids are elongate bristly flies with a horny proboscis, frons excavated above, ocelli situated on a rounded tubercle, mystax between eye margin and above epistome, antennae three segmented with or without style or arista on flagellum; thorax convex; legs stout, prehensile, empodium bristle-like and pulvilli pad-like; wings with one marginal, two to three submarginal, and four to five posterior cells; abdomen eight-segmented with prominent hypopygium and ovipositor.

Historical Resumé

Linnaeus (1758) in the tenth edition of "Systema Naturae" erected the genus *Asilus*. Family status was given by Leach (1819) based on *Asilus crabroniformis* Linnaeus as the type of family. Macquart (1838) divided the family into Asilites, Dasypogonites and Laphrites. In 1847, Loew divided it into subfamilies: Dasypogoninae, Laphriinae and Asilinae. Later Schiner (1868) added Leptogastrinae. This system was followed by subsequent workers, notable among them being Hermann (1920), Efflatoun (1934), Bromley (1934,1935) and Martin (1957). Hardy (1934) divided the family into two subfamilies based on the number of palpal segments, *viz.*, two-segmented Dasypogoninae and one-segmented Asilinae. Carrera (1949)followed Hardy's classification.

Hull (1962) studied the world genera and proposed a new classification. He divided the family into five subfamilies: Asilinae, Dasypogoninae, Megapodinae, Laphriinae and Leptogastrinae. Hull's classification is often opposed because it attaches too much importance to the number of segments of palpus. Martin (1968) elevated Leptogastrinae to family rank. Papavero (1973) gave a detailed history of classification and divided the family into eight subfamilies: Asilinae, Apocleinae, Dasypogoninae, Laphriinae, Laphystiinae, Ommatiinae, Stenopogoninae and Trigonomiminae. Unfortunately this scheme attaches too much significance to the tibial spur. Thus, there is no agreed opinion on the division of family into subfamilies, but many follow the classification of Oldroyd (1974) for the sake of convenience. Oldroyd followed the earlier classification of Williston (1908), Hermann (1920) and others. It is based on the characters of palpus, antenna and venation, and includes four subfamilies: Asilinae, Dasypogoninae, Laphriinae and Leptogastrinae; the subfamily Megapodinae of Hull (1962) is included in the Dasypogoninae.

In 1758 Linnaeus described 11 species under *Asilus* and later in 1767 he added 4 more species to it. Fabricius (1775-1805) described 76 species, and Wiedemann (1817-30) erected 235 species. The other notable workers include Macquart (1826-49), Walker (1837-71), Loew (1840-81). Rondani (1845-75), Bigot (1852-92), Schiner (1854-68), Osten Sacken (1858-92), Lynch (1879-83), Roeder (1881-90), Williston (1884-1908), Becker (1887-1926). Strobl (1893-1909) and Villeneuve (1904-33). Outstanding contributions were made by Hermann (1905-26) on the Oriental, Hardy (1917-51) on the Australian, Engel (1925-30) on the Palaearctic, Efflatoun (1927-37) on the Ethiopian and Hobby (1931-48) on the Nearctic Asilidae. Hull (1962) in his monumental work monographed the world genera giving along with the distributional records of all the then known species. Wiedemann (1817-30), Doleschall (1856-58), van der Wulp (1872), Ricardo (1900-27), de Meijere (1907-24), Hermann (1914-17), Frey (1911-37), Bromley (1935-38),

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Oldroyed (1938-75) and Joseph & Parui (1970) have contributed several papers on the Oriental fauna.

Estimation of Taxa

Asilids are common in arid and semi-arid regions of the world. In temperate countries they are common in wet or swampy localities and forests. Forest dwelling species are usually centered at places where shrubs are predominant. Considerable number of species have limited distribution. As for example, more than 50 examples. of *Clephydroneura brevipennis* Oldroyd could be collected in December 1975, in a couple of hours, from a locality of about 75 m^2, situated in the boundary between Kerala and Tamil Nadu, but in the adjoining areas with near by similar habitat they were found scarce. Other workers have also reported similar observations. Many predominant genera and species are found in widely separated localities within the same geographical region.

The Asilidae are distributed throughout the world. Of the over 400 genera only seven namely *Stichopogon* Loew, *Leptogaster Meigen*, *Andrenosoma* Rondani, *Pogonosoma* Rondani, *Ommatius* Wiedemann, *Promachus* Loew and *Neoitamus* Osten Sacken are widely distributed in all the zoogeographical regions. The zoogeography of the Oriental fauna is however, poorly studied. *Hoplopheromerus* Becker, *Oligoschema* Becker, *Damalina* Doleschall, *Trigonomima* Enderlein, *Orthogonis* Hermann, *Laloides* Oldroyd, *Anoplothyrea* de Meijere, *Dichaetothyrea* de Meijere are restricted to the Oriental region and *Clephydroneura* Becker, *Laxenecera* Macquart, *Cyrtopogon* Loew, *Merodontina* Enderlein, *Pseudomerodontina* Joseph & Parui and *Pseudonusa* Joseph & Parui are restricted to the Indian subcontinent, except for one species *Clephydroneura bengalensis* (Macquart) which is known from Java, Sumatra and Philippines.

Over 400 genera and about 5000 species of Asilidae are distributed through all parts of world. Of these, 83 genera of about 800 species are known from the Oriental region. To date 482 species under 55 genera are recorded from India. Of the Indian fauna, 232 species have been proposed by Joseph and Parui, and they are preparing a volume 'Fauna of India' on this family.

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Animal Resources of India : 407–411 : 1991

DIPTERA : Tephritidae

Introduction

Tephritidae, commonly known as the fruit flies, are represented in all zoogeographical regions. They are distributed throughout the temperate, subtropical and tropical parts of the world; however, predominance of species is found in the tropics and subtropics. Their common name is derived from the habit of many species breeding in fruits of different kinds. Almost all the fruit flies, of which biology is known, have phytophagous larval stages. The larvae complete their development while feeding in developing ovaries of fruits and seeds or while minig the stems and also forming galls in host plants. Pupation sometimes takes place within the plant, but usually the larvae leave the plant to pupate in soil. Many species of fruit flies are host specific.

Of the approximately more than 130 families of Diptera, Tephritidae cause by far the most extensive damage to plants. Many of the fruitflies (*Dacus* and *Ceratitis*) are serious pests of economic fruits and vegetables while some of the cecidogenous members (*Procecidochares, Urophora, Eutreta* and *Tephritis*) are beneficial in the bio–control of weeds.

There are no fossil records of Tephritidae, although species in the closely related family Otitidae have been recorded fom fossils of the Oilgocene age (Bush, 1966). It is believed that Tephritidae could not have arisen much before the Miocene (Novak, 1974).

Three different names *Tephritidae* Macquart, 1835; *Tryptidae* Loew, 1862 and *Trypaneidae* Bezzi 1913 have been used for the family by various authors; however, the first one is considered valid by recent workers. Tephritidae comes under the superfamily Tephritoidea along with the families Pyrgotidae, Otitidae, Platystomatidae, Richardiidae and Tachiniscidae. This family is closely related to Platystomatidae and Otitidae (Kapoor *et al.*, 1980).

Membes of the family Tephritidae are medium sized flies having the following characters : well developed inferior fronto–orbital bristles in most of the species; post vertical (post ocular) bristles parallel or divergent and never cruciate; wings typically marked in patterns, with the subcostal vein bent sharply upward at nearly a right angle before apex and weakened or evanescent beyond the bend; costa with a break at apex of subcosta and the cubital cell (anal cell) typically lobate at apex.

Classification

Taxonomists generally agree that the supra specific classification of the family is not in a satisfactory state (Freidberg, 1984). The classifications at the subfamily and tribal levels are based largely on the works of Bezzi (1913) and Hendel (1927), modified and expanded by Hering (1947). Hering (1947) divided the family into eight subfamilies, namely Dacinae, Schistopterinae, Terellinae, Aciurinae, Trypetinae, Myiopitinae, Oedaspinae and Tephritinae. However, the most pertinent classification applicable to the fruitfly fauna of the Oriental Region is proposed by Hardy (1977).

The Tephritidae known from Indian fall under four subfamilies and thirteen tribes as classified below :

Class Insecta
- Order Diptera
  - Family Tephritidae
    - Subfamily Dacinae
      - Tribe Dacini

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Subfamily Schistopterinae

Subfamily Trypetinae

Tribe Acanthonevrini

Tribe Aciurini

Tribe Adramini

Tribe Ceratitini

Tribe Euphrantini

Tribe Trypetini

Subfamily Tephritinae

Tribe Ditrichini

Tribe Platensinini

Tribe Tephrellini

Tribe · Tephritini

Tribe Xyphosini

Tribe Terellini

Tephritidae is a fairly large family of Diptera, with a world figure of about 4000 species. About 839 species are known from the Oriental Region, of which 327 are known from the Indian subcontinent and 187 from India proper. It is generally accepted that about 8–12 recent of th world species of most of the Acalyptrate Diptera are represented in India. Judging from this, approximately more than 400 species of Tephritidae can be expected in India whereas only 187 species are recorded so far. This indicates that ou: knowledge on the status of the family in India is far from complete.

Historical Resumé

i) Pre-1900

Fabricius (1794, 1805) was the first to describe fruit flies from the Indian subcontinent. This was followed by the work of Robineau-Desvoidy (1830), Wiedemann (1830, 1834), Saunders (1841), Macquart (1843), Walker (1849), and Westwood (1849), in the first half of the nineteenth century. The second half of the nineteenth century resulted in the taxonomic works of Macquart (1851), Walker (1852, 1860), Schiner (1868), Bigot (1889, 1896) and van der Wulp (1899).

ii) 1901-1947

Workers who had contributed much in this period to the fruit fly faunal studies of India were Coquillette (1904), Bezzi (1913, 1914, 1916), Enderlein (1911, 1920), Hendel (1914, 1915, 1927), Brunetti (1917), Senior–White (1922, 1924), Munro (1935, 1938), Perkins (1937, 1938, 1939) and Hering (1939, 1940, 1941, 1942, 1944).

iii) 1948-1990

In recent years, the contribution of Hardy (1954–1987) has greatly advanced our knowledge of the fruit flies from the Orient. Besides, Zaka–ur–Rab (1960, 1961, 1977), Kapoor (1970, 1971, 1972), Kapoor *et al.*, (1969, 1977, 1978, 1979, 1980), Agarwal *et al.*, (1983, 1989), Radhakrishnan (1984) and Premlata (*1987*) have also worked on the family.

The biology of fruit flies has been reviewed by Christenson and Foot (1960) and Fletcher (1987). Cedidogenous Tephritidae have been reviewed by Freidberg (1984) and the ecology of fruit flies by Bateman (1972). A number of studies have been conducted in the recent past on the evaluation and management of fruit flies of economic importance (Cavalloro, *ed.*, 1982). Publications of Foote (1965, 1967, 1980) on the Tephritidae of Aiericas, Drew (1975, 1978) of the South Pacific, Hardy (1977) of the Oriental Region and Cogan and Munro (1980) of the Afrotropical Region, deal with the family in different zoogeographical areas.

Studies from Different Environs

The information available in Indian Tephritidae are the results of random surveys and studies conducted by various workers based on the material collected from the states of Kerala, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, Himachal Pradesh, Haryana, Jammu and Kashmir, Bihar, Sikkim, West Bengal, Orissa, Assam, Arunachal Pradesh, Nagaland, Meghalaya and Andaman and Nicobar. In general, the surveys have often been conducted in fairly easily accessible and selected pockets, and hence there is scope for further exploration and study of the family from other environs in India.

Estimation of Taxa

About 4000 species of Tephritidae are known from the world, about 839 from the Oriental Region, 327 from the Indian subcontinent and 187 from India alone. The species known so far from India fall under 70 genera and 4 subfamilies.

In the fruit fly fauna of India, the Oriental element dominate by 94.67 %; the Palaearctic element is poorly represented by 2.13 %; the Ethiopian the least by 0.53 % and the cosmopolitan species by 2.67 %.

The species-wise status of the family known from Indian and adjacent countries is given below :

Country	*Total No. of species known*	*No. of Endemic species*
India	187	77
Pakistan	26	4
Bangladesh	11	?
Sri Lanka	61	18
Burma	125	68
Nepal	23	6

At least 106 species are considered to overlap in their distribution in these countries is estimated to be 54.4 % in the Burmese species, 41.17 % in the Indian species, 29.5 % in the Sri Lankan speices, 26 % in the Nepalese species, 15.4% in the species of Pakistan and none in the species of Bangladesh. No published information is available on the family from Bhutan.

Classified Treatment

Subfamily Dacinae

The Dacinae known from India is treated under the tribe Dacini and represent 45 species belonging to the two genera of *Callantra* Wall and *Dacus* Fabricius. The genus *Dacus* is known by 10 subgenera in India. Members of this subfamily are the most important fruit infesters.

Subfamily Trypetinae

The Trypetinae is represented in Indian by 92 species under an assemblage of 44 genera belonging to the six tribes, Acanthonevrini, Aciurini, Adramini, Ceratitini, Euphrantini and Trypetini. The subfamily Trypetinae represent the largest number of species known from India. Their dominance could be attributed to the fact that members of this subfamily enjoy wide range of biological habits. They are fruit infesters, flower bud breeders, leaf miners or gall formers.

Subfamily Schistopterinae

The Schistopterinae is the least known subfamily and is represented in India by only three species under the genus *Rhabdochaeta* de Meijere. Members of this subfamily probably breed in the flower heads of the plant family Asteraceae (Compositae).

Subfamily Tephritinae

The Tephritinae is represented in India by 47 species under 23 genera belonging to the six tribes of Ditrichini, Platensinini, Tephrellini, Xyphosini, Terellini and Tephritini. Members of this subfamily mostly breed in the flower heads and other part of the plant family Asteraceae (Compositae) and many are gall formers.

Current Studies

In the Zoological Survey of India, systematics and distribution of Tephritidae of North–Eastern states of India and collections from Kerala and Tamil Nadu states are currently under study. Outside Z.S.I. research on Indian Tephritidae is carried out in the Punjab Agricultural University, Ludhiana; Panjab University, Chandigarh; and the Aligarh Muslim University, Aligarh.

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Animal Resources of India : 413–414 : 1991

DIPTERA : Agromyzidae

Introduction

The members of the family Agromyzidae are popularly known as 'leaf–miners' and constitute an interesting and agriculturally important group of minute to small flies. These flies cause extensive damage to agricultural and ornametal plants during their larval stages. They tunnel through the tissues of leaf, root, stem, flower bud, fruit and developing seed, and leave behind characteristic patterns, the 'mines' These mines may be either linear, serpentine or the blotch type. On the completion of their larval life (feeding stage), they enter the pupal stage. The pupation takes place either within the leaf–mine, or the final instar larva leaves the mine to pupate in the soil. On emergence, the adult flies mate and the female lay eggs on selected part of the plant. On hatching, the larvae start feeding on the plant tissue and thus cause damage to the plants.

In India about 40% of the *Cajanus indicus* (Hindi Arhar) yield is lost annually due to attack of *Melanagromyza obtusa*. The common pulses like *Phaseolus radiatus* (Hindi : Moong) and *P. mungo* (Hindi : Urad) are attacked by *Ophiomyia phaseoli*. *Chromatomyia horticola* is known to attack most of the ornamental plants and mustard *Brassica campestris* (Hinid : Sarson).

Historical Resumé

The pioneering works on Agromyzidae were by Fallen (1810, 1823) and Lioy (1864). Hendel (1920–1936) has studied in detail the European Agromyzidae and described numerous species and erected a number of genera. Malloch (1913–1927) studied the North American, Australian and Oriental Agromyzidae. In recent years i.e., from 1950 onwards our knowledge of Agromyzidae has been enriched by the works of Frick (1951–1959), Griffiths (1957–1967), Hering (1927–1958), Kato (1953–1961), Sasakawa (1954–1967) and Spencer (1957–1986).

The systematics of the Agromyzidae has made marked progress in the foreign countries, but in India, till 1960, only a few species were known. Spencer (1961) during the course of his study on Oriental Agromyzidae described about a dozen new species from India. In recent years Tandon (1963, 1965, 1966, 1970 a, b and 1972), Singh and Ipe (1967–1973), Singh and Garg (1970), Ipe (1971–1987), and Garg (1971) have made detailed and comprehensive studies on agromyzid fauna of India. Besides the taxonomic studies, the notable ecological and biological works on Agromyzidae from India are of Ahmed (1938), Ahmed and Gupta (1941), Sehgal and Trehan (1963), Sehgal (1966–1986), Tandon (1963, 1973), Beri (1971) and Singh and Ipe (1973).

The agromyzids are known to infest vegetation in almost all the major ecosystems from sea-level to alpine zones. Extensive surveys of the country were undertaken by Spencer, Tandon, Sehgal, Singh and Ipe.

Current. Studies

The family Agromyzidae is known in India by over 137 species belonging to 17 genera and two subfamilies (Singh and Ipe, 1973). Active work on taxonomy, ecology and biology of Agromyzidae is being conducted at School of Entomology, St. John's College, Agra. Santokh Singh has recently completed a five years PL480 project on the 'Bioecology of hymenopteran parasites of Agromyzidae (Diptera) pest species in India'

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Animal Resources of India : 415–417 : 1991

DIPTERA : Chloropidae

Introduction

Chloropids are small flies belonging to Section Acalypteratae of the order Diptera. They are smooth, bristless flies, usually predominantly black or basically yellow with black to brown stripes and maculae. They are recognised by the presence of large. plate-like frontal triangle, parallel or convergent postvertical bristles, sharply margined ridge on propleuron, often peculiar flexure of vein M3 + 4 at the middle of the discal cell and absence of anal cell.

Flies of the family may be observed almost anywhere in grasslands, marshes, moors, and low vegetation in forests, and are frequently collected in great numbers in fields of graminous plants. The larvae are mainly phytophagous or saprophagous, sometimes carnivorous, and rarely exoparasitic. The saprophagous forms feed especially on the grass from damages by other insects. Some of the phytophagous species are known pests of cereals, like rice and barley, and grasses in many regions, and some of the carnivorous species are important as predators of root aphids or eggmasses of poisonous spiders. The adult flies have functional mouthparts and feed on honey dew. Members of this family are frequently captured on flowers. Some, such as the 'eye fly' of the Orient *(Siphunculina funicola)* and the 'eyegnats' or *Hippelates* flies of the New world, annoy man and other animals by feeding at wounds or external body openings and are of medical importance as vectors of certain eye diseases.

Historical Resumé

The genera and species of Chloropidae were usually included under the genus *Musca* in family Muscidae (sens, lat) including the first chloropid species *Musca frit* Linnaeus, 1758, in earlier works. In 1803 *Chlorops* Meigen was erected as the first separate Chloropid genus. Fallén (1810) included the genera and species in family Micromyzides, but in 1820 he separated several as a new family Oscinides. This family grouping was generally not accepted, as we find Newman (1834) and Macquart (1835) placing various genera under different acalypterate families. But most of the earlier workers used the family name Oscinidae, following Fallén (1820), whereas later workers used the name Chloropidae, on the ground that *Oscinis* was a synonym of *Chlorops.*

Historical review and revision of the taxonomic work on Chloropidae were made with detailed explanations by Anderson (1963, 1977). The classification of the family in the early part of the present century was principally established by Becker (1910, 1911); Enderlein (1911), and Duda (1930, 1933) for the world; Duda (1934) and deMeijere (1916) for the Oriental Region; and Malloch for the Australian Region. Consequently, a little fewer than 300 genera were proposed. After the significant contributions by Sabrosky (1941, 1964 and 1980), with revisional work on many confused generic classification, the number of genera was reduced to nearly 200. As a result of the works of Nartshuk and Fedoseeva, especially their stress on post-abdominal structures, the objective recognition of the species in the Palaearctic Region has progressed rapidly. Phylogenetic considerations on the family, subfamilies, tribes and generic groups were recently presented by Andersson (1977) and Nartshuk (1977, 1987). Andersson (1977) reviewed 98 old world genera and subgenera from a phylogenetic angle, examined pleisomorphic and apomorphic characters, discussed phylogenetic relationships and proposed new subdivisions of tribes and genera. Nartshuk (1977, 1987) on the basis of 54 genera and 300 species of the family, in the Palaearctic Region elucidated the direction and tendency of evolutionary development of the genital organs.

Chloropidae has been traditionally and conveniently been divided into two subfamilies,

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Chloropinae and Oscinellinae, of which the first has long been accepted under its present name and scope. The second has passed under several names Oscinellinae and Palaeoscinellinae (Duda, 1930), and Oscinellinae, Siphonellopsinae and Heringinnae (Enderlein, 1934). Nartshuk (1987) proposed the superfamily name Chloropidea, separated members of Siphomellopsinae with 8 genera and treated them under family Siphonellopsidae (Duda, 1932) and treated the rest of the genera under four subfamilies Rhodesiellinae, Oscinellinae, Hippelatinae and Chloropinae, under family Chloropidae. She recognized 21 tribes and 141 genera under these groups, besides 2 genera *Aragara* and *Merochlorops*. Of these, all the four subfamilies, 19 tribes and 70 genera are recorded from the Oriental Region, in addition of some genera of Nartshuk's family Siphonellopsidae.

Till 1970, only 23 species under 15 genera were known to occur in India. But within the last two decades all the Indian States except for Himachal Pradesh, Haryana, Bihar and Assam and Union Territory of Lakshadweep and Minicoy islands, have been surveyed, species were collected and studies have been carried out.

Studies from Different Environs

Faunistic surveys, were made in 21 Indian States and all Union territories, except Lakshadweep and Minicoy Islands. Most of the different ecosystems, starting with the Alpine zones of the Himalaya and ending with the shores of Kanyakumari, have been covered during the various surveys by parties and collection of the group has been made from various ecological niches.

Estimation of Taxa

Of the more than 2100 species of Chloropidae, spread under 4 subfamilies, 21 tribes and 141 genera from the whole world, all the subfamilies, 19 tribes and 70 genera are known from the Oriental Region. Of these, all the four subfamilies, 10 tribes, 15 genera and 23 species were known to be represented in India, till 1970. Since then 9 more tribes, 70 genera and more than 270 species have been collected from India. This includes 5 genera and 82 species new to science. Studies on 45 genera and approximately 150 species are in progress. The studies when completed are expected to more than double the number of species known from the Oriental Region so far.

But for some stray references, practically not much work on the taxonomy of Chloropidae of the Oriental Region was done during the period from 1940 to 1970, and almost nothing on species of the Indian subcontinent. In recent years Kanmya (1983) has been working on some Oriental species available in its eastern belt. Cherian (1976, 1977, 1984, 1989, 1990) has been studying the family from India and adjacent countries.

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LEPIDOPTERA

Introduction

The Order Lepidoptera (*lepidos* = scale, *ptera* = wings) includes scale-winged insects and exhibits unity in diversity and diversity in multitude. The origin of this Order from ancestral prototype is known from Upper Permian. Therefore, the studies on phylogeny and evolution of the group are largely based on evidences from other disciplinary tools like biology, ecology, zoogeography, etc., of the extant forms.

The butterflies and moths constituting Lepidoptera, are very familiar to mankind on account of their beautiful colouration, size, and plant relationship. They are cosmopolitan in distribution, occurring in every conceivable environs : from coastal areas and plains to deserts, forests, and valleys of hills and mountains. The order is supposed to have originated from the Panorpoid Complex and is closely allied to another Order Trichoptera (caddiesflies and water moths). They belong to the holometabolous endopterygote series of insects, with complete metamorphosis passing through egg, larva, pupa and adult. Each of these stages exhibits characteristic features in habit, habitat and structure which afford to differentiate the later evolved butterflies from the earlier evolved moths.

The term 'butterfly' is derived from the butter-yellow colour of the male of the Common Brimstone (*Gonepteryx rhamni* Linnaeus) of the family Pieridae. Linnaeus (1758, 1767) described all species of butterflies under genus *Papilio* and moths under *Phalaena* and *Noctua*.

Classification

The classification of Lepidoptera at subordinate level has undergone a series of periodical changes. Hampson (1892) attempted division into Rhopalocera and Heterocera on the basis of antennal structure. On the basis of size two suborders, *viz.* Macrolepidoptera and Microlepidoptera were recognised. Meyrick (1898) categorised Lepidoptera into Homoneura and Heteroneura on the basis of wing venation, whereas Comstock (1892, 1893) based his classification on wing-coupling apparatus and divided the order into Jugatae and Frenatae. Packard (1895) separated it on the basis of mouthparts into Lepidoptera Laciniata and Lepidoptera Haustellata, the latter was further divided into two namely, Palaeolepidoptera and Neolepidoptera. Pupal characters also aided to categorise the order into Pupae Incompletae and Pupae Obtectae. Besides, the classification of the Order was based on the sets of earlier stages including egg and larva, too. In the recent past, several workers, *viz.* Busck (1932), Borner (1939), Hinton (1946) and Bougogne (1951) have proposed a classification primarily based on the female genitalia, into Zeugloptera, Montrysia and Ditrysia. But this system was not agreed upon by Meyrick, Tillyard and others, because separation of most of the families became difficult at the subordinal level, particularly of Ditrysia. The present classification of Lepidoptera up to superfamily level may be summarised as follows:

Order	*Suborder*	*Superfamily*
Lepidoptera	Rhopalocera	Papilionoidea
	(Butterflies)	Hesperioidea
	Heterocera	Eriocranioidea
	(Moths)	Hepialoidea
		Stigmelloidea
		Incurvarioidea
		Tinaeoidea

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Order	*Suborder*	*Superfamily*
		Gelechioidea
		Cossoidea
		Psychoidea
		Castnioidea
		Tortricoidea
		Pyralidoidea
		Bombycoidea
		Calliduloidea
		Geometroidea
		Sphingoidea
		Noctuoidea

Economic Importance

The Lepidoptera are of great economic importance being both injurious and beneficial. Injurious effects are made by larvae which devour foliage and bore into stems and roots, thereby running crops and causing financial loss of crores of rupees. Some of them also attack manufactured goods like carpets, clothings, stored products like grains and flour. Some depredate on the lac insect *Kerria lacca*, while some other are known to be attacking beehive combs containing honey. The beneficial lepidopterans belong mainly to families Bombycidae and Saturniidae. The pure silk is produced by *Bombyx mori* Linn. of the family Bombycidae. In Saturniidae, *Antheraea paphia* (Linn.), *A. assamensis* Helfer and *Samia cynthia* (Drury) produce wild silks, namely, Tasar, Muga and Eri, respectively. The sericulture industry flourishes entirely on these silk moths and provides job to lakhs of people in urban and rural areas. Besides, larvae of some species are potentially considered of great use in biological control as they devour aphids, coccids and fulgorids, which cause great damage to crops and other plantations. The role of these insects in the pollination needs no explanation.

Historical Resumé

i) Pre-1900

The earliest faunistic record of Lepidoptera from India is by Linnaeus (1767) based upon his studies of Koenig's collection made from Coromandel and Madras. It was followed by Cramer (1775-83), Fabricius (1775-98), Hübner (1786-1825), Guérin-Méneville (1829-44), Huegel *in* Kollar (1844,1848), and Butler (1869-74). The lists and catalogue were published by Horsfield (1829), Walker (1854-69), Horsfield and Moore (1857-58), Moore (1857-59), Kirby (1871-1903), Cotes and Swinhoe (1887-89) Elwes (1888) and Swinhoe (1898). Knowledge enhanced with the revisionary and monographic works of Boisduval (1829), Meyrick (1875) and Moore (1883) on butterflies in *Lepidoptera Indica*. Three volumes on butterflies published by Marshall and de Nicéville (1883-90) and four volumes on moths under 'Fauna of British India' series published by Hampson (1892-96) deserve special mention. Foresayeth (1884), Buckler (1886,1893) and Davidson and Aitken (1890) studied the life history of 60 species of Lepidoptera occurring in northern India.

During 1762-1900, a number of explorers namely Koenig, Cuvier, Delessert, Blanch, Lang, Spraight, Wimberley, Stoliczka, Atkinson, Yerbury, Doherty, Hocking etc., collected large number of specimens from different belts of the vast Indian region. Area-wise works were mainly from Kashmir, Himachal Pradesh and adjoining areas of the North West Himalaya and also Yarkand, Afghanistan, Baluchistan and Pamir by Lang (1864), Moore (1865, '74, '78, '82), Butler (1800, '81, '86, '88) and Alcock (1898). From the Kumaon hills of Uttar Pradesh of the Western Himalayas, works were mainly made by Doherty (1886), Mackinnon and de Nicéville (1897, '98). Fauna of Sikkim, Assam, Manipur, Naga Hills, Chin-Lushai and also Upper Burma of the Eastern Himalaya were studied by Butler (1879, '85), de Nicéville (1881-'83, '85, '90) Wood-Mason and de Nicéville (1887), Doherty (1889) Snellen (1891), Elwes (1891-'92) and Meyrick (1894). The fauna of the peninsular areas were studied, from Madhya Pradesh by Butler (1870), Swinhoe (1886) and Betham (1891); from Gujarat and Maharashtra by Swinhoe (1885),' Aitken (1887) and Nurse (1899); from Karnataka, Kerala and Tamil Nadu including the Nilgiri Hills by Hampson (1889), Fergusson (1891) and Davidson, Bell and Aitken (1896, '97); from Bengal including Calcuttaq and also Orissa by Moore (1865, '86), de Nicéville (1885), Taylor and de Nicéville (1888); Robbe (1892) and Walsingham (1890). Out of the insular ecosystem, the fauna of Andaman and Nicobar Islands are known through the works of Hewitson (1874), Moore (1877) and Wood-Mason and de Nicéville (1881, '82). It may be noted that some important illustrated volumes, dealing with the moths in particular, are by Moore (1867, '81), Elwes (1890), Snellen (1890) and Warren (1893) from Sikkim and Bengal and by Swinhoe (1886, 1891-'94) from Himachal Pradesh and the Khasi Hills of Meghalaya.

Contributions on ecological studies were made by de Nicéville (1900) dealing with the food plants of butterflies of Kanara, and Meyrick (1879, '81) on the micro-lepidopterans destructive to potato. Besides, Poulton's (1890-1936) long series of papers highlighted interesting aspects of colurs, their significance and use, cause of mimicry, migration, ethology, gregarious resting habits, etc., of butterflies. Literature on Zoogeography of Lepidoptera were furnished by Wallace (1865) covering the phenomena of variation and geographical distribution of butterflies.

ii) 1901-1947

During this period, contributions on systematics were made by Moore (1901-1907) in *Lepidoptera Indica* series, Hampson (1901-13) in *Catalogue Phalaenae* series, Mabille (1903-09), Aurivillius (1904), Bingham, (1905-07) in two volumes on butterflies in '*Fauna of British India*' and also Verity (1905-11). Seitz (1906-37) exhaustively dealt with butterflies and moths in *Macrolepidoptera of the World* series (Palaearctic and Indo-Australian Regions). Meyrick's (1905-14) account of 7,327 species of Microcopidoptera includes a good number of species from India. The other important works on Lepidoptera from the region are by Swinhoe (1909-13), Bell (1909-14), Fletcher (1910-31) in *Catalogue of Indian Insects* series, Forbes (1911), Eltringham (1923), Antram (1924), Evans (1932) in 'Identification of Indian Butterflies', Piele (1937), Diaknoff (1938), Bell & Scott (1937), and Talbot (1939, 1947) in '*Fauna of India*' series (previously known as 'Fauna of British India'). Handbooks on Lepidoptera by Meyrick (1928), Ayyar (1940) and Cooper (1942) also deserve mention. Lepidoptera of economic importance were dealt with by Watt (1908) in *Commercial products of India*, Lefroy (1906, 1911) in '*Insect Pests of Crops and Stored Grains*' and '*Indian Insect Life*', respectively, followed by Fletcher (1914) in '*Some South Indian Insects*' The other notable publications on morphology, classification and phylogeny are by Chapman (1903), Petersen (1904), Bordas (1910), Busck (1914, 32), Braun (1919, 1924), Muir (1929), Mehta (1933), Borner (1939), Pradhan & Aren (1941), Hinton (1946) and Turner (1946). Studies in biology were made by Lefroy and Howlett (1909), Beeson (1910), Chapman (1911-20), Ghosh (1914, 1923-40), Fletcher (1914, 21, 33) and Sevastopulo (1933, 35, 38, 40-42, 44-46, 48). A number of publications on ecology of the group were made by Marshall (1901, 1908-09), Lefroy (1906), Meyrick (1914, 20, 27) and Fletcher (1925).

In the field of distributional studies, Meyrick was first to investigate the lepidopteran collections made by Gardiner in 1902 from the Indian Laccadives and Maldives. His other chronological studies include Microlepidoptera collected during Percy Sladen Trust Expedition to the Indian Ocean (1905, 1911), Zoological Mission to Great Atlas of Morocco in 1927 (1928) and also Oriental Lepidoptera collected by H. R. H. Prince Leopold of Belgium in 1932 (1933). Evans (1927, 1932) provided keys to the butterflies from India and other neighbouring countries. Other workers, viz., Rhé-philipe (1902-05, 08), Fawcett (1904), Hannyngton (1910, 11, 16), Evans (1910, 12), Annandale and Dover (1921) and Sevastopulo (1935) worked on materials from various parts of India. Pagenstecher (1909) studied pattern of lepidopterous dispersion, whereas Meyrick (1925) correlated the Wagner's hypothesis and distribution of Microlepidoptera. Besides, Corbet (1943) dealt upon the biogeography of the Indo-Australian archipelagic fauna.

iii) 1948-1990

Contributions in lepidopteran taxonomy during this period were made by Evans (1949), Talbot (1940), Wynter-Blyth (1957), Jolly *et al.*, (1975), Watson and Whalley (1975), Satyamurti (1966), Varshney (1981), D'Aberra (1982), Ackery and Vane-Wright (1984), etc. Some publications on nomenclature, systematics, morphology and economically important Lepidoptera are by Kapur (1950, 64), Bhasin and Roonwal (1954), Srivastava (1956, 57, 61, 62), Vasudeva (1956), Bhasin *et al.*, (1958), Mathur and Singh (1959-61), Common (1960, 69-70), Munroe (1961), Banerji (1964), Cantlie (1965), Pajni and Rose (1973, 77), Arora and Gupta (1979), Bhattacharya (1981), Mandal (1985) etc. The classification, phylogeny and origin of Lepidoptera are known through the works of Clench (1955), Hennig (1965, 66, 91), Elliot (1973), Razowski (1976), Hancock (1981), Tindale (1981), Mishler and Donahue (1982), William (1983) and Minet (1986). Notable publications on chromosomal studies on Indian Lepidoptera are by Gupta (1964), Rishi (1975), Murty and Rao (1977) and Mohanty and Nayak (1982). Besides, observations on palatability spectrum of butterflies; haemolymph proteins in taxonomic studies and their influence on growth, moulting and reproduction; physiological, biochemical and histochemical studies on butterflies and moths are due to Varshney and Sundaram (1967-68, 71), Sundram and Varshney (1969), Duffey (1970), Varshney *et al.* (1970-71), Gupta (1975, 77), Nandi *et al.*, (1976), Shukla (1976), Agrawal *et al.* (1978), Saxena (1981), etc.

Studies on the biology of Lepidoptera were made by Patel and Kulkarny (1956), Mathur (1959), Mathur and Singh (1963), Bhattacharjee and Menon (1963) and Joshi (1975, 76).

Ecological studies on Lepidoptera are mainly by Hinton (1951), Gupta and Thorsteinson (1960), Simmonds and Rao (1960), Singh (1960) , Batra and Bhattacharjee (1961), Venkatraman and Chacko (1961), Tuli and Mukherjee (1963), Patel *et al.* (1964), Ganguly and Varshney (1970), Mohansundaram and Sivakumar (1970), Sukul and Jana (1972), Mathavan and Muthukrishnan (1976, 86), Maity and Mandal (1977) and others.

Studies, reviews and notes on distributional and zoogeographical aspects of Lepidoptera from different belts of India and elsewhere were made by Ferrar (1948, 51), Betts (1950), Bernardi and de lesse (1952), Batra (1956), Mathur and Champakvalli (1961), Kushwaha *et al.* (1964), Donahue (1967), Varshney and Chanda (1971), Mandal and Bhattacharya (1980), Gupta (1980), Arora and Mandal (1981), Varshney *et al.* (1981), Mandal and Nandi (1983), Mandal (1984), Mathew and Menon (1984), Bhattacharya (1985 a,b,c), Rose and Pajni (1985), Ghosh and Chaudhury (1986), Gupta and Thakur (1986), Khatri (1986 a,b), Gupta and Shukla (1987, 88), Haribal *et al.* (1988), Nandi and Varshney (1988), Radhakrishnan *et al.* (1990), etc.

Meanwhile, several works on distributional studies are under preparation, namely, from West Bengal, Arunachal Pradesh, Assam, Tiger Reserve Areas at Palamau and Sunderban, Maharashtra, Karnataka, Neora Valley, Lakshadweep, Orissa and Gujarat by the scientists of Zoological Survey of India.

Studies from Different Environs

A number of faunistic surveys have been conducted in different ecotonal areas of the Indian region. These areas covered from Kashmir to Kanyakumari in the north-south direction and from Arunachal Pradesh to Goa in the east-west direction, together with the insular areas of the Andamans, Nicobars and Lakshadweep archipelago in the Indian Ocean. Thus, the belts represent the major ecosystems covering mountains, forests, deserts, plains, mangroves and islands, in thirty one states and union territories of India. Zoological Survey of India and its various regional stations, have conducted faunistic explorations by their own parties or sometimes in collaboration with foreign agencies, e.g. Indo-Swiss and Mt. Everest expeditions, Tibet Frontier Commission etc.

Many surveys in recent times were undertaken by different scientific departments, including

Z.S.I., in Uttar Pradesh, Madhya Pradesh, Punjab, Rajasthan, Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Eastern Ghats, Orissa, Bihar, West Bengal, Sikkim, Arunachal Pradesh and also the Andaman, Nicobar, Great Nicobar and Lakshadweep groups of islands. Studies on fauna of Orissa, West Bengal and Sikkim have been completed. The Neora Valley of the Kalimpong subdivision, Darjeeling district (W. Bengal) has been worked out in detail. The Indian Tons Valley Expedition at Western Garhwal Himalaya (Uttar Pradesh); the plains of several south-eastern districts of Uttar Pradesh; Bastar (Madhya Pradesh), parts of Karnataka and Andaman Nicobar Islands have also been surveyed by Z.S.I. At the end of the last century, Gardiner pioneered the work on the insular ecosystem but only at southern Minicoy of Lakshadweep archipelago, and since then insects from these islands could be brought to the Survey in recent times.

Estimation of Taxa

Hampson (1918) estimated as many as 89 families and subfamilies, while Hamlyn (1969) reported about 1,40,000 species comprising 13,000 butterflies and 1,27,000 moths from the world. Out of about 20 superfamilies, a great majority are known from India. According to the recent trend, certain changes in the number of families, particularly of the butterflies, have taken place. For example, the butterflies from the Indian region were earlier distributed over 10 families, but now reduced to five, since the families Danaidae, Satyridae, Amathusiidae and Acraeidae are treated as subfamiles of Nymphalidae, and due to synonymising of Erycinidae with Lycaenidae. Presently, about 1000 species of butterflies, in 250 genera under five families and 12000 species of moths in 3000 genera under 75 families, [excluding Amatidae, Cossidae, Arctiidae and Noctuidae] are known from the Indian region.

The north-eastern part of India along the border of Burma may be considered as the most rich area of the Indian lepidopterous fauna, but other areas are also no way less significant. The members appear in their largest number where there is an abundance of larval food plants, like plenty of young green leaves and shoots amidst suitable weather conditions. The post-monsoon period ranks second and the south-west monsoon period third. In the arid parts of north and north-west India, the spring is delayed and the monsoon and post-monsoon periods are the favourable months. In the high hills, the summer is very short and the insects are on the wing for a brief period. In South India, due to the absence of clearly defined seasons, the individuals occur during the time of local rainfall. Endemism, like distribution, is mostly an artifact of collection. Actually, due to paucity of knowledge it is rather extremely difficult to assess the real endemic position of the Lepidoptera in India.

Classified Treatment

Suborder Rhopalocera (The Butterflies)

Superfamily Papilionoidea

Four families are recognised from India, viz., Nymphalidae (450 spp), Lycaenidae (380 spp), Pieridae (105 spp) and Papilionidae (94 spp).

Superfamily Hesperioidea

Only one family, Hesperiidae, with 310 species is known from India.

Suborder Heterocera (The Moths)

Superfamily Eriocranioidea

Out of three families, the Neopseustidae with three species is known from India.

Superfamily Hepialoidea

Out of four families, the Hepialidae with 14 species is known from India.

Superfamily Stigmelloidea

A family comprising the smallest lepidopterans of wide distribution is the Nepticulidae (= Stigmellidae) with 16 Indian species.

Superfamily Incurvarioidea

This is represented by three families from India, viz., Adelidae (14 spp), Heliozelidae (10 spp) and Incurvariidae which is, however, scarce in India.

Superfamily Tinaeoidea

The classification of this very large and complex superfamily presents difficulties particularly amongst the Tinaeina division that comprises over 20 families. The leading authorities are at variance as to the actual number of families. The families known from India are Tinaeidae (151 spp), Gracillariidae (144 spp), Cosmopterygidae (114 spp), Lyonetidae (106 spp), Oecophoridae (94 spp.), Glyphipterygidae (61 spp), Sesiidae (55 spp), Heliodinidae (53 spp), Plutellidae (25 spp) and Yponomeutidae (22 spp). The other minor Indian families are Scythridae (19 spp), Xyloryctidae (16 spp), Elachistidae (15 spp), Coleophoridae (14 spp), Epermeniidae (9 spp), Tinaegeridae (4 spp), Orneodidae (2 spp), Copromorphidae, Douglasiidae (1 sp each), etc.

Superfamily Gelechioidea

This superfamily is represented by the cosmopolitan family Gelechiidae comprising over 300 species from India. A minor Indian family is the Blastobasidae comprising 17 species.

Superfamily Psychoidea

Out of nine families, Zygaenidae (155 spp), Limacodidae (94 spp), Psychidae (39 spp), Arbelidae (4 spp) and Ratardidae (3 spp) are known from India.

Superfamily Castnioidea

This is a very poorly known superfamily, represented by the Neocastridae (1 sp) from India.

Superfamily Tortricoidea

This superfamily is more characteristic of the temperate than the tropical region. It comprises adults with crepuscular habit. The Indian families are Eucosmidae (92 spp), Tortricidae (72 spp). Carposinidae (15 spp), Phaloniide (8 spp) and Chalidanotidae (1 sp)

Superfamily Pyralidoidea

The tropical families which are represented in India are Pyralidae (1160 spp), Thyrididae (67 spp) and Pterophoridae (13 spp).

Superfamily Bombycoidea

Out of 8 families, Lasiocampidae (49 spp), Eupterotidae (46 spp), Saturniidae (40 spp), Bombycidae (15 spp) and Brahmeidae (2 spp) are known from India. The Saturniidae has the largest moth of tropical origin, *Attacus atlas*, which has a wing expanse measuring *c* 25 cms.

Superfamily Calliduloidea

The Callidulidae (6 spp) and Pterothysaniidae (4 spp) are known from India.

Superfamily Geometroidea

This superfamily consists of eight families, of which Geometridae (1120 spp), Drepanidae (80 spp), Epiplemidae (35 spp), Cymatophoridae (27 spp), Uraniidae (15 spp), and Epicopeidae (12 spp), are known from India.

Superfamily Sphingoidea

Family Sphingidae comprises 120 Indian species.

Superfamily Noctuoidea

This superfamily has about a dozen families, majority of which are nocturnal in habit. The Indian families are Lymantriidae (171 spp), Notodontidae (139 spp), Agaristidae (35 spp), Hypsiidae (28 spp) and Thaumetopoeidae (1 sp). The Agaristidae and Hypsiidae are, however, largely tropico-diurnal in habit.

Current Studies

In the Zoological Survey of India studies on the systematics of Lepidoptera from West Bengal and Meghalaya are currently being conducted. These deal with the taxonomy, faunistics, status and abundance of about twenty families of moths and butterflies; amongst the former the microlepidoptera are also included.

Outside Z.S.I., certain other centres in India are actively engaged in different field of researches, including applied aspects. These include the Central Research Institute for Jute and Allied Fibres, Barrackpore; I.A.R.I., New Delhi; Regional Tasar Research Station, Manipur; and Department of Zoology, Punjabi University, Patiala and Panjab University, Chandigarh.

Among the foreign organisations engaged in this group are : The Papilio International, Denmark; Department of Entomology, University of Queensland, Australia; National Museum, Zimbabwe; Department of Entomology, British Museum (N.H.) London; Smithsonian Institution, Washington; Department of Entomology, Mississippi State University (U.S.A.); and Entomological Institute, Hokkaido University, Japan.

Expertise

INDIA

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Elsewhere

P. Singh & Shri A. Chander, Forest Research Institute, Dehra Dun, [Geometridae, Pyralidae].

S. L. Gupta, Division of Entomology, I.A.R.I., New Delhi, [Lymantriidae and allied moths].

M. Haribal, Bombay Natural History Society, Bombay, [Rhopalocera].

H. R. Pajni & Dr. H. S. Rose, Department of Zoology, Punjab University [Pyralidae].

ABROAD

J. D. Bradley, British Museum (N.H.) London. [Microlepidoptera].

A. K. Zagulyaev, Academy of Sciences, Zoological Institute Leningrad, USSR [Tineidae, Adelidae].

P. P. d' Entreves, Mus. Inst. Zool. Sistematica, Torino. [Pyralidae].

T. Kumata, Hokkaido University, Entomological Institute, Sopporo, Japan [Gracillaridae].

I. F. B. Common, C.S.I.R.O., Canberra [Pyralidae].

N. B. Tindale, S. Australian Museum, Adelaide, [Hepialidae].

E. G. Munroe, Ent. Res. Institue, Canada. [Pyralidae and Papilionidae].

J. F. Gates-Clarke, Dept. of Ent. Nat. Mus. Nat. hist., Smithsonian Institution, Washington - D.C. [Microlepidoptera].

H. K. Clench, Carnegie Mus., Pittsburg, [Lycaenidae].

Don R. Davis, Smithsonian Inst. Washington. [Tineidae & Psychidae].

Colin Pratt 5, View Road, Peace haven, East Sussex, England. [Geometridae].

P. R. Ackery & R. I. Vane-Wright Dept. of Ent., Brit. Mus. (N.H.), London. [Danainae Nymphalidae].

D. Adamski, Dept. of Ent., Mississippi State Univ., P.O. Drawer EM, Mississippi State, MS 39762, [Gelechioidea including Blastobasidae].

H. Goankar, Skt. Thomas Alee 10, 4, TV. 1824 Frederiksber C, Denmark (C/o Zool. Mus., Deptt. of Ent. Univ. of Copenhagen). [Rhopalocera].

J. Haugum, Papilio International Lundhusvej, 33, 7100 Vejle, Denmark. [Papilionidae].

D. L. hancock, Curator, Dept. of Ent. Nat. Mus., P.O. Box 240 Bulawaye, Zimbabwe. [Papilionidae].

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LEPIDOPTERA : Amatidae, Arctiidae & Noctuidae

Introduction

In continuity with the foregone chapter, this account is concerned with the three major families of Noctuoidea, viz., Syntomidae (now Amatidae), Arctiidae and Noctuidae, all and particularly the last two of which are of much economic importance to mankind, mainly in the form of pests on different crops and vegetations. It may be noted that the ophiderine larvae (army worms, cut worms, boll worms, stem worms, etc.) of the family Noctuidae alone, feeding on fruits as well as forest trees, cause damage to the exchequer worth lakhs of rupees. In the preceding chapter, brief details of references covering the important items of work on the noctuoid moths, amidst the Lepidoptera in general, have been provided, so that those on families in question are selectively cited here.

Classification

The Hampsonian system is universally followed, but with certain modifications both at the subfamily and generic levels, particularly of the Arctiidae and Noctuidae by subsequent authors like different specialist in Seitz (1909–38). The other family, Amatidae, has no subfamily. In fact, all these families bear very close affinities with one another not only in the adult stage but also in the early stages. The Amatidae is the nearest ally of the Arctiidae, and the latter, of the Noctuidae.

Historical Resumé

i) Pre–1900

Guenée (1852) exhaustively dealt with the natural history of Lepidoptera with particular reference to the noctuoid moths. Walker (1854–'66), Butler (1877) and Hampson (1898–1914) published lists and catalogues along with descriptions of the Indian and exotic noctuoid moths lying in the collection of the British Museum (Natural History), London. Butler (1875) revised the arctiid genus *Spilosoma* and the allied groups, while Moore (1878) further geared up the revisionary work of Lithosiinae with descriptions of other genera and species. Moore (1881, 1988) continued to describe more genera and species of nocturnal Lepidoptera collected by W. S. Atkinson, W. C. Hewitson, J. H. Hockings and also by himself from Calcutta and North–West Himalaya; earlier, he (1877) prepared a long list of the fauna occurring in the Andaman and Nicobar Islands. Apart from the work on the Lepidoptera of Bengal and the Deccan (1885) and Mhow in the Madhya Pradesh (1886), Swinhoe (1889) described other nocturnal species. Similarly, Cotes (1889–'91, 1891–'93, '96) contributed a series of notes on insect pests and other important aspects of performance appraisal from the Entomological Section of the Indian Museum in the *Indian Mus. Notes*, Calcutta. Besides, Hampson (1892–'96) published volumes in the 'Fauna of British India Series of the Indian subregion, dealing *interalia* with all the three families concerned; he (1891–'93) also illustrated the type–specimens of moths deposited in the British Museum (Nat. Hist.), London and later (1895) described new moths from India.

ii) 1901–1947

During the period under report, series of contributions to the studies on taxonomy in particular and also to certain extent on other aspects of systematics related to the noctuoids, were in full swing. Of these, the notable works in taxonomy were made by Hampson (1902, 1903, 1905,

D. K. Mandal and Sanjit Kumar Ghosh, Zoological Survey of India, Calcutta.

1907, 1926), Swinhoe (1903), Warren, *in* Seitz (1909–'13, 1912–'37), Seitz, *in* Seitz (1910, 1912, 1913, 1915, 1919-25), Rotschild in Seitz (1912, 1914 and 1936), Seitz & Draudt, *in* Seitz (1913), Draudt, *in* Seitz (1914, 1934), Gibson (1915), Fletcher (1926), Corti, *in* Seitz (1933), Corti & Draudt, *in* Seitz (1933), Collenette (1935), Gaede, *in* Seitz (1937–'38), Jordan (1939), Gardner (1943) and Daniel (1943–'54). Maxwell-Lefroy (1906) elaboratively brought to light important Indian insect pests, while Fletcher (1921, 1925) furnished detailed inventory of the Indian crop–pests as well as interpreted migration as a factor in pest outbreaks; there are also other notes on economic insects and insect pests from the Indian Museum by Barlow (1900, 1903). As to the morphological work, Pierce, *et al.* (1909–'43) made note–worthy contributions to the studies of noctuid genitalia in as many as seven volumes, while Tillyard (1918), Ripley (1925), Richards (1933), Gohrbrandt (1940) and Faure (1943) made salient observations on other features like wing–coupling apparatus, comparative skeletal structures of tympanum, wing–antenna correlation, phase–variation, etc. Apart from the Hampson's Catalogues, such type of work was further attributed to the credit of Zerny (1912–'17), Strand (1919, '20, '22) and Bryk (1937). On habits and ecology, works of Kaye (1913), Lloyd (1920) and Beeson (1941) dealing with mimicry, instincts of glasshouse tomato moth, different forest insects and their control, etc., are worth mentioning. Meanwhile, certain significant reports during the Proceedings of entomological meetings, on agricultural experiments etc., held at various places in India were published by Fletcher (1917), Burt (1918), Chopra (1928) and others. Sevastopulo (1935, '45) worked out the faunistic aspects of the noctuoids from Darjeeling and Calcutta. Over and above, Zerny & Beier (1936) and Ramakrishna Ayyar (1940) published Handbooks on insects and economic entomology, while Roepke (1944) made valuable revisional notes on the arctiid genus *Cyana*.

iii) 1948–1990

Contributions to the morphological studies including certain new observations on the noctuoids were made during this period by Koning & Roepke (1949), Kiriakoff (1950), Sibatani, *et al.*, (1954), Arora (1975) and Smithe (1975). These studies were consecrated to different aspects, viz., remarks on the morphology of teak Moth, typanal organs in relation to the classification, male genitalia, observation of ocelli and the naturalist's colour guide. Serious researches were continued in the field of taxonomy and systematics by different authorities. Prominent amongst them were Travassos (1949), Roepke (1949, '57), Rego–Barros (1956), Kostrowicki (1961), Obraztsov (1966), Bhattacharjee & Gupta (1969), Kapur & Arora (1971), Cayrol (1972), Brown & Dewhurst (1975), Barlow (1982), Holloway (1982) and Kitching (1984). It may be noted here that according to Kitching, the suprageneric or the subfamily treatment of Noctuidae is rather far from the up–to–date level of satisfaction. Bhasin (1963) and Roonwal & Sen–Sarma (1963) prepared a systematic catalogue of the noctuoids, housed at the Forest Research Institute, Dehra Dun. Dr. R. W. Pools of Smithsonian Institution, U.S.A., is currently producing a catalogue of the World Noctuidae. Franclemont (1951) reviewed generic names for the various segregates of *Leucania*, while Boursin (1957), Ramamani & Subbarao (1965), Nye (1975) and Watson, *et al.* (1980) provided different synonymic and critical notes on Agrotidae (now subfamily of Noctuidae) and allied subgroups. Rao (1952) made an extensive investigation into the statistical methods in biometric research. Müller (1953) contributed an account of Noctuidae in a Handbook edited by P. Sorauer, Berlin. In respect of habits, behaviour and allied areas of the group with particular reference to the Noctuidae, Venkataraman (1954) observed on the migration of *Agrotis ypsilon* (Rott.) from the plains to the hills, while several authors like Jacobson (1972), Campion (1972, '75, '76), Neumark, *et al.* (1977), Neshitt (1978), Sato, *et al.* (1980), Campion & Nesbitt (1981) and Zeleny, *et al.* (1982) contributed to the studies on sex–pheroinoes, light–traps and pest management of tropical species. Food habits were studied by Banziger (1979, '80, '82, '83) and Wheeler & Blackwell (1984); the former dealt with the fruit–piercing and blood–sucking behaviour of the adults belonging to the ophiderine noctuids, while the latter referred to the concern of recent economic status of these moths, of which the larvae feed on lichens and fungi. Amongst other investigations on pests and control, several may be cited as Lal (1955, '64), Shirname (1955), Rivnay (1962), Singh (1963), Srivastava (1964) and Nayar *et al.* (1976). Besides, Benson (1973) worked out the biology of the species infesting stored products with special reference to the population dynamics. Vidal (1979) threw light on the outline of ecology and vegetations, and Spitzer, *et al.* (1984) dwelt upon the bionomics with reference to the fecundity and long-term variability in abundance of noctuid moths. Spitzer *e t al.* (1983) also imparted knowledge on the flight activity of some moths monitored by sex pheromones during the dry season. Results of faunistic explorations of the families concerned were achieved from several ecotonal belts in India, viz., Noctuidae of Kashmir (Boursin, 1954), Rhotang-Pass in North-west Himalaya (Kapur, 1955) and Orissa (Mandal & Maulik, *in* press); Arctiidae of the Great Nicobar Island (Arora & Singh, 1975), Andaman & Nicobar Islands (Arora, 1983) and Arunachal Pradesh and adjoining areas of Assam in East Himalaya (Arora & Chaudhury, 1982); and Amatidae (= Ctenuchidae) of the Andaman Islands (Arora, 1976, '80). Besides, Bursin (1955) also reported the faunistic account of Noctuidae on the Dutch-Nepal Expedition, while Kapur (1971) dwelt upon the origin and composition of certain Himalayan species of the same family. All these contributions bear paramount significance from the Zoo-geographical point of view. Amongst other references, Mansingh's (1971) work on the physiological classification of dormancies in insects may be worth citing.

Studies from Different Environs

A number of eco-faunistic surveys were made at various localities of India by scientists of different institutions, including Z.S.I. These cover many of the known areas sprawling from the mountain to the mangrove-ecosystem and also the major insular belts.

These are indicated in the preceding chapter on Lepidoptera.

Estimation of Taxa

The three families of the Noctuoidea under report comprise a vast assemblage of species. Noctuidae outnumbers all other families of the order Lepidoptera in respect of the taxa composition. As per the known global estimate of the fauna belonging to the three families together, the sum total of the species reaches to an approximate number of 12,000 (Amatidae : *C* 2000 spp.; Arctiidae: *C* 3500 spp.; Noctuidae: *C* 6500 spp.). As compared to this, the overall fauna of the Indian subregion, with particular reference to post-independent India, still considered with a great potency of faunal resources under almost all the climatic conditions prevailing around the planet, however, represents rather a small fraction, say about 17%. This simply indicates that both intensive and extensive exploration of the core areas of the widespread forests and other ecotonal belts in the country, are yet to be systematically carried out so as to assess the real position of many more species that hitherto remain unknown. The break-up of the approximately known Indian taxa of the concerned families thus shows that the Amatidae comprises 80 species in 10 genera; Arctiidae, 450 species in 90 genera under nine subfamilies; and Noctuidae, 1500 species in 280 genera in 13 subfamilies. For details of classification at the sub-family level, the works may be consulted on the Arctiidae by Seitz (1910), Daniel (1943, '51, '52, '54) and Kiriakoff (1950) and on the Noctuidae by Hampson (1903-'14) and Seitz (1909-'14).

Classified Treatment

Family Amatidae (= Syntomidae, Ctenuchidae)

The family represents small to medium-seized inactive moths of largely tropico-diurnal habit. Many are brilliantly coloured and mimic the hymenopteran Aculeata and other insects (Kaye, 1913) by virtue of their largely transparent wings and other features. Hampson (1898, 1914), Zerny (1912) and Fletcher (1925) prepared Catalogues, while Seitz, *in* Seitz (1913, 1933) and Obraztosov (1966) dealt with the Indo-Australian and Palaearctic species of the family. Arora (1980) has dealt with the faunistics of the Andaman species.

Family Arctiidae

The family includes 'Tiger moths', 'Ermine moths', 'Footmen', etc., usually with stout body and long, narrow to moderately broad, prominently spotted and brightly coloured wings. They are mostly nocturnal, being attracted by light and found predominantly in the tropics. The family is divided into as many as nine subfamilies, of which the Lithosiinae is perhaps the largest. The members are known to feed on low herbage and lichens around tree-trunks, etc. Amongst other references already cited on the family, works of Hampson (1900, 1901, 1914), Strand (1914, 1920), Bryk (1937), Daniel (1943-'54), Kiriakaff (1950) and Arora & Chaudhury (1982) are important. Besides, Nayar, *et al.* (1976) dealt with the pests on different crops and vegetations related to the applied entomology.

Family Noctuidae

The family comprises 'Army Worms' 'Boll Worms', 'Cut worms', 'Stemworms', etc., - all these names being derived from the patterns and characteristics of larval behaviour - adults of which are nearly always nocturnal and posses cryptic and sombre colour, especially on fore wings so as to assimilate themselves in the diaposematic posture to their surroundings for protection against the enemies at day time. The family has 13 subfamilies, of which the Acronyctinae is the largest. Its species, which are predominantly tropical in distribution, present a monotonous similarity of structure particularly of wing venation and labial palpi. Their capture is rather easy, since these are very often attracted by light and baits like sugar-mixture, rotten fruits, etc., while others frequent flowers at dusk. Their habits, specially in early stages, are quite varied, sometimes showing polyphagy on low foliage, fruits, forest trees, lichens and fungi, and sometimes behaving as stem or seed-borers; as serious pests or as predators upon the lac insects, or in the extreme case as blood-sucking moths. It is also interesting to note that Faure (1943) observed some larvae of 'Army worms' eliciting a "phase" variation in colour analogous to that seen in locusts. Important works amongst others were contributed to the studies on taxonomy, systematics and faunistics by Hampson (1903-'14) Warren, *in* Seitz (1909-'14), Corti *in* Seitz (1933), Corti & Draudt, *in* Seitz (1933) Draudt, *in* Seitz (1934), Gaede, *in* Seitz (1937-'38), Kapur & Arora (1971), Watson *et al.* (1980) and Mandal & Maulik (in press); and on physiological and bionomical aspects by Varshney & Sundaram (1967-'68), Sundaram & Varshney (1969), Varshney *et al.* (1971), Campion (1976) and Spitzer (1984).

Current Studies

In the Z.S.I., systematics of the concerned families from West Bengal and Meghalaya have been studied. The group has also attracted attention of the scientists from elsewhere in India, as already mentioned in the preceding chapter. It may further be noted that several scientists from abroad, viz., H. Banziger of Thailand, J. D. Holloway of British Museum (N.H.), London, K. Spitzer of Czechoslovakia, R. W. Pools of Smithsonian Inst., U.S.A. and others are actively engaged in diverse fields of systematics of the group with particular reference to the Noctuidae.

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Animal Resources of India : 435–438 : 1991

LEPIDOPTERA : Cossidae

Introduction

The members of the family Cossidae, commonly known as 'Goat Moths', 'Carpenter Moths' or the 'Leopard Moths', have assumed considerable phylogenetic and economic importance. Some of the species like the notorious teak-wood borer, *Xyleutes ceramicus* (Walker) and *X. persona* (Le Guillou) form numerous galleries inside the tissues of living trees, and are not detected till the tree is sawn. Sometimes the wound caused by insects are sufficient enough to kill the valuable teak. *Zeuzera coffeae* Nietner is another well known Cossid borer in coffee, which is reported to attack other 35 host-plants, including valuable sandalwood, citrus, cotton, jasmine, and teak. The presence of larvae in the tree, can be detected only by the presence of pellets of frass on ground below the infested branches. If the tree is young, the attack by Cossids may prove to be fatal.

Phylogenetically, the Cossidae have been considered to be most primitive and believed to have retained the ancient type of wing venation (Turner, 1918, Seitz, 1929). Seitz (1912) traced its relationship with Microlepidopteran families, viz., Tortricidae and Hepialidae. Turner (1918, 1946) claimed that all the major families of Lepidoptera have, probably, evolved from Cossidae by the process of reduction of veins. His hypothesis led him to propose a new name, Protocossidae, a hypothetical name, which gave Cossidae an ancestral status. Gaede (1929) commented on the highly remarkable features of this family and opined, 'We can distinguish different types of Lepidoptera among the Cossidae; they deviate so much from each other that even the homogeneousness of the family is doubted and some lepidopterologists are of the opinion that the characteristics common to the family are for the greater part merely to be considered as resemblance by convergence, produced by endophyte habits of larvae'

Classification

Family Cossidae was for the first time divided into two distinct subfamilies, Cossinae and Zeuzerinae, by Neumoegen & Dyar (1894) and this was followed by several other workers like Tillyard (1926), Gaede (1933), Mehta (1933), Bryk (1937), Dyar (1937), Clench (1959), Comstock (1962) and Daniel (1962, 1965). Berger (1957), however, separated the Indian genus *Dudgeonea* Hampson from Cossidae and formed a distinct family Dudgeonidae due to the presence of tympanic organ, and proposed two subfamilies *viz.*, (i) Cossinae, to include the whole of cossid-fauna and (ii) Eulophonotinae. This classification has, however, not been followed by most of the workers. Handlirsch (1925), Janse (1932) and Brues, Melander & Carpenter (1954) went a step further and treated Cossidae in a broad sense and included several subfamilies, *viz.*, Argyrotypinae, Eulophonotinae, Metarbelinae and Cossinae, the latter including whole of the Cossid fauna, under two tribes Cossini and Zeuzerini. Essig (1951), however, considered Cossid fauna under two separate families, Cossidae and Zeuzeridae, which has been followed by Nayar, Ananthakrishnan & David (1976). Minet (1986) was of the opinion that the Metarbellinae is one of the subfamilies of Cossidae.

Clench (1956-1960) in a series of paper on Cossidae and Roepke (1955, 1957) retained only two subfamilies, Cossinae and Zeuzerinae, as true Cossids and this classification has been followed by Arora (1965, 1971, 1976, 1982).

Historical Resumé

i) Pre-1900

The first record of Cossid fauna from India appears to be by Donovan (1800), who reported

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Phalaena scalaris (Fabr.) and *Phalaena mineus* (Cramer) from Bengal, of which the original records being from China and Batavia, respectively. Leach (1815) proposed the word 'Cossida' for a group of moths which included *Cossus cossus* (Linn.) and its allied species, *viz., Hepialis scalaris* Fabricius, *Phalaena Noctua strix* Linn (1758) from America and *Phalaena mineus* Cramer (1779) from Batavia. Boisduval (1829) proposed 'Zeuzeridi' for the genus *Zeuzera* Nietner and its allies but subsequently changed (1834) it to 'Zeuzerides' Newman (1832) used 'Cossidae' and 'Zeuzeridae' and for this reason the credit of the authorship of the family name goes to him.

Additions to the Indian fauna were made in contributions by Herrich Schaffer (1854); Walker (1856, 1865); Nietner (1861); Moore (1865-1883); Butler (1890); Swinhoe (1884-1895) and Hampson (1891-1892). Of these, Hampson's (1892-1894) 'Fauna of British India, Moths' (Vol. 1-4) series is the most noteworthy, which contributed to the study of 23 species from the Indian region. Another eight species were added by Swinhoe (1894), Hampson (1895) and Dudgeon (1899), as one, six and one respectively, to the Indian fauna.

ii) 1901-1947

From the beginning of twentieth century to the year 1947, a variety of research papers was contributed on the Indian Cossidae. These are Dalla Torre (1923) and Kirby (1937), on bibliographical research; Beeson (1916-1941) and Chatterjee (1917) on Forest Entomology; Bethune- Baker (1914) and Mehta (1933) on genitalia; Lefroy (1909), Kalshoven (1919-40), Fletcher (1920-30) and Ayyar (1940) on economic entomology; Gardner (1945) on immature stages; and Seitz (1912, 1929, 1937), Tillyard (1919, 1926), Turner (1918, 1945, 1946), Gaede (1929, 1933, 1934) and Daniel (1940, 1945) on taxonomical research.

ii) 1948-1990

The period after 1945 was most productive, as contributions were made by Daniel (1954-1965) in the form of Monographs on the Palaearctic Cossidae;, Viette (1951-52); Roepke (1955-1957) on Cossidae of New-Guinea and Malayasia; Clench (1956-59) on Neotropical, African and Western Chinese Cossidae; Berger (1957); Arora (1965-1982) on Cossidae of Indian region; Barlow (1982) on Cossidae in 'Moths of South-east Asia'; Hua (1986) and Chou *et. al.* (1986) on Cossidae of China; Eitschberger (1987) on Cossidae of Turkery; and Holloway (1987) on Cossidae in 'Moths of Borneo'

Studies from Different Environs

The Indian Cossidae are well represented in the both Palaearctic as well as Oriental region of the Indian sub-continent. The genera *Catopta* Staudinger, *Cossus* Fabricius and *Holcocerus* Staudinger, being mainly Palaearctic and the remaining being mainly Oriental. The genus *Paracossus* Hampson is endemic to the Oriental region, represented by one species each from Sri Lanka and Myanmar (Burma). In India, the Cossidae have been recorded from Kashmir in the north to the southern most parts of India, the Andaman and Nicobar Islands, and Arunachal Pradesh, Assam, Sikkim and Meghalaya in the east, through Bengal, Bihar, Andhra Pradesh, Orissa, U.P., M.P., Kerala, Karnataka to Maharashtra in the west. The Cossidae have not been reported to occur in arid zone areas. Only the scientists of Zoological Survey of India, have contributed papers on the study of Indian Cossidae.

Estimation of Taxa

Dalla Torre (1923) catalogued about 500 species from the world which included 35 species from the Indian region. This number included all those which were either synonyms or erroneously placed as Indian. Subsequently, Viette (1951) recorded as many as 97 genera, of the world.

The systematic revision of Indian Cossidae by Arora (1965-1982) has brought to light several species new to science, and the Indian fauna is estimated as follows:

Cossinae	Zeuzerinae
Catopta Staudinger - 2 spp.	*Azygophleps* Hampson - 4 spp.
Cossus Fabricius - 5 spp.	*Phragmataecia* Newman - 10 spp.
Eremocossus Hampson - 1 sp.	*Xyleutes* Hübner - 8 spp.
Paracossus Hampson - 2 spp.	*Zeuzera* Nietner - 6 spp.
Holcocerus Staudinger - 2 spp.	(including one sub sp.)

Genera *Eremocossus* and *Paracossus* are endemic to the Oriental region, each represented by species as given above.

Expertise

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Animal Resources of India : 439–443 : 1991

TRICHOPTERA

Introduction

Trichoptera was considered for a longtime by the entomologists within the heterogeneous assemblage of the order Neuroptera. It was Kirby who recognised Trichoptera as a separate Order. MacLachlan (1880) accepted this view to retain its status as an Order.

Trichopterans or Caddisflies, one of the large groups of aquatic insects, are generally aquatic in immature stages and occur in most types of aquatic habitats, but are abundant in freshwaters. Because of the broad trophic habits of larvae, they take an important part in the energy transfer at several levels in aquatic ecosystem and are therefore significant in the nutrition and management of fish, waterfowl and other aquatic vertebrates. Most larvae eat plant materials in one form or other, as for example, algae specially diatoms on rocks or decaying vascular plant tissue. Some larvae are predacious. Some of the larvae of the family Hydropsychidae are resistant to pollution. Their involvement in many parts of food webs in diverse freshwater habitats also makes the trichopterans a sensitive indicator of change (Wiggins, 1979). Therefore, though this group is generally not recognised as insects of economic importance but they play the important role in freshwater ecology.

Classification

The recent classification of Trichoptera after Weaver and Morris (1986) may be tabulated, in order to highlight the Phylogeny of the group (*vide* Table 2).

Amongst a total of 38 families reported from the whole world, 18 families (marked asterisk *) are recorded from India. Family Arctopsychidae has not been considered in the above classification because it is generally not accepted as a family but as a subfamily of Hydropsychidae by a number of workers. The approx. number of genera and species hitherto known from India are given as follows :

Table 1. Trichoptera in India

Family	No. of genera	No. of spp.
Molannidae	2	8
Hydropsychidae	16	60
Polycentropodidae	5	24
Stenopsychidae	1	13
Calamoceratidae	2	5
Phrygaenidae	3	4
Philopotamidae	3	47
Hydroptilidae	8	65
Leptoceridae	14	201
Sericostomatidae	13	36
Limnephilidae	20	52
Economidae	1	6
Psychomyidae	6	31
Xiphocentronidae	6	46
Rhyacophilidae	4	176
Glossosomatidae	4	19
Odontoceridae	1	1
Arctopsychidae	2	9
Hydrobiosidae	1	9
Total	112	812

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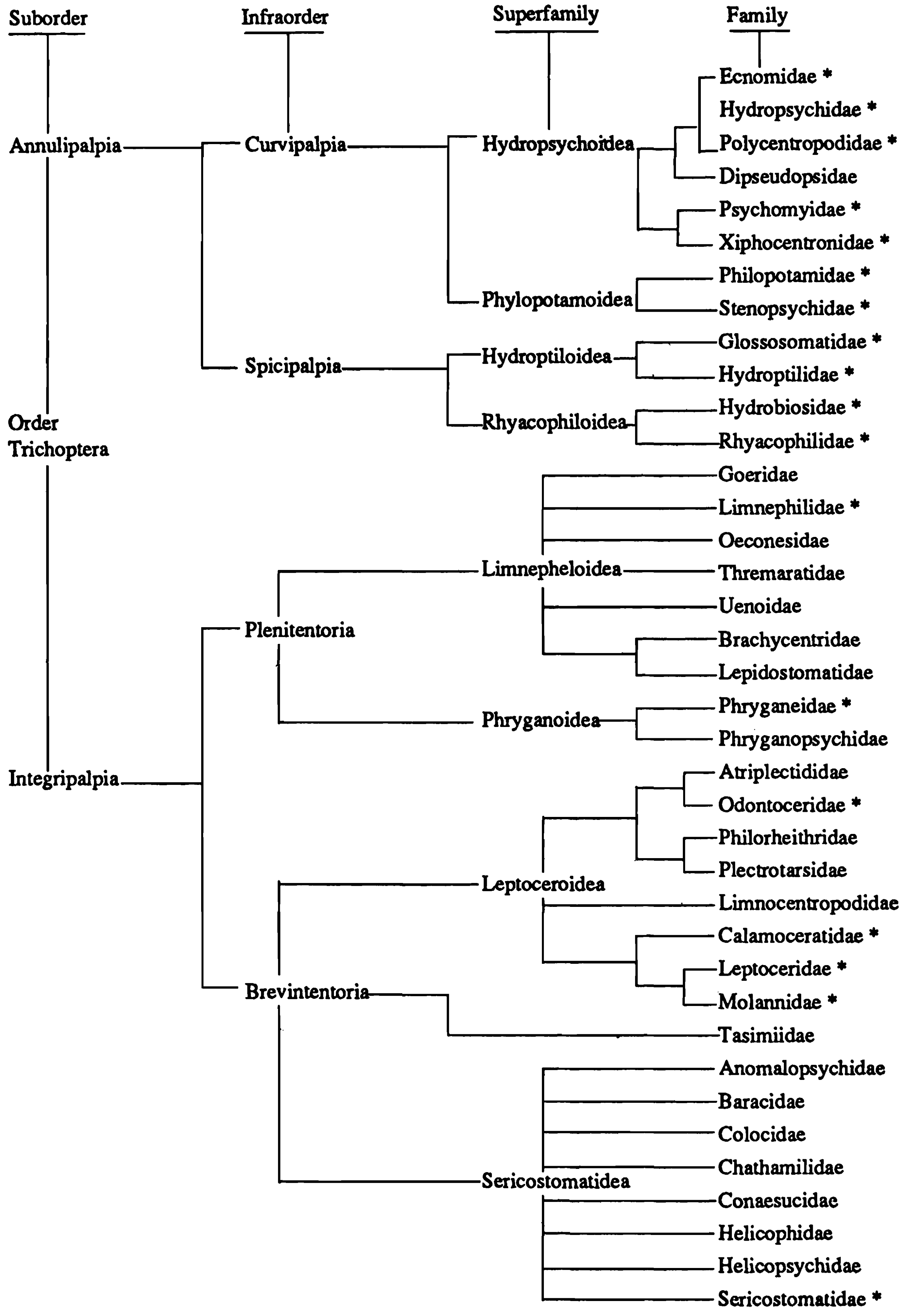
Table 2. Classification



Historical Resumé

i) Pre-1900

The study of Trichoptera started a little before the middle of the 19th century. Kolenati (1864-1873). Walker (1852), MacLachlan (1873, 1875, 1886) and Hagen (1864-1873) may be referred to as the earliest references to the study of Indian Trichoptera.

ii) 1900-1947

In early part of this century, Morton (1900-1902), Banks (1909-1939), Betten (1909) and MacLachlan (1916) contributed much to the study of Indian Trichoptera. Martynov (1935-1936) worked out the collections present in the Indian Museum (Zoological Survey of India). Mosely (1935-1949) worked out some Indian forms.

iii) 1947-1989

Kimmins (1950-1956), Schmid (1949-1987), Wiggins (1968) and Malicky (1979-1981) contributed extensively to the study of Indian Trichoptera. Schmid (1949-1987) described more than 500 species, distributed over 9 families, namely, Limnephelidae, Arctopsychidae, Leptoceridae, Rhyacophilidae, Philopotamidae, Glossosomatidae, Xiphocentronidae, Stenopsychidae and Hydropsychidae, collected from Arunachal Pradesh, Sikkim, Assam, Manipur, West Bengal, Kerala, Tamil Nadu, Karnataka and Uttar Pradesh in India. Wiggins (1968) contributed to the study of Asian Trichoptera, particularly the family Molannidae, and described several new species from India with particular reference to Assam, Manipur and Madhya Pradesh. Malicky (1979-1981) made some contributions from Andaman Islands. It may be mentioned here that Fisher's (1960-70) "Trichopterorum Catalogus" is a very useful work and it included some Indian species also.

In Zoological Survey of India research work on Trichoptera has been initiated very recently. Ghosh and Majumder (1989) have published description of a new species of Phryganeidae and a paper on the fauna of Trichoptera from West Bengal is under publication. Studies on materials from Meghalaya and Garhwal Hills are in progress.

Studies from Different Environs

The National Zoological Collections of Trichoptera have been developed through extensive and intensive field explorations by the Zoological Survey of India parties for the last 75 years. The trichopterans are found in the neighbourhood of rivers, streams, ponds, lakes, etc. They are either crepuscular or nocturnal and generally concealed during the day. They may be collected from herbage and bushes bordering water bodies, the bushes and branches of trees overhanging water, isolated trees at a little distance away from water, crevices of the bark, underside of the bridges, under stones, or on the artificial light at night. The collections of Trichoptera have so far mainly been made from Himalayan ecosystem, specially from the Garhwal Himalayas, Sikkim, Darjeeling, Arunachal Pradesh, and from Meghalaya, peninsular part of West Bengal and Uttar Pradesh. It is obvious that extensive faunal surveys are required for the collections of Trichoptera not only from the remaining States and Union Territories, but also from the Insular regions, i. e. Andaman & Nicobar Islands and Laccadives.

Estimation of Taxa

Kolenati (1884) created two main subdivisions, namely, Inaequipalpia and Aequipalpia, on the basis of relative number of joints in the maxillary palpi in the two sexes. These subdivisions were retained both by MacLachlan (1880) and Ulmer (1907). Martynov (1924) divided Trichoptera into two suborders, the Annulipalpia and the Integripalpia, partly on the basis of the form and habits of the larvae and partly on structures in the adult insects. The ultrascientific school, however, has divided Annulipalpia and Integripalpia into several superfamilies. Ross (1967) and Parker (1982) divided the order Trichoptera into three superfamilies, namely Rhyacophiloidea, Hydropsychoidea and Limnephiloidea. Schmid (1980) recognised four super families namely, Hydropsychoidea, Rhyacophiloidea, Limnephiloidea and Leptoceroidea. Weaver (1983) classified Annulipalpia into two infraorders Curvipalpia and Spicipalpia, and included two superfamilies namely, Hydropsychoidea and Phylopotamoidea in the former, and Rhyacophiloidea and Hydroptiloidea in the latter. He also divided Integripalpia into two infraorders of which Plenitentoria contained two superfamilies namely, Limnephiloidea and Phryganoidea, whereas Brevitentoria included two superfamilies, Leptoceroidea and Sericostomatoidea. In these superfamilies a total of 38 families are known from the whole world (Weaver & Morse, 1986). Linnaeus (1758) recognised a single genus *Phryganea*, comprising 17 species. Since then the knowledge of Trichoptera has increased so substantially that by 1990 about 7000 species in 38 families from the whole world and about 812 spp. in 18 families from India are known.

Expertise

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HYMENOPTERA

Introduction

The order Hymenoptera appeared on this planet during Jurassic period in Mesozoic era, ca. 155 million years ago, alongwith Dermaptera. The former is highly evolved in comparison to other insects and is considered as the third largest insect order. They are economically, medically and biologically important. Bees pollinate flowers, collect nectar and store honey and wax in bee hive. Honey is used for feeding and medical purpose; wasp larvae and ant eggs are used for fish bait in angling. The ants show a developed way of social living through polymorphism, in their nest with colony of male, female and workers. They also maintain relations with other insects either as parasites, or harbour in their nests, as with termites. Braconids are used for pest control in agricultural fields and horticultural gardens. Scolid wasp larvae are used to control the population of some beetles. Chalcids bore and damage rice and wheat stems, whereas Cynipids produce galls in plant tissues and retard their growth.

Hymenopterans are colourful also, e.g. wasps and bees; a few are metallic in Chalcids and Cynipids. These insects become pest and damage the plants, when they aggregate in large numbers, as in the case of Carpenter bee, Red ant and Sawfly. The number of Hymenopterous insects is over 100,000 species known from the world, while only about 5,000 species are recorded from India. Parthenogenesis is common in Hymenoptera than in other orders of insects. Though most of the Hymenopterans are entomophagus and parasites, some of them are phytophagus (sawflies). While the bees feed on nectar, the ants live on sweet granules. The size of Hymenopterous insects may vary from 0.2mm to 50.0mm in length. They are soft to hard bodied insects, with mobile head, long-jointed antennae; antennae may be short, clubbed and elbowed as in Chalcids. They possess two pairs of veined or almost veinless wings in Chalcids or may be wingless, as in worker ants; mouth parts (with mandibles) are well developed for sucking and piercing. In most of these insects a constriction lies between thorax and abdomen, but it may be absent in some e.g. Sawflies. Female hymenopteran insects are furnished with ovipositors having stings or saws. Larvae of Hymenoptera are apodous or polypodous.

Historical Resumé

From the beginning of human civilization, man observed the hovering of bees on flowers for pollen and nectar. Their swarming in bee hive for storing honey, making of tree holes by carpenter bees for their nests, and building of papery nests by hornets on tree branches are common sight. The bitter experience of sting by wasp or bee and severe burning irritations by red ants are also common. All these factors attracted naturalists and paved the path for further study of these valuable insects in later years.

i) Pre-1900

Studies on Hymenoptera can be traced back from the published work by Cameron (1877) on Tenthredinidae. Dalla-Torre (1894-1896) published in 10 volumes as "Catalogus Hymenopterorum" Afterwards, Bingham (1897) brought out his monographic Vol. I, of the 'Fauna of British India' dealing with species of wasps and bees. Still later, Ashmead (1899) published his work on Apterogyna (Mutillidae) and its allies.

ii) 1901-1947

Bingham (1903) published his Vol.II, of the 'Fauna of British India', covering 'ants'

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(Formicidae) and cuckoo wasps (Chrysididae). Turner (1912) brought out a monograph on Indian species of *Cerceris* (Sphecoidea) and *Elis* (Scoloidea). Subsequently Morley (1913) published the monographic Fauna volume III, for British Indian species on Ichnenmonoidea. Rohwer (1915) published the work on Tenthredinidae and Ayyar (1924) made a checklist of chalcids (Chalcidoidea). Emery (1925) brought out the catalogue on world Formicidae. In later years, Wilkinson (1928) made some papers on Braconidae, Maa (1938) published a work on Xylocopa (Apoidea). Mani (1938) did a monographic work for the catalogue on chalcids and Soika (1947) made a revisionary work on *Eumenes* (Vespoidea).

ii) 1948-1990

Chapman and Capco (1951) published a checklist of Asian ants. Van der Vecht (1952) did some work on Oriental *Ceratina* (Apoidea). Alam (1952) brought out a work on biology of *Stenobracon deesae* (family : Braconidae). Kurian (1954) worked on Oriental Bethyloidea, Nixon (1965) published the reclassification of Microgasterinae (Braconidae). Linsenmair (1968) revised the family Chrysididae. Mani *et al.*, (1973) brought out some publications on Chalcidoidea. Sharma (1982) recorded several Indian species on Braconidae. Saraswat (1982) worked on Scelionids (Proctotrupoidea) and Mani (1989) made his monographic volume in 'Fauna' series on Chalcidoidea.

Studies from Different Environs

Studies on Hymenoptera along with other insects, were carried out in India, even during the pre independent period by the entomologists from different ecosystems, like agricultural fields, horticultural gardens, forests, and other plantations and the results were published in different scientific journals. Since 1907 study on the group was initiated by the scientists of the Indian Museum and later Zoological Survey of India, Calcutta. Based on the collections brought from different ecosystems a number of papers were published. In recent times collections of Hymenopteran insects have been made from Arunachal Pradesh, Meghalaya, Rajasthan, Tripura, West Bengal, Tamil Nadu and Andaman & Nicobar Is.

Classified Treatment and Estimation of Taxa

The Order Hymenoptera is divided into two suborders: Apocrita and Symphyta.

A. *Apocrita* : With a narrow constriction of body between thorax and abdomen and having 11 superfamilies (Apoidea, Vespoidea, Scoloidea, Formicoidea, Ichneumonoidea, Chalcidoidea, Bethyloidea, Cynipoidea, Evanoidea, Proctotrupoidea and Ceraphronoidea).

Superfamily I. Apoidea

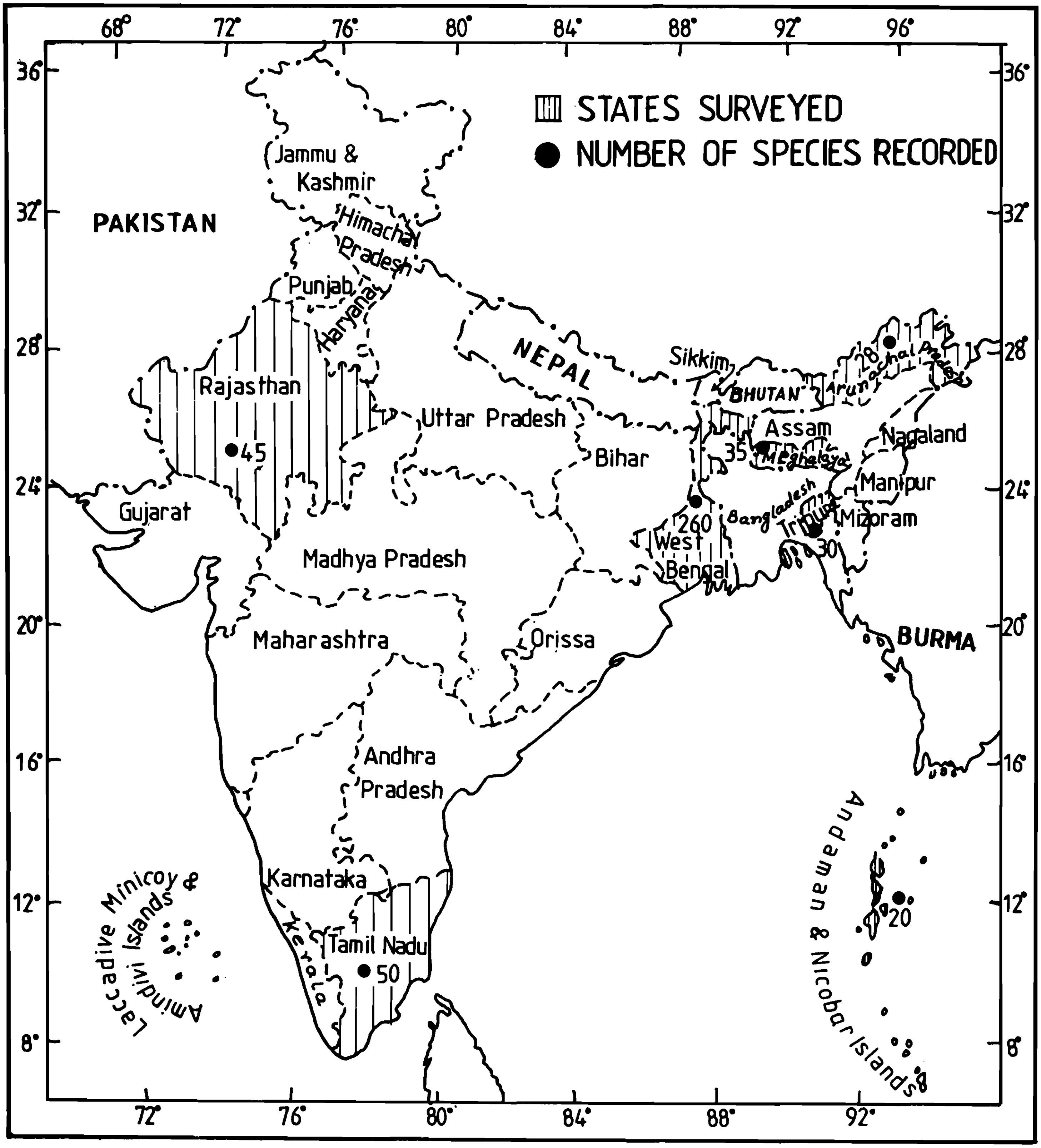
This superfamily includes 11 families namely Apidae, Andrenidae, Anthophoridae, Bombyliidae, Bremidae, Ceratinidae, Colletidae, Halictidae, Megachilidae, Nomidae and Xylocopidae. In India, Apoidea is represented by over 350 species and in the world by about 100,000 species.

Superfamily II. Vespoidea

The superfamily includes 3 families, namely Eumenidae, Vespidae and Masaridae. In India, Vespoidea is known by 200 species and in the world by over 600 species.

Superfamily III. Scoloidea

Scoloidea is represented by 5 families, namely Mutillidae, Pompiliilae, Scoliidae, Sphecidae and Thynnidae. In India, the superfamily is represented by over 600 species whereas in the world by over 1,500 species.



Areas surveyed for Hymenoptera

Superfamily IV. Formicoidea

Formicoidea includes the family Formicidae with 5 subfamilies namely Componotinae, Dorylinae, Dolichoderinae, Myrmecinae and Ponerinae. In India, Formicoidea is known by over 500 species, whereas species recorded from the world is over 2,000.

Superfamily V. Ichneumonoidea

Ichneumonoidea includes 2 families, Ichneumomidae (dealt separately in this volume) and Braconidae. The latter has 17 subfamilies; viz., Agathidinae, Alysinae, Aphidinae, Braconinae, Calyptinae, Cheloninae, Cosmophorinae, Doryctinae, Eulophorinae, Exothecinae, Helconinae, Hybrizoninae, Macrocentrinae, Microgasterinae, Mymagathidinae, Neoneurinae and Rogadininae. Braconidae is known by 250 species in India, whereas from the world it is represented by over 7,000 species.

Superfamily VI. Chalcidoidea

This superfamily includes 11 families; viz., Agaontidae, Chalcididae, Encyrtidae, Eulophidae, Eupelmidae, Eurytomidae, Mymaridae, Perilampidae, Pteromalidae, Torymidae and Trichogrammatidae. In India, Chalcidoidea is known by over 1039 species, whereas over 30,000 species are recorded from the world.

Superfamily VII. Bethyloidea

Bethyloidea includes 6 families, viz., Chrysididae, Bethylidae, Dryinidae, Emboleneidae, Loboscelidae and Scelogibbidae. In India, over 200 species and from the world over 2,000 species were reported.

Superfamily VIII. Prototrupoidea

This superfamily includes 7 families; viz., Proctotrupidae, Scelionidae, Diapriidae, Heloridae, Pelecinidae, Roproniidae and Vanhorniidae. In India, Proctotrupoidea is known by nearly 100 species, whereas over 2,000 species, were recorded from the world.

Superfamily IX. Cynipoidea

Cynipoidea includes 4 families; namely Cynipidae, Figitidae, Ibatiidae and Liopteridae. This superfamily includes nearly 50 species described from India and approximately 500 species reported from the world.

Superfamily X. Evanoidea

Evanoidea includes 3 families; viz., Evaniidae, Gasteruptidae and Aulacidae. In India, the superfamily is known by nearly 50 species, whereas from the world approximately 350 species were recorded.

Superfamily XI. Ceraphronoidea

The superfamily is known by a single family Ceraphronidae. In India, it is represented by 5 species and in the world by 35 species.

B. *Symphyta* : With a broad constriction of body between thorax and abdomen and having four superfamilies; viz., Tenthredinoidea, Cephoidea, Megalodontoidea and Siricoidea.

Superfamily I. Tenthredinoidea

The superfamily includes 6 families; viz., Tenthredinidae, Argiidae, Blasticotonidae, Cimbicidae, Diprionidae and Pergidae. Tenthredinoidea is known from India by nearly 200 species, whereas over 2,000 species were recorded from the world.

Superfamily II. Cephoidea

Cephoidea is known by a single family Cephidae and includes 5 species from India and about 100 species belonging to 13 genera from the world.

Superfamily III. Megalodontoidea

The superfamily includes one family Xyelidae of which 2 species are known from India and 15 species belonging to 5 genera are known from the world.

Superfamily IV. Siricoidea

Siridoidea is known by two families viz., Siricidae and Orussidae. Siricidae is known from India by 5 species and from the world by 85 species belonging to 9 genera; whereas in Orussidae 3 species are known from India and 66 species belonging to 14 genera from the world.

Current Studies

Studies on Hymenoptora are currently being carried out by the scientists of the Zoological Survey of India, Calcutta, based on collections from different ecozones. Outside Zoological Survey of India, studies are being carried out in the State Agricultural farm, Chinsura (Hooghly); Agricultural Research Institute (under ICAR), Barrackpore (North 24-Parganas); North Bengal University (Zoology Department), Darjeeling and Agricultural University, Kalyani (Nadia); all in West Bengal; Genda Singh Sugarcane Breeding and Research Institute (Deoria), Pantnagar Krishi Viswavidyalaya (Nainital) both in U.P.; Punjabi University (Zoology Department), Patiala, Punjab; International Crop Research Institute for Semi Arid Tropics (Patancheru), Andhra Pradesh; Rice Research Institute (Cuttack), Orissa; Loyola College (Zoology Dept.), Madras, Tamil Nadu; Calicut University (Zoology Dept.), Kerala and Rajrishi Autonomous College (Zoology Dept.), Alwar, Rajasthan.

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HYMENOPTERA : Ichneumonidae

Introduction

The family Ichneumonidae of the order Hymenoptera is one of the largest of all animal groups as it includes numerically more species than those of entire vertebrates, and among insects ranks only next to the family Curculionidae of the Order Coleoptera. Of the total species of insects known from the world, 5-8% belong to the family Ichneumonidae. They have mimicking colour pattern, usually in the form of black spots and stripes and are associated with foliage. They are usually parasitic in cocoons of the order Lepidoptera, but also parasitize cocoons of Symphyta, Braconidae, other Ichneumonidae, Neuroptera, Diptera and spiders. They kill the host by feeding on body fluids of the host, then spin their own cocoons, pupate and emerge as adult ichneumonids. By their parasitic habit they destroy a large number of agricultural and forest insect pests, thereby preventing the undue increase of pest species. They serve as an important agent for the biological control of pests. Thus, knowledge of their speciation, distribution and biology has potential practical value.

The oldest fossils of Ichneumonidae are known from the early Cretaceous. It is estimated that 60,000 species of ichneumonids are known from the world, which are classified in 26 subfamilies. There are 4140 species of ichneumonides in the Indo-Australian region, of which about 1200 species occur in the Indian subregion.

Classified Treatment

The family Ichneumonidae is readily recognised by the costal and sub-costal veins touching or fused with each other, and also in the presence of second recurrent vein in the fore wing. In Braconidae and Stephanidae also costal and subcoastal veins agree with Ichneumonidae, but in these families second recurrent vein is always lacking. Some ichneumonids lack second recurrent vein, but then they are recognised by the characters of tibial spurs. The ichneumonids have long antennae, with more than 16 segments. The only other hymenopterans with 16 antennal segments are Braconidae, Stephanidae, Pamphilidae, Trigonalidae and Sclerogibbidae. The other distinguishing feature of Ichneumonidae is the mandible (and also in most braconids) having only two teeth, but ther are exceptions in some ichneumonids where the upper tooth is subdivided and the lower tooth entirely absent.

The family Ichneumonidae is divided into following 26 subfamilies (those with an asterisk (*) are not known to occur in India) : 1. Pimplinae, 2. Tryphoninae, 3. Eucerotinae, 4. Labeninae, 5. Xoridinae, 6. Agriotypinae, 7. Banchinae, 8. Ctenopelmatinae, 9. Porizontinae, 10. Cremastinae, 11. Tersilochinae, 12. Ophioninae, 13. Mesochorinae, 14. Metopinae, 15. Anomaloninae, 16. Gravenhorstiinae, 17. Acaenitinae, 18. Helictinae*, 19. Orthocentrinae, 20. Diplozontinae, 21. Phygadeuontinae, 22. Hemigasterinae, 23. Mesosteninae, 24. Ichneumoninae, 25. Lycorininae*, 26. Phrudinae*.

Historical Resumé

i) Pre-1900

Linnaeus (1758) placed all Ichneumonidae, Braconidae and other Terebrantia in a single genus *Ichneumon*. Since then new genera have been added to the family up to 1850, followed by their rapid increase by the end of the century.

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Table showing number of subfamilies, genera & species known from India

Subfamilies	Genera	Species
Pimplinae	44	175
Tryphoninae	19	80
Eucerotinae	1	1
Labeninae	1	1
Xoridinae	7	14
Agriotypinae	1	1
Banchinae	14	71
Ctenopelmatinae	8	10
Porizontinae	20	178
Cremastinae	4	23
Tarsilochinae	1	2
Ophioninae	7	95
Mesochorinae	2	9
Metopiinae	10	23
Anomaloninae	1	2
Gravenhorstiinae	10	22
Acaenitinae	3	8
Helictinae	2	3
Diplozontinae	6	18
Phygadeuontinae	15	34
Hemigasterinae	9	21
Mesosteninae	66	213
Ichneumoninae	86	192
Total : 23	337	1,195

Gravenhorst (1829) published a classification of the family Ichneumonidae in '*Ichneumonologia Europaea*' His genera were super-generic groups containing subunits which were treated nomenclaturally as true genera, but designated by him as "families or subgenera" To translate his terminology to modern usage, Gravenhorst's "genera" will be called subfamilies, and his "families or subgenera" as genera. Therefore, his subfamilies were : 1. Ichneumon; 2. Tryphon; 3. Trogus; 4. Aloneya; 5. Cryptus; 6. Pimpla; 7. Metopius; 8. Bassus; 9. Banchus; 10. Ophion; 11. Hellwigia; 12. Acoenites; and 13. Xorides.

Wesmael (1844) in his classification divided the family into 36 groups and these were accorded family rank by later workers. Ashmead (1890) reduced the "families" of Foerster to tribes. Foerster (1850-76) proposed 489 generic and species names.

Addition of more new taxa and their classification in more natural groups were significant contributions made during this period by several workers namely : Fabricius, (1798-1804); Latreille (1809); Nees (1815-1818); Gravenhorst, (1823-1829); Haliday, (1832-1838); Kirby, (1837); Boi (1841-1856); Wesmael (1844-1859); Holmgren (1855-1889); Cresson (1856-1873); Kriechbaumer, (1872-1902); Thomson (1873-1893); Brulle (1888); Dalla Torre (1888-1902); Saussure (1892) and Tosquinet (1896-1903).

ii) 1901-1947

The early three decades of this century were dominated by Cameron, (1895-1925); Schmiedeknect (1900-1933); Moley (1903-1917); and Viereck, (1911-1925). Their work included many new taxa, most of them valid even today. Cushman and Rohwer (1920) broughtout a new classification of the tribes of Ichneumoninae ("Pimplinae"). Cushman also made important studies on the ichneumonids upto 1947. Roman (1903-1943) improved upon the classification of Thomson and Schmiedeknect for European species. Seyrig (1932-1934) published an account of Madagascan Ichneumonids.

The fourth and fifth decades of this century were taken over by Heinrich (1934, 1938) on Madagascan ichneumonids. Townes (1944) published a catalogue and revised classification of Nearctic ichneumonids.

The knowledge of Ichneumonidae was also due to the contributions of the following workers namely : Szepligeti (1900-1916); Kukujev (1901-1904); Perkins (1902-1915); Schulz (1906-1911); Brues (1910-1913); Viereck (1911-1925); Enderlin (1912-1921); Cushman (1915-1947); Clement (1924-1938); Meyer (1927-1935); Heinrich (1930-1965); Betrem (1932-1941); Blanchard (1936-1947) and Cheesman (1938-1953).

iii) 1948-1990

During the period addition to new taxa and information on various other aspects were by the efforts of Hedwig (1949-1961); Burk (1952); Gupta *et al.*, (1957-1989); Perkins (1958-1963); Porter (1963-1967); Tobias (1963); Dash (1964); Jonathan (1967-1982) and Fitton (1976-1985). On account of major and significant contributions by Townes (1958-1989) during these four decades, these were often referred to as the "Townes era of ichneumonid research" Up to 1952, his work was confined to Nearctic fauna, followed by a taxonomic arrangement and catalogue on the Indo-Australian ichneumonids in 1961, on the Palaearctic ichneumonids in 1965 and also on Neotropic ichneumonids in 1966. Townes (1967) undertook a more extensive work on the generic and higher classification of Ichneumonidae on the world basis. His four volumes on "the gener of Ichneumonidae" during 1969-1971 were widely appreciated. Townes and Townes (1973) also brought out a catalogue and reclassification of Ethiopian Ichneumonidae.

Studies from Different Environs

Till 1955, out knowledge of Ichneumonidae of Indian subregion was scanty. Morley's "Fauna of British India, Hymenoptera Vol III (Part I) Ichneumonidae", published in 1913, did not include important groups such as the Mesostenini (Cryptinae) and Ichneumoninae. Cameron (1901-1902), Cushman and Rohwer (1920), Gupta (1955-1975), Gupta *et al.*, (1966-1975), Perkins (1943), Townes *et al.* (1944-1984) published elaborate works on the Indo-Australian Ichneumonidae.

Gupta and collaborators (M. K. Kamath, J. K. Jonathan, D. T. Tikar, Sharda Maheshwary, M. L. Gupta, Girish Chandra and Santosh Gupta) have published several monographs and other revisions on the Oriental Ichneumonidae, jointly as well as independently. Gauld and Mitchell contribued much to our knowledge of the Anomaloninae and Ophioninae of the Orient. Kaur (1979), Rao (1972), Nikam (1972-1984) also contributed to the knowledge of Ichneumonidae of the Indian subregion.

Several surveys have been conducted to collect ichneumonid fauna from all parts of India, particularly Assam, Jammu and Kashmir, Himachal Pradesh, Meghalaya, Tripura, Uttar Pradesh, West Bengal (mainly Darjiling Hills), Punjab, Haryana, Delhi, Rajasthan, Kerala and Karnataka. Of these, collections made from Meghalaya, Tripura and Darjiling Hills are represented by a good number in National collections at the Zoological Survey of India.

Current Studies

There are revisionary works on the taxonomy of Indian Ichneumonidae by Jonathan (1973, 1980) and Kaur and Jonathan (1976, 1979). These studies were based on the material available at the Zoological Survey of India as well as material borrowed from various museums in India and abroad. These contributions included taxonomic descriptions of 25 genera and 325 species belonging to subfamilies Mesosteninae and Tryphoninae. Of these, 204 species and subspecies are new to science. The new taxa constitute an increase of 17% of the known species of Ichneumonidae from India. The results of the studies of ichneumonid fauna of States of Meghalaya, Tripura, and West Bengal are under publication.

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Animal Resources of India : 457–459 : 1991

DIPLOPODA

Introduction

Millipedes are joint–footed, many segmented, animals having double pairs of legs on each body segment, of which the body coils when disturbed or exudes some badly odourous fluids for self defence. The body (trunk) segments are being formed by the fusion of two originally separate somites. Due to presence of diplosegment, these are grouped as the class Diplopoda of the phylum Arthropoda, though all the body segments are not always diplosegmented. The first post–cephalic segment (column) forms a large collar behind the head and devoid of any legs, while second the fourth segments carry only a pair of legs. Body terminates in telson on which the arms opens ventrally.

Millipeds prefer damp, humid and shady places. Usually they are found beneath the fallen leaves, stones, bark rotten logs and in the soil. Some are seem even in the houses, or underside the thatch of the cottages. They show a wise choice of food preference. They are primarily hervivourous, mostly feed on decaying plant tissue, including leaf, litter, fungi, fruiting bodies and the excrement of herbivorous mammals. A large number of species also consume food of animal origin; some are obviously omnivores.

Millipodes and centipedes were originally included in the class Insecta in which they were retained until Leach (1814) who impressed by their distinctness created a separate class Myriapoda for them. The separation of millipedes was further supported by Newport (1844) and Koch (1817). Subsequently Symphyla and Pauropoda were also included under Myriapoda. On the basis of the anterior gonopore, the millipedes, symphylids are pauropods were transferred under Superclass – Progoneata, and the centipedes with posterior gonopore formed another superclass – opisthogoneata. Thereafter, superclass Progoneata has been further split up into classes Diplopoda, Symphyla and Pauropoda.

Economically the millipedes are important both as friend and foe. A good number of millipedes are found in the agricultural fields, such as jute, cotton banana, guava etc., where they help us in soil aeration as well as humification of the soil. The millipedes play a prominent role in the ecosystem and can be easily called as "Macrodegrader" Millipedes also damage a wide range of horticultural and field crops including beans, peas, cucumbers, cabbage, cereals, potatoes, sugarbeat etc.

Works on the Indian forms of Diplopoda are fragmentry and scattered.

Historical Resumé

Diplopoda have hitherto, received comparatively less attention from scientists then other groups of arthropods.

i) Pre-1900

Pocock (1849) published a monograph on the pill millpedes inhabiting India, Sri Lanka and Burma, in which he described a number of species from India.

ii) 1901-1947

Silvestri (1917 and 1920) studied the Oniscomorpha – Glomeriidae of Oriental region, and described 16 new species of millipedes from India. Carl (1932), a well known diplopodologist,

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explored the South India and published the first chapter of his results on the Indian species of Polydesmoidea. In his monograph he described 41 new species and 23 new genera from India. In 1936 Attems who was also a pioneer worker on this group, published his monographic work on Indian Diplopoda in *Mem. Indian Museum.* Attems has described 62 new species and 15 new genera in this work.

iii) 1948-1900

Krishnan (1968) published a memoir on the millipede *Thyrophygus poseidon*, in which anatomical, ecological and physiological aspects of this species have been discussed. Deka *et al.* (1971) have described a new species of millipede from Assam. In 1987 Enghoff, while revising the genus *Nepalmatolulus* from South east Asia, described a new species from India. A new species of millipede has also been reported by Golovatch (1988). Recently Prasad *et al.*, (1981 and 1985) have described the bioecology of banana inhabiting millipede, *Anoplodesmus saussurei* and a jute field inhabiting millipede, *Streptogonopus pripsoni* from West Bengal. Sen & Mitra (1977) recorded one species *Orthomorpha coaretala* (Saussure), for the first time from India.

Karyological studies in adults of nine Indian species of Diplopoda has been made by Achari (1983). Sukla *et al.* (1980) have also studied the morphology of the malpiglian tubules of a millipede from Gorakhpur (U.P.).

Studies from Different Environs

Informations available on the Indian Diplopoda are published in various scientific journals *viz.*, *Rec. Indian Mus.*, *Mem. Indian Mus.*, *J. Bombay nat. Hist. Soc.* and *J. Assam Sci. Soc.* Among all the parts of India, only South India can be considered as properly explored for this purpose, and out of 162 species of millipedes 93 species are recorded from there alone. Next to South India is West Bengal, from where 32 species of Diplopoda are recognised. From Eastern part (Sikkim, Assam and Meghalaya) 20 species of millipedes are reported. Only 7 species are recorded from Northern parts of India. One species each is reported from Andaman and Nicobar Islands, and Maldive Islands. Diplopoda materials present in the Indian Museum, Calcutta, from Bombay (Maharashtra) and Gujarat have been earlier studied. Altogether 10 species of millipedes were recorded from Maharashtra (Bombay) and two species from Gujarat.

Estimation of Taxa

Diplopoda fauna of India is incompletely known at present. Therefore, an accurate assessment of taxa is not feasible in the present state of knowledge of this group. So far only 162 species belonging to 59 genera, under 12 families, are recorded from India.

Classified Treatment

In India, millipedes are represented by 12 families, *viz.*, Sphaerotheridae (5 genera, 45 species), Glomeridae (one genus, 3 species), Glomeridesmidae (one genus, one species), Strongylosomidae (one genus, one species), Paradoxosomatidae (14 genera, 33 species), Vanhoeffiniidae (4 genera, 8 species), Cryptodesmidae (9 genera, 18 species), Cambalidae (4 genera, 7 species), Harpagophoridae (9 genera, 23 species), Spirobolidae (one genus, one species), Trigoniulidae (5 genera, 6 species) and Pachybolidae (3 genera, 10 species). A large number of Indian species of Diplopoda are recorded from South India, Darjeeling, Sikkim, Assam and Meghalaya, because these have been better explored for this purpose. A few species of the group are also reported from Bombay, Gujarat, Bihar, Uttar Pradesh and Himachal Pradesh.

Current Studies

Presently from the taxonomic point of view nobody is working on millipedes in India. G. S. Sukla, G. Krishnan, K. Bano and S. K. Gokhale are working on the bioecology, cytology, anatomy and physiology etc., of this group, in various universities.

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CHILOPODA : Scolopendromorpha

Introduction

The myriapods are worm-like (Myrias = thread; pedes = feet), multi-segmented, multi-legged, tracheate (*i.e.*, air-breathing through trachea), land arthropods. On the basis of the segmentation of their body and possession of number of pairs of legs per segment the myriapods are divided into four classes: 1. Chilopoda, 2. Diplopoda, 3. Pauropoda and 4. Symphyla. No. 1 is called Opisthogoneate, and Nos. 2-4 as Progoneate.

Although Class Symphyla shows a close resemblance with the insects, the chilopods are the animals from which the present-day insects are believed to have descended. The chilopods are the group of animals which bear one pair of legs per segment. The diplopods, however, have two pairs of legs per segment, which is presumed to be formed by the fusion of two segments.

Both chilopods and diplopods live mainly, hiding in the day time in damp, dark places, under stones, cow dung, flower-pots, bark of trees; in gardens, cultivated and semi-cultivated lands or in the wild.

Economic Importance

The scolopendrid centipedes are animals of economic importance despite the fact that they are poisonous and their bite is painful. They are predators of many species of pests of crops (Khanna, 1977 a). It is evident from the literature that they have been found eating on the millipedes, grubs of some harmful beetles, larvae of butterflies and moths, termites, etc. Even small birds and lizards are often seen to have been eaten by centipedes. At the same time on account of their retiring habits, the centipedes tend to escape by using poison as a mechanism of defence. There are numerous scattered accounts of the ill-effects of their bite (McCann, 1931; Jangi 1984; Khanna and Tripathi, 1984). The centipede-bite may cause Oëdaema, Lymphangites with inflammation of skin and subcutaneous tissues and ulceration, and in most cases, a localised nacrosis may also take place.

Historical Resumé

While no major contribution seems to have been made on the orders Lithobiomorpha, Geophilomorpha and Scutigeromprpha of class Chilopoda, in India, comparatively good accounts on the taxonomy, biology, ecology, myology, locomotion, etc., are available on the centipedes belonging to order Scolopendromorpha.

From the time of Linnaeus (1758) till date not much work on the taxonomy of the Indian Scolopendrid centipedes seems to have been carried out. From the survey of the available literature it is noticed that Haase (1886/87), Pocock (1890, 1891, 1892) Kraepelin (1903), Gravely (1910, 1912a, and 1912b), Silvestri (1919, 1924), Chamberlin (1913, 1920, 1944, 1959), Attems (1930), Verhoff (1937), Jangi (1955a, 1955b, 1956, 1957, 1959 and 1966), Vazirani and Khanna (1976, 1977), Khanna (1977a, 1977b), Ahmed (1980), Khanna and Tripathi (1984a, 1984b, 1985a, 1985b, 1986, 1987 and in press), have made their contributions to the study of this group of centipedes.

A considerable amount of work, has, however, been undertaken by contemporary workers outside India. Noteworthy among them are the works of Bucherl (1946, 1974), Crabill (1955, 1960), Demange (1963, 1967), Dobroruka (1968, 1969, 1973), Lawrence (1953, 1955, 1966,

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1968), Lewis (1966, 1967, 1968a, 1968b, 1973, 1978, 1982 and 1986), Wurmli (1972, 1975), Chelazzi (1977a, 1977b), Koch (1983a, 1983b, 1983c, 1984, 1985a and 1985b), Koch and Bergman (1984) and Koch and Colless (1986).

Workers like Shukla (1965, 1968, 1971 and 1973) have conducted certain researches on the internal morphology and food and feeding habits of the most common centipede *Scolopendra morsitans* Linn. Khanna (1977) has studied the food and feeding habits of *Scolopendra valida* Lucas. He (1984, 1987) has also undertaken the ecological studies on some selected species of centipedes in and around Dehra Dun. Shukla (1974, 1975) has studied the amino-acid contents in different body systems in *Scolopendra morsitans*; Kanwar and Nagpal (1981) on the poison in the centipede *Otostigmus ceylonicus*; Jangi and Dass (1984b) on the centipede venoms; and Khanna and Tripathi (1984) on the harmful and beneficial effects of the scolopendrid centipedes.

Studies from Different Environs

The information available on centipedes from different ecosystems, as at present, cannot be claimed to be complete and comprehensive. The reports of the studies undertaken by previous authors like Chamberlin, Haase, Gravely, Pocock, Attems, etc., were based on stray collections. No efforts had been made to collect them from different ecosystems. Some concerted efforts have been made by Khanna 1977 (Desert ecosystem); Ahmed 1980 (Andaman and Nicobar Islands); Jangi and Dass 1984 (Deccan Plateau); Khanna and Kumar 1984, Khanna and Tripathi 1984, Khanna 1987 (Western Himalayan ecosystem); Khanna and Tripathi 1985 (Terai of Uttar Pradesh) and Khanna and Tripathi (under publication) (Conservation areas), in this direction.

Estimation of Taxa

Out of the 17 genera of the Scolopendrid centipedes known world-over, 8 genera are found in India.

Khanna (1987, thesis) undertook the study on the centipedes of the family Scolopendridae, which in India, is known to be represented by two subfamilies (Otostigminae and Scolopendrinae) and three tribes (Scolopendrini, Asanadini and Otostigmini). These include altogether seven genera *viz.*, *Scolopendra*, *Cormocephalus*, *Asanada*, *Otostigmus*, *Rhysida*, *Ethmostigmus* and *Digitipes*; the first three belonging to subfamily Scolopendrinae and the four to last subfamily Otostigminae. These genera contain, in all, 73 species (including 21 subspecies). Out of these, only five genera *viz.*, *Scolopendra*, *Cormocephalus*, *Asanada*, *Otostigmus* and *Rhysida* are represented in the Western Himalaya, Uttar Pradesh, by 20 species.

A detailed account of taxonomy and distribution of Indian species has been provided by Khanna (1987, thesis) besides providing a checklist. While reviewing the status of the family Scolopendridae in India, he has come to the conclusion that out of the total known Indian species (including subspecies), 71 are Oriental (comprising 59 as fully *endemic*, 10 *Indo-Malayan* and two *Indo-Malayan extending to Australia*); 4 Palaearctic; 7 Ethiopian; one circumtropical and two cosmopolitan in distribution.

Classified Treatment

Class Chilopoda consists of four Orders : 1. Geophilomorpha, 2. Scolopendromorpha, 3. Lithobiomorpha, and 4. Scutigeromorpha. First two orders belong to Epimorpha (body segments complete at the time of hatching), and last two orders belong to Anamorpha (body segments completed after hatching).

The centipede *Craterostigmus tasmanianus* Pocock occurring in Tasmania and Newzealand, occupies a position intermediate between Lithobiomorpha and Scolopendromorpha (Jangi, 1966). It has 15 pairs of legs, 15 sterna and 7 pairs of spiracles, as in Lithobiomorpha but as many as

TABLE 1

Classification of the Order Scolopendromorpha

Scolopendromorpha

SCOLOPENDRIDAE | CRYPTOPIDAE

Scolopendrinae | Otostigminae

Tribe Scolopendrini	Tribe Asanadini	Tribe Otostigmini	Tribe Arrhabdotini
1. *Scolopendra* Linn*	1. *Asanda* Meinert*	1. *Otostigmus* Porath*	*Arrhabdotus* Pocock
2. *Cormocephalus* Newport*	2. *Rhysida* Wood*		
3. *Hemiscolopendra* Kraepelin	3. *Ethmostigmus* Pocock*		
4. *Psiloscolopendra* Kraepelin	4. *Digitipes* Attems*		
5. *Campylostigmus* Ribaut	5. *Alipes* Imhoff		
6. *Rhoda* Meinert	6. *Alluropus*		
7. *Notiasemus* Koch	7. *Congobius* Dobroruka		
8. *Scolopendropsis* Brandt			

(*) Genera marked with an asterisk are reported from India.

21 tergal segments corresponding with equal number of leg-bearing segments of Scolopendromorpha. To justify this peculiar situation, some authors place this 'Relic Centipede' under a different Order Craterostigmomorpha, while others place it under Lithobiomorpha on the basis of number of pairs of legs, sterna and spiracles. Table I may be seen for classification upto genera.

Current Studies

Recently, Jangi and Dass (1984) have described and listed 26 species from Deccan Plateau, (southern Madhya Pradesh, Orissa, Maharashtra, Andhra Pradesh, Goa, Karnataka, Tamil Nadu and Kerala) in India. Khanna and Tripathi (1985) recorded 7 species from U.P. Terai; Khanna and Tripathi (1985, 1986) listed eleven species, including the two new ones from Himachal Pradesh; one new species from Haryana (Khanna and Tripathi, 1987) and 20 species from Western Himalaya, Uttar Pradesh. Besides this, Khanna (under publication) has contributed to the studies of Scolopendrid fauna of Conservation areas like Rajaji National Park, Corbett National Park and Dudhwa National Park. Study of the centipedes collected from NE Himalaya, Rajasthan and Gujarat, and also from the Nanda Devi Biosphere Reserve, are in progress.

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PALAEOSTRACHA : Xiphosura

This class is composed almost entirely of extinct forms. The Xiphosura is only living representative, with only three genera, *viz. Limulus, Carcinoscorpius* and *Tachypleus.*

The members of this order are popularly known as 'king-crabs' or 'horseshoe-crabs' The king-crabs are marine; they are found in shallow water from two to six fathoms deep on sandy and muddy shores and they burrow a short distance in the sand or mud and feed chiefly on worms. Two somewhat variable species of king-crabs, *Tachypleus gigas* (Müller) and *Carcinoscorpius rotundicauda* (Latreille) are common in Indian waters; but little information is available as regards their habits, which seem to differ considerably from those of the Japanese and American forms. It is observed that *Tachypleus gigas* is essentially a marine species, occurring on sandy and muddy bottoms from the tide-line to a depth of 20 fathoms and *C. rotundicauda* is mainly, if not entirely, estuarine. It ascends the river Hooghly at least as far as Calcutta from the open sea, and can live in water that is practically fresh. On the coast of Bengal *T. gigas* breeds at the end of the winter season, i.e., in March. The eggs, which are not very numerous, have a green colour and measure about 3 mm in diameter, are carried on the ventral surface of the abdominal appendages, to which they adhere tightly.

The most familiar of the fossil representatives of the Palaeostracha are the Trilobites.

Extract from *Handbook : Indian Spiders* (Tikader, 1987), a ZSI publication.

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SCORPIONIDA

Introduction

Scorpions are one of the oldest forms of life still to be found on the surface of the earth. They have remained unchanged for hundreds of millions of years. Fossils scorpions resemble the present day scorpions. Hence, they may will be described as one of the living fossils. Scorpions have originated from an extinct group, the Eurypterids, which existed during Silurian period. These eurypterids were acquatic inhabits. First terrestrial scorpions appeared on earth in Europe and North America, during carboniferous period.

The number of recognized world species is about 1500, out of which 102 species and subspecies, distributed in 18 genera and 5 families, are found in India. Scorpions are distributed all over the world, with the exception of Newzealand and extreme south of South America. They are abundant in tropical and subtropical zones. They live partly in habitats such as cracks in the rocks or leafaxill or under barks of a tree or in burrows. They are nocturnal in habit. The majority of species are more or less harmless to human beings; others give painful stings causing swelling and sometimes fever as well; such symptoms usually disappear after one or two days. Some species are dangerous, their sting can lead to death, especially of children. These poisonous scorpions are found in Northern Africa and American desert regions.

The poison from the Sahara Scorpion (*Androctonus australis*) is comparable in strength to that of the cobra snake and can kill a dog within seconds.

Scorpions belong to phylum Arthropoda; subphylum Chelicerata; class Arachnida and order Scorpionida.

Historical Resumé

The studies on scorpions were first began in Europe in the middle of eighteenth century. Linnacus (1758) recognized some species which he put in genus *Scorpio*. Then the study on scorpions gradually drew attention of other naturalists and arachnologists of different parts of world.

i) Pre-1900

The work on Scorpions of British India was done by Gervais (1844), Dufour (1856), Oates (1888), Kessler (1876) and Kreeplin (1893). Pocock (1900) compiled all previous works of different authors on Indian scorpions and published a volume of Fauna of British India, on Arachnida, in which he described all known species and genera of scorpions.

ii) 1901-1947

In the early part of twentieth century, scientists from different institutions took initiative in studying scorpions. Birula (1913-1928) Hirst (1915), Henderson (1915-1919) etc. added much to the knowledge by describing many new species. Apart from working on systematics, scientists took interest in other aspects of scorpions also, such as toxicity, ecology, histology, biology embryology etc. Caius and Mhaskar (1934) carried on research on the toxicity and ayurvedic remedy for the poison of scorpions. Rahimulla (1939) published his works on systematics of scorpions. Tembe and Awati (1940-45) studied the histology of scorpions.

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iii) 1948-1990

Mathew (1948, 1960) made significant contribution on the embryology of some Indian scorpions. Mani (1959) described few new species of the group.

Systematic studies on scorpions from Hazaribagh, Bihar and Western Himalayan ranges were made by Basu (1964). Dubale and Vyas (1968-73) made contributions to the histology of Chela and endosternite and mylogy of feeding apparatus. Sreenivasa Reddy has been working on the systematics of scorpions for more than three decades. He has revised species of the family Ischnuridae. Raj Tilak (1970) studied the burrowing Rabits of some scorpions. Tikader and Bastawade (1977) have been carrying research on the systematics of the scorpions for more than two decades. Tikader (1973) published a list of scorpions in Deecan, India. Tikader and Bastawade (1977) described a new species from Maharashtra Tikader and Bastawade (1983) subsequently studied the Indian scorpions thoroughly and made a valuable publication on the group The Fauna of India, volume on Scorpions. Couzijn 1981 made significant contribution on Indian scorpions by revising genus *Heterometrus* of the family Scorpionidae. Ahamed studied scorpions of West Bengal and his research paper is under publication.

Scientists in the Zoological Survey of India have taken projects on the study of scorpions in different areas of India. The scorpions of Meghalaya and Tripura are being studied by Ahamed.

Studies from Different Environs

Though scorpions are distributed in three different ecological niches, the plain lands, rocky areas and forests, their representatives are found in less number in each area except the first. Hence scorpions of different environs are studied rather collectively.

Zoological Survey of India has made scorpion collections through several faunistic surveys, since its inception. Patchy collections had been made earlier. Among the areas thoroughly surveyed in India so far are : West Bengal, Orissa, Madhya Pradesh, Maharashtra and Punjab. The scorpions in Maharashtra were studied by Tikader and Bastawade in the early seventies. Mani (1959) studied high altitude scorpions and pseudoscorpions from North West Himalaya in late fifties. Recently Ahamed has studied, the systematics of scorpions of West Bengal, Meghalaya and Tripura.

Estimation of Taxa

Scorpionidea comprises only one order Scorpionida, which contains 33 recognized families in the world, out of which 5 families namely Buthidae, Chaerilidae, Vaejovidae, Ischnuridae and Scorpionidae occur in India. It is represented by 102 species and subspecies in India, out of 810 species in the world.

Classified Treatment

Order Scorpionida

Family 1. Buthidae

Ths systematic studies on scorpions were made by Caius (1938) who reported the distribution of *Butheolus melanurus* Kessler. Awati and Timbe (1952) published their work on the morphology, anatomy and bionomics of *Buthus tamulus* Fabricius. In 1964, Basu made some interesting observations on two new species of *Lychas*.

Family 2. Scorpionidae

Bahadur (1952) studied the morphology of the scorpion *Palamnaeus bengalensis* Thorell. Sreenivasa Reddy has been working on different aspects of scorpions since 1959. He has made valuable publications on physiology (1959) and systematics (1970). The embryology of the scorpion *Palamnaeus scaber* Thorell was studied by Mathew (1948). Rao (1967) contributed much knowledge on the feeding apparatus in the scorpion *Heterometrus fulvipes* Koch. Dubale and Vyas (1970) published their work on the histology of a scorpion of the genus *Heterometrus*. In 1980, Couzijn of the Rijks museum Lieden, (the Netherlands), revised the genus *Heterometrus* and described some new species of the same group. Among the scientists of Zoological Survey of India, Mani studied the systematics of high altitude scorpions in 1959.

Subsequently Tikader and Bastawade (1983) have described two new species of the family Scorpionidae.

Family 3. Vaejovidae

Mani (1959) recognized one new species of the scorpion *Scorpiops* (*Scorpiops*) *rohtanensis* Mani. Tikader and Bastawade (1977, 1983) described two new species *Scorpiops (Neoscorpiops) deccanensis* and *S. (Euscorpiops) bhutanensis* of this family. Deoras (1961) studied the Bombay Scorpion and its method for the electrical extraction of venom. Chowdhury and Ganguly (1978) studied some cardiovascular effects of crude scorpion venom.

Expertise

INDIA

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PEDIPALPIDA

These strange animals called 'The Whip-Scorpions', are found in the Oriental Region from India and Sri Lanka to the Fiji Islands and New Herbrides, and extend northwards into China and Southern Japan; Neotropical Region from Brazil northwards into the Southern States of North America. They are absent from Africa, Madagascar, Australia and New Zealand. In their general forms, they bear some resemblances to scorpions; but they can be easily distinguished from scorpions by the form of the pedipalps, of the first pair of legs and of post abdomen.

These arachnids are of moderate or large size, none of them are minute like Microthelyphonida. Cephalothorax is longer than wide, the carapace sometimes segmented posteriorly; the ventral surface narrow and furnished with two or three sternal plates. The first pair of legs are elongated, slender and antenniform, and are modified into feelers. Each first leg consists of six segments: *coxa, trochanter, femur, patella, tibia* and *tarsus;* the tarsus is divided into many segments, the last of which has a rounded tip instead of claws. The rest of legs ambulatory in function, and consists of 7 segments named as above with the addition of a *protarsus* which precedes the three-jointed tarsus; the tarsus bearing three claws; coxae of second and third legs not widely separated in the middle line of sternal area. The abdomen is segmented and consists of 12 somites, represented by tergal and sternal plates. The respiratory organs are two pairs of book-lungs; they open on the posterior edge of the second and third abdominal segments.

The whip-scorpions are of both tailed and tailless forms. In tailed whip-scorpions, the last three abdominal somites are annuliform or cylindrical, forming a movable stalk for the postanal skeletal piece, which consists of a single segment of many jointed caudal flagellum or filament. In the family Schizomidae, this caudal appendage is short, consists of 1-3 segments. The tailless whip-scorpions do not possess any caudal appendage.

This order is divided into three families separated as follows (after Warner 1935) :

1. Cephalothorax longer than broad, with nearly parallel sides; caudal appendage present.......... 2

   Cephalothorax broader than long, with the sides strongly arched; caudal appendage absent .... Tarantulidae

2. Carapace with transverse segmentation posteriorly; caudal appendage short, 1-3 segments ....Thelyphonidae

   Carapace without transverse segmentation; caudal appendage long, many segmented .... Schizomidae

Pocock (1900) revised this group of arachnids in his Fauna of British India (Arachnida), where it was divided into two separate orders-Uropygi and Amblypygi. Indian forms of Uropygi represented by 6 genera and 19 species out of 2 families, where Amblypygi contains 4 genera and 6 species in 2 families. But in this book, these two orders are represented as a single order-Pedipalpida and classified likewise (after Werner 1935). It is felt that there are lot of confusions regarding the taxonomy of Indian forms of whip-scorpions, so a wide revisionary work is needed.

The tailless whip-scorpions are in many ways intermediate between the whip-scorpions and the true spiders. They resemble the former in habits, being found under stones, fallen tree-trunks or in crevices of rocks and termite mounds; and differ in lacking of caudal appendages, abdomen jointed with the carapace by a slender pedicel, these are present in spiders. According to Gravely (1915) the Indian forms of tailless whip-scorpions appear to breed at about the same time of year. The eggs, number of which varies from 15-60 or more, are carried under the abdomen of female. The newly hatched youngs are white, like young scorpions they climb up on the dorsal surface of the abdomen of the mother till their first moult.

Extract from *Handbook : Indian Spiders* (Tikader, 1987), a ZSI publication.

SOLPUGIDA

The Arachnids of the order Solpugida or Solifugae sometimes known as 'false-spiders' or 'Wind-scorpions', are among the most formidable of the terrestrial invertebrates. The solpugida include a moderately large group of curious arachnids which are primitive. They are not considered as rare within the region they inhabit. They are commonly nocturnal and hide away during the daytime. The body of solifuge is hairy and divided into two parts, a prosoma or cephalothorax and an opisthosoma or abdomen which are ten segmented and united to one another with a narrow pedicle as in spiders. The chelicerae are extremely well developed forming two powerful pincers with which they prey is killed. Sometimes these chelicerae are very long as the entire prosoma and they have possibly the most formidable jaws in the animal world.

The legs of the solifugae are quite characteristic. The first pair of legs is long and rather feeble and is not used for walking but is carried stretched out in front and used as additional tactile organs. The remaining legs are true ambulatory limbs, the fourth pair are the strongest of all and bear ventrally five funnel-shaped sensory organs called *malleoli* or *racquet organs.* Among these five organs two on the coxa, two on the trochanter, and one on the trochantella. Each organ consists of a slender basal piece or *stalk,* and an expended distal piece-the *blade.*

Solpugids are nocturnal, exclusively predatory and carnivorous, having an extraordinary voracity. Though they principally are desert forms but they live in forests in India. Some of the species dig holes in the ground, and females at the breeding season live in burrows for the protection of themselves and their youngs. The common food of Solifugae are insects, including hard beetles, they also kill and eat large spiders, scorpions and small lizards. Very little is known about the enemies of Solpugida, but probably they are eaten by insectivorous birds, small mammals and reptiles.

This group of Arachnida is somehow moderately represented from our country. About a century ago, Pocock (1900) dealt with Solifugae in his 'Fauna of British India (Arachnida)' and attempted to workout the Indian forms of this group including only 15 species distributed in 2 families and under 3 genera. After Pocock till today, unfortunately there is no attempt to explore this group of animal in our country.

Extract from *Handbook : Indian Spiders* (Tikader, 1987), a ZSI publication.

OPILIONES

The members of the order Opiliones or Phalangida are the 'harvestmen', the majority of which can be recognised by their long and slender legs and segmented abdomen which is jointed to the cephalothorax across the whole breadth and not by a narrow pedicel as in spiders. The cephalothorax is composed of six segments and is separated from the abdomen by a fairly deep groove. The carapace is generally smooth and, in most species, bears two eyes, which may be rarely absent. The eyes are always situated on a prominent ocular tubercle near the middle of the cephalothorax. The body of harvestmen is usually covered with spines, pointed tubercles and bristles. On the underside of the body, the coxae of the legs almost meet in the middle, so that there is no sternum as in spiders.

The abdomen is composed of 10 segments, but these can be distinguished only in the most primitive suborder Cyphophthalmi, in others not more than 9 tergites are present. The Opiliones are divided into three suborders of which the Cyphophthalmi is the most primitive and other two suborders are Mecostethi and Plagiostethi.

The adults ordinarily hide during day, but at twilight they wander out in search of food. Some species are often found in the fields, where they are congregate in large numbers. Sometimes, they congregate in a similar manner on the tree trunk. The name harvestmen for these creatures was probably suggested by the fact that they are most often seen in the field during harvest time. The Harvestmen are primarily carnivorous and usually feed on fresh or recently dead animal tissues, but they also eat various organic matter such as bread, fat, the gills of fungi, etc.

The Opiliones (harvestmen) are among the most ubiquitous arachnids that are too conspicuous to escape notice, and the Indian subcontinent has a large diversity of harvestmen fauna, rich in variety as well as abundance. But unfortunately in our country practically not much research work has been done on this group. Only Roewer (1929) made some attempts to work out the Indian harvestmen and described 167 species distributed under 40 genera of the subfamily Gargellinae of the family Phalangodidae. There are excellent works on these animals in the European countries and America. Roewer's monumental work on this group "Die Weberknechte der Erde" appeared in 1923 and adopted the Simon's classification and included all harvestmen under three suborders *viz.*, (1) Mecostethi (2) Plagiostethi (3) Cyphophthalmi, with description of about 1,600 species in 12 families.

Extract from *Handbook : Indian spiders* (Tikader, 1987), a ZSI publication.

Animal Resources of India : 479–481 : 1991

PSEUDOSCORPIONIDA

The Order Pseudoscorpionida (or Chelonethi) are small, dorsoventrally flattened arachnida commonly called 'Pseudoscorpions' or 'false-scorpions', which resemble scorpions in the general form of their pedipalps and body, except that the hind part of the abdomen is not narrow as in the post-abdomen or metasoma of scorpions. They have no caudal sting. The body of pseudoscorpion is flattened, which enables these small creatures to live in narrow spaces, as beneath the bark of tree, between the leaves of a book and crevices in buildings. They are generally seclusive in habits, occurring mostly in dark, damp places, beneath the bark, in soil cover, rotten logs of wood, under stones and in poultry houses. A good number of them seem also to prefer to live in the nests of birds. Because of their natural habitat in dark places and their small size these animals escape the notice of the naturalists. The pseudoscorpions have great diversity of form and occur in a variety of habitats. They have not, however, attracted much attention of the zoologists in our country so the number of known species is negligibly small, though they are very common and abundant. Recently, Murthy and Ananthakrishnan (1977), and Sivaraman (1980) have dealt with psedoscorption. They have attempted at a comprehensive compilation of the Indian fauna of this group including about more than 100 species distributed under 47 genera and 13 families. The psedoscorptions fauna is one of the major orders of the Arachnida and in number of species, they take the second place among Arachnida (mites not included). At present about 2,300 species, belonging to 410 genera under 19 families of psedoscorpions are known from the world.

The psedoscorptions are small shy creatures. The dorsal surface of the prosoma or cephalothorax is formed of a large sclerite bearing the eyes and six pairs of appendages : the chelicerae, pedipalps and four pairs of legs. The chelicerate are complexly developed structures which serve as grasping, spinning, cleansing and sensory organs, and are pre-oral in position. Each chelicera is composed of two segments. Their fingers bear a series of complicated structures known as the serrulae and laminae. The serrula exterior is keel-like and set with fine teeth and attached for varying degrees of its length to the movable finger while the serrula interior, attached to the base of the fixed finger, is even more variable in form. A flagellum, formed of setae whose number and shape are valuable taxonomic characters, is also attached to the fixed finger.

The mouth is situated between the basal segments of the six-segmented pedipalps. The pedipalps are enormously developed and resemble the claws of scorpions. They serve as prehensile organs to capture and kill the prey and bear sensory hairs or setae. The immovable finger of the chela has a row of cutting teeth along its inner edge, the last of which is considerably enlarged. Through this passes the duct of the elongated poison gland, which itself is embedded in the finger. In certain families both fingers are equipped with poison glands.

The four pairs of walking legs differ from those of other arachnids, in fact the tibia is unsegmented so that there is no patella. At the same time in many species, the femur is divided into two distinctly segments. The number of tarsal joints is of great systematic value and is the chief character upon which the three suborders of the psedoscorpions are differentiated. According to the basis of the segments on the legs, the order Psedoscorpionida is divided into three suborders. In the suborder Monosphyronida, each leg has six segments: *coxa, trochanter, basifemur, telofemur, tibia* and *tarsus*. In the Diplosphyronida, the tarsus of each leg consists of the proximal metatarsus and the distal telotarsus so that the leg appears to be made up of seven segments. The Heterosphyronida have in the first two legs a single tarsal segment each, whereas each of the third and fourth legs has two tarsal segments. Pseudoscorpions are exclusively carnivorous and feed on living or recently killed prey such as collembolans, psocids, thysanurans and other small insects. They are not usually cannibalistic but cannibalism has been observed in some Indian species like

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Extract from *Handbook : Indian Spiders* (Tikader, 1987), a ZSI publication.

Euryolpium indicum Murthy and Ananthakrishnan, *Calocheiridius beieri* (Murthy) and *Oratemnus indicus* (With). The poison glands seem to serve a definite purpose by secreting a toxic substance by which the prey is usually paralysed. Pseudoscorpions possess poison glands in both the fingers, kill their prey very quickly. The phenomenon is observed in which the chelicerae are cleaned by the chelae. Incidentally one false-scorpion has been observed by Vachon (1949) to rob another of its food after a short struggle.

Large bodied pseudoscorptions belonging to the suborders Monosphyronida and Diplosphyronida, are collected by hand picking from underneath the bark of trees and logs, underneath stone and rotten wood leaves. Medium sized specimens are collected by lifting litter and debris on a piece of white cloth. Bulk collection of the pseudoscorpions in these ways is laborious and time consuming because of their small size. The most efficient method of collecting Pseudoscorpions is the use of Berlese funnels.

An excellent scientific account of the pseudoscorpions with morphological descriptions of the species occurring in France, was published by Simon (1874-1937) and later Bálzan (1891) proposed an excellent classification. The most important pioneer work on the American pseudoscorpions is that of Bank (1895) who gave a synopsis of the species known at that time and described many species from America. After Bank, and more recently there was a monographic revisionary work of the order Chelonethi by Chamberlin (1931) who based his system on an intensive analytical study of the morphology and ecology of these creatures, and introduced the classification which was now generally accepted by chelonethologists. Although the systematic portion of this monographical work deals with the higher categories and deals with only upto the generic level, students will find it indispensable to any serious study of the pseudoscorpions. Most of the American species are listed by Beiel (1932) in his comprehensive treatment of the world fauna. The order is a difficult one for the beginner, because of the requirements in preparation and technique which must be satisfied before any critical study can be attempted.

Chamberlin has divided the order into three suborders, all of which are found in India. They are based on the segmentation of the legs and may be separated as follows :

1. First and second legs with a single tarsal segment, third and fourth legs with two tarsal segments....................Heterosphyronida (Chthoninea)

   Tarsi of all legs with an equal number of segments 2

2. All legs with two tarsal segments, so that the legs have six segments exclusive of the coxae; primitively four-eyed, sometimes secondarily two eyes or blind....................

   ....Diplosphyronida (Neobisiinea)

   All legs with single tarsal segment; always two-eyed or blind....................

   ....Monosphyronida (Cheliferinea)

The Indian pseudoscorptions are represented so far by the following suborders, families and genera:

Suborder Heterosphyronida

Family Tridenchthoniidae

Genus Compsaditha Chamberlin

Family Chthonidae

Genera *Paraliochthonius* Beier, *Tyrannochthonius* Chamberlin, *Lagynochthonius* Beier, and *Lechytia* Balzan.

Suborder Diplosphyronida

Family Neobisiidae

Genus *Microcreagris* Balzan

Family Hyidae

Genera *Hya* Chamberlin, and *Indohya* Beier

Family Ideoroncidae

Genus *Dhanus* Chamberlin

Family Olpiidae

Genera *Calocheiridius* Beier & Turk, *Olpium* Koch, *Indolpium* Hoff, *Parolpium* Beier, *Euryolpium* Redikorzev, *Amblyolpium* Simon, *Indogarypinus* Murthy & Ananthakrishnan, and *Heterolpium* Sivaraman

Family Garypidae

Genera *Garypus* Koch and *Geogarypus* Chamberlin

Family Feallidae

Genus *Fealla* Ellingsen

Suborder Monosphyronida

Family Cheiridiidae

Genera *Pseudocheiridium* Chamberlin and *Apocheiridium* Chamberlin

Family Sternophoridae

Genera *Sternophorus* Chamberlin and *Indogaryops* Sivaraman

Family Atemnidae

Genera *Paratemnus* Beier, *Oratemnus* Beier, *Atemnus* Canestrini, *Anatemnus* Beier, *Micratemnus* Beier, *Catatemnus* Beier, *Stenatemnus* Beier, *Tullgrenius* Chamberlin and *Diplotemnus* Chamberin

Family Chernetidae

Genera *Lamprochernes* Tomosvary, *Indochernes* Murthy & Ananthakrishnan, *Parachernes* Chamberlin, *Pselaphochernes* Chamberlin, *Ochrochernes* Beier, and *Orochernes* Beier

Family Cheliferidae

Genera *Withius* Kew, *Metawithius* Chamberlin, *Hygrochelifer* Murthy & Ananthakrishnan, *Ellingsenius* Chamberlin, *Mecrochelifer* Beier, *Nannocheliferoides* Beier, *Laphochernes* Chamberlin and *Lophochelifer* Beier.

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ACARI : Prostigmata, Astigmata & Mesostigmata

Introduction

The mites belonging to Prostigmata, Astigmata and Mesostigmata (excluding soil forms) have achieved tremendous importance because of their manifold economic importance in agriculture, poultry, medical and veterinary sciences as well as in public health and, therefore, have drawn the global attention. Many members of Prostigmata are very serious pests of agricultural, horticultural and commercial crops and damage directly by feeding and also indirectly by acting as vectors of a dozen plant viral diseases and all these reduce the yield to as much as 50-80% causing economic loss to the tune of several crores of rupees in India. Many members of Astigmata as well as some Prostigmata and Mesostigmata act as parasites of both vertebrates and invertebrates.

Many of those, which parasitize vertebrates also act as vectors, co-operators and aggravators of different types of bacterial, fungal, viral, protozoan, filarial and other diseases. Some of the mesostigmatids and prostigmatids directly suck the blood of vertebrates (including man) and some astigmatids are skin parasites and all these result in itching causing pain, anaemia, pneumonia, tumors, scabies, nodules, skin thickening, loss of hair, loss of weight and vigour, etc. Some even occur in house dust and are responsible for the causation of different respiratory allergies including bronchial asthma, rhinities, etc. to man. A large number of mites of all the three orders occur in stored products of all kinds and cause enormous loss by feeding and destroying the products. However, not all are our enemies as there are many who are our friends too. Three families of Mesogtimata and at least five families of Prostigmata are definitely known as efficient and useful predators of the plant feeding mites and can successfully suppress their population below economic injury levels. Likewise, there are some water mites which are known to feed upon mosquito larvae and thus check their population. The one most important character which separates these group of mites, is the position of stigmata (respiratory aperture) which is present lateral to corae 2nd and 4th in Mesostigmata, at the base of chelicera or gnathosoma in Prostigmata and altogether absent in Astigmata.

These mites are soft bodied, size varying from 0.25 mm (eriophyids and tarsonemids) to 2-3 mm (trobiculids and trombidiids), usually have 4 pairs of legs in adults (exception: Fam. Eriophyidae or gall mites with 2 pairs of legs and podapolipodidae, insect associated mites having 3 pairs of legs in adults, both under Prostigmata). Body may be white or brownish as in many Astigmata/Mesostigmata, brightly coloured or variously coloured as in many Prostigmata, or brilliantly coloured as in water mites. Body is normally round, oval or slightly elongated but most peculiar among mites is the eriophyid mites (gall mites) which are elongated and worm-like. The habitats occupied by members of these orders are diverse ranging from bottom of ocean to snow-clad mountains and so also is their food habits ranging from phytophagous, saprophagous, fungivorous, coprophagous, necterophagous, bacterophagous, predators, blood suckers, lymph feeders, etc. Due to their tiny and obscure nature although this fauna was very inadequately explored earlier but recently due to their growing economic importance and development of more sophisticated optical instruments, more and more studies are being taken up in these groups specially during the last two decades and the number of species what was known in these three groups from India upto 1973, (Prasad, 1974) has almost doubled during the past two decades. Out of the total acarine fauna known from India, which is estimated to be around 2000, these account for around 1500 species. Though no attempt has been made by any one to estimate the total number of species from the world in these 3 groups but according to Krantz (1978) the total acarine species known from the world is 30,000.

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Historical Resumé

i) Pre-1900

Only 5 papers were published during this period dealing with 3 species of mites, one each under Tetranychidae, Eriophyidae and Tenuipalpidae, all from tea plants in Assam and belonged to Prostigmata. Peal (1868) was the first to report a mite from India when he recorded a species of *Tetranychus* on tea in Assam. Subsequently, Green (1890) and Christison (1893) reported one species each of Eriophyidae and Tenuipalpidae on tea. Watt (1898) brought out an account of tea pests of India which included these three mites also.

ii) 1901-1947

58 Papers were published during this period, of which 16 were devoted to plant mites (dealing with 25 species), 1 to stored product mite (1 sp.) 1 to insect associated mite (5 spp.), 4 to water mites (49 spp.) and 3 to vertebrate associated mites (dealing with about 30 species). These included not only new report of species but also descriptions of some new species chiefly in parasitic mites, water mites and plant mites belonging to Prostigmata, Astigmata and Mesostigmata. The noteworthy publications during this period are:

Plant mites: Wood Mason (1901), Hirst (1924), Cherian (1931, 1938), Massee (1933) and Rahman and Sapra (1940) - dealing mostly with tetranychilds and eriophyids (Prostigmata).

Water mites: Daday (1908), Viets (1926), Walter (1928), Lundblad (1934) and Vitzthum (1942).

Parasitic mites: Hirst (1926), Abdussalam (1941), Radford (1946) on reptile parasitic mites; Hirst (1932), Abdussalam (1939), Sen (1940), Radford (1946) on bird parasitic mites and Oudemans (1914), Hirst (1915, 1923, 1924), Ewing (1928, 1937), Abdussalam (1939), Radford (1946, 1948) on mammal parasitic mites.

Other publications dealt with the records of species and some were on etiology of the various diseases caused by these mites to man and his domesticated animals and birds.

iii) 1948-1990

With more realisation of the importance of mites in agriculture, medical and veterinary sciences and invention of more and more sophisticated optical instruments and other aids made the study of mites more elaborate and critical. The first twenty years i.e., during fifties and sixties, the progress was not that rapid as it was in the seventies and eighties as is evident from the fact that while about 740 papers were published during the last two decades that could add over 750 species of these three groups, only 769 species belonging to 277 genera and 102 families were known till 1973 (Prasad, 1974) and that raised the total now to 1480 species belonging to 394 genera under 97 families. Not only mites having economic importance received attention but also many whose economic importance is still doubtful were also worked out for the exploration of mite fauna of India. It is during this period that concerted efforts were made to study various other aspects like morphology, histology, biology, ecology, etiology, chemical control, biological control, karyology and biochemical aspects of some economically important groups besides taxonomy and faunistic surveys and all these resulted in reaching our knowledge to a new height.

As many as 75 papers were published during 1948-1960, of which 30 were on plant mites, 5 papers on insect associated mites and about 40 papers on parasitic mites dealing with mites from reptiles, rodents and other mammals. In plant mites, no serious effort was made for starting the critical taxonomic studies and papers of these period were devoted mainly to records of new agricultural pests/predators. Rao (1951), Puttarudriah and Channa Basavanna (1956), Dutta (1958), Evans (1953), Narayanan & Khot (1959), etc. are some of such publications. Whereas, in parasitic mites, some important contributions were made on Laelapidae, Macronyssidae, Myobiidae and

Spinturnicidae associated with bats and other mammals (Hirigaudar & Bal, 1955, 1956; Strandman & Wharton, 1958 on Macronyssidae; Alwar & Lalitha, 1960 on Laelapidae of rodents and Womersley, 1952 on trombiculids. Wharton & Fuller (1952) listed the trombiculids from India while Audy & Nadchatram (1957), Audy & Womersley (1957), Womersley & Audy (1957), Traub & Morrow (1957), etc. either reported or described many new species of trombiculids from different hosts. Rao & Hiregaudar (1958), Hiregaudar (1958), Audy & Womersley (1957), Womersley *et al.* (1957), etc. contributed on reptile parasitic mites while Singh and Adalakh (1958) and Peshwani (1960) dealt with mites from honey bees and grasshoppers, respectively.

Invertebrate associates: Narayana & Ghai (1961) reported a *Melichares* from Diptera, Krantz & Khot (1962) reported *Treatia* from Hemiptera, Krantz (1965, 1967), Lindquist (1969), Bhattacharyya (1971) dealt with mites from beetles; Prasad (1973) described a moth mite while a number of papers were published on bee mites like: Delfinado (1973), Atwal & Goyal (1971), Putatunda *et al.*, (1984), Putatunda & Kapil (1987), Kapil & Aggarwal (1987), Aggarwal & Sihag (1988), Mathur (1990), etc. The other contributions are Rawat *et al.* 1981 on *Bochartia* (Erythraeidae) infesting Hemiptera, Kulkarni *et al.* (1981) on erythraeid occurring on sorghum shoot fly; Sudarsanam & Murthy (1990) infesting pseudoscorpion, etc. Recently, Mohansundaram and his co-workers (1990), Basit (1990) and Patel *et al.* (1990) recorded many new mites including undescribed species from various groups of insects and through all these as many as 46 spp. are known as per break up given below:

	Family	*Genera*	*Species*
Prostigmata	9	20	30
Astigmata	2	3	6
Mesostigmata	6	9	10
	17	32	46

Vertebrate associates : Bird associates : Contributions came from Lalitha & Alwar (1961,1971,1972,1973), Alwar & Lalitha (1961,1963), Gaud (1961), Sen & Fletcher (1962), Gaud & Mouchet (1963), Alwar (1970), Atyeo *et al.* (1972) etc., on feather mites of poultry birds (*Megninia*, Astigmata); Fain (1963-1969) on ercynetid mites and Kapur and Kaur (1975) on several ectoparasitic species of birds. Recently, Putatunda *et al.* (1981), D'souza & Jagannath *et al.* (1986) and Putatunda *et al.* (1990) contributed on exploration of bird mite fauna belonging to Prostigmata: Pyemotidae, Cheyletidae, Tarsonemidae, Cheyletiellidae, Syringophilidae; Astigmata: Analgidae, Acaridae, Dermoglyphidae, Freyanidae, Protolichidae, Gabucinidae and Mesostigmata: Macronyssidae, Rhinoyssidae, etc.

Reptile associates: Mitchell & Nadchatram (1966) and Nadchatram & Joshee (1966) made some studies on mites occurring on gecko.

Mammal associates: Domrow (1962), Mitchell & Nadchatram (1966), Mitchell *et al.* (1966), Verma (1969), Kulkarni (1973,1988), Kulkarni *et al.* (1979) on the trombiculid mites from mammals; Mitchell (1970), Advani & Vazirani (1981) on bat mites.

Through all these, 327 species in following groups are known:

	Family	*Genera*	*Species*
Prostigmata	12	40	204
Astigmata	16	42	74
Mesostigmata	12	25	49
	40	107	327

Plant associates: An impressive progress was made in the study of plant mites during this period as major parts of the country could be surveyed and that resulted in making many new records and descriptions of new species of all the three orders. Maximum emphasis was laid on the plant feeding groups of Tetranychidae, Tenuipalpidae, Eriophyidae and Tarsonemidae, all under Prostigmata as well as on predatory groups like Phytoseiidae (Mesostigmata) and Stigmaeidae, Cunaxidae, Bdellidae, Anystidae, Tydeidae, Cheyletidae (Prostigmata). In gall/blister/bud mites, (Superfamily : Eriophyoidea) the first monograph on Indian species was brought out by Channa Basavanna (1966) treating 71 species, majority being new. Thereafter, intensive and extensive explorations were undertaken by Mohansundaram (1979-1990) and Chakrabarti and Co-workers (1979-1990) and through publication of over 70 papers nearly 250 species could be added. Gupta (1985) in his Handbook on Plant mites, treated 257 species for which he provided keys, diagnosis, hosts, distribution, etc. Mohansundaram (1990) elaborately dealt with 59 species of *Aceria* describing 33 new species and giving keys for them. Till date, nearly 360 species of this group are known from India. In family Tetranychidae (spider mites), one of the most injurious plant mites, the important contributions in taxonomy of this group are Manson (1963), Menon & Ghai (1968), Channa Basavanna (1971), Prasad (1975, a,b,c), Gupta (1976), Gupta & Gupta (1977-1985), Sadana and his Co-workers (1980-81), Rishi & Rather (1982-1987), Rather (1982-1987), Nassar & Ghai (1981), etc. exploring fauna from major parts of the country including some of the remote areas like NE hill region, Andaman & Nicobar Is., Ladakh etc. Through all these till date about 100 species under 20 genera are known. In addition to taxonomy and faunistic surveys, over 100 papers have been published by different works on biology, seasonal occurrence, host preference, chemical and biological control etc. and reviewing all those is not within the scope of this report and interested workers may refer to Prasad (1974), Channa Basavanna (1981), Channa Basavanna & Viraktamath (1989), Gupta (1985), etc. Gupta (1985) dealt with 82 species of this family from India giving detail informations on diagnosis, hosts, distribution, nature of damage, bionomics and control. In family Tenuipalpidae (false spider mites), also an economically important group being agricultural pests, received considerable attention and, therefore, besides taxonomy, works on various other aspects have also been done and all those have been well reviewed by Gupta (1985), Sadana (1985) and Banerjee (1987). The important papers are Manson (1963), Ghai (1964), Nageschandra & Channa Basavanna (1974), Channa Basavanna & Lakkundi (1977), Gupta & Ghosh (1980), Nassar & Ghai (1981), Sadana & Chabra (1980, 1982), Maninder & Ghai (1984), Ghai & Maninder (1984), Mohansundarm (1909), etc., and through all these 65 species in 10 genera are known. Gupta (1985), in his Handbook, dealt with 53 species. The family Tarsonemidae is not well worked out and only 5 species are known that are associated with plants of those Gupta (1985) dealt with four. Among the predatory plant mites, the family Phytoseiidae has received the maximum attention being recognised world over as potential predators of phytophagous mites. In sixties, a group of workers like Narayanan, Khot, Ghai, Menon, Rao and Bhattacharyya from India while Chant and Muma from USA made some contributions in this family and till end of that decade about 33 valid species were known from India, majority of those were described as new. Thereafter, through a series of papers numbering over 40 Gupta (1969-1989) explored this group from all over the country and in his 'Fauna' volume, the first on Indian mites, dealt with 143 species under 10 genera, for which he provided full descriptions and illustrations besides giving comments on biology of some important species. Recently, Rather and his co-workers from Kashmir also made useful studies of this group and till this time little over 150 species under 10 genera are known from India. Biology, predator-prey reaction, effect of pesticides, etc., have also been studied for a couple of important predators, the references of some of those are available in Gupta (1985,1986,1987). Among other predatory mites under Prostigmata, *viz.* Stigmaeidae, Cheyletidae, Tydeidae, Bdellidae, Cunaxidae and Erythraeidae are very inadequately known and the number of species in these families (associated with plants only) are respectively, 4 spp. (Gonzalez, 1965; Gupta & Ghosh, 1980; Gupta, 1985), 3 spp.(Narayanan & Kaur, 1960; Gupta & Ghosh, 1980, Gupta, 1985), 5 spp.(Baker, 1965; Gupta & Dhooria, 1972, 1974; Gupta and Ghosh, 1980; Dhooria, 1982; Gupta, 1985), 1 sp. (Gupta & Ghosh, 1980), 9 spp. (Gupta &

Ghosh, 1980; Gupta, 1985) and 8 spp. (Khot, 1963-1965; Gupta, 1985). Through all these, 727 species are known as per break up given here:

	Family	*Genera*	*Species*
Prostigmata	14	135	568
Astigmata	1	2	2
Mesostigmata	3	13	155
Cryptostigmata	1	2	2
	19	152	727

Storage associates : Hughes (1961) in his book listed the mites known from India. Prasad (1974) recorded 12 species while Ghai (1976) recorded 29 species from the habitat belonging to all the three groups but Astigmatid mites being dominant. Nagia and Channa Basavanna (1989) in their study reported a total of 53 species of those 24 were astigmatids, 12 were mesostigmatids and 17 were prostigmatids. A considerable amount of works on morphology, histology, etc. were done on mites of Astigmata (*Lardoglyphus, Aleuroglyphus* spp.) occurring on stored fishes and prawns by Pillai (1955–1957) and Vijayambika & John (1973–1981). The other important contributions in this group came from Mathur and Mathur (1983), Abrol *et al.* (1989), etc. Works related to seasonal occurrence, effect of abiotic factors, effect of radiation, etc are also available from India and interested workers may refer to Channa Basavanna (1981) and Channa Basavanna and Viraktamath (1989). So far, a total of 71 species are known as per break up given below :

	Family	*Genera*	*Species*
Prostigmata	5	8	17
Astigmata	6	22	34
Mesostigmata	7	15	20
	18	45	71

Nest associates : So far about 68 species as per following break up are known through the works of Ramchandra Rao and Rajagopalan (1970), Gupta & Chattapadhyay (1977) and Gupta & Paul (1985, 1988). Most of these are from nests of different species of birds. Apart from that only one paper is available from nest other than bird and that is by Gupta and Bhattacharyya (1989) on mite–fauna of squirrel nests which reported 7 mesostigmatids, 3 prostigmatids and 1 astigmatid mites.

	Family	*Genera*	*Species*
Prostigmata	13	23	34
Astigmata	6	6	10
Mesostigmata	7	11	17
Cryptostigmata	6	4	4
Metastigmata	2	2	3
	34	46	68

House dust associates : This includes members of Prostigmata, Astigmata and Mesostigmata. The first report on house dust mites was by Krishna Rao *et al.* (1973) who reported a pyroglyphid mite (Astigmata) from dust at Bangalore. Subsequently, Dixit & Mehta (1973), Gupta & Datta Ray (1975), Shivpuri *et al.* (1977), Dar & Gupta (1979), Dar *et al.* (1974, 1975), Maurya and Zamil (1981), Channa Basavanna *et al.* (1984, 1985), Modak *et al.* (1987), Tandon *et al.* (1989) Kumar *et al.* (1989), etc., made further additions to the house dust mite fauna of India and about 57 species are known as per break up given below. The most important species causing allergies are pyroglyphids, glycyphagids and may be saproglypids, which all belong to Astigmata.

	Family	*Genera*	*Species*
Prostigmata	6	10	12
Astigmata	6	20	27
Mesostigmata	10	12	18
	22	42	57

In addition, several other works are also available on seasonal occurrence, isolation of allergen from mites, comparative faunal study of different types of houses as well as different types of beds, role of mites in causing allergies, etc.

Soil associates (Prostigmata) : Gupta (1981) is the only reference available on Prostigmata occurring on soil and in that 12 species belonging to 10 genera under 4 families have been recorded describing new species as well as recording hitherto unknown genera and species.

Water associates : The most important contribution in Indian water mites during this period is the monograph of Cook (1967) wherein he described 173 species/subspecies belonging to different Indian regions. The majority were described as new. Later, Nayar (1969, a) Tomar & Raychoudhuri (1981, 82) also worked out the water mite fauna and described new species with erection of new genera. Other references are Robaux (1969), Rao (1970) and Kulkarni & Cherwatkar (1983) who also contributed on this group. Through all these a total of 216 species belonging to 57 genera under 23 families are known from India and all belonged to Prostigmata.

Studies from Different Environs

The members of Prostigmata, Astigmata and Mesostigmata occupy two types of habitats like terrestrial (which includes plant associates, soil associates, invertebrate associates, vertebrate associates, storage associates, dust associates and nest associates) and aquatic (including fresh water, interstitial and intertidal zones). The studies in the aforesaid environs are reviewed below very briefly. While reviewing only the taxonomic literature are taken into consideration as the works done in applied aspects specially in some groups like plant associated mites and vertebrate associated mites are so vast because of their tremendous economic importance both in agriculture as well as in medical and veterinary sciences that it will be absolutely impossible to include those in such a brief account. For those, the interested workers may refer to Prasad (1974), Gupta (1985), Gupta (1986), Channa Basavanna (Ed.) (1981), Channa Basavanna and Viraktamath (Eds.) (1988–1989), etc.

Plant associates : As because many of these mites are economically important either as injurious plant pests or as effective predators, this group has received maximum attention and as a result more intensive and extensive surveys were undertaken throughout the country and that resulted in record of 727 species belonging to 53 genera under 20 families, of those the phytophagous forms account for 538 species belonging to 6 families, *viz.* Tetranychidae, Tenuipalpidae, Eriophyidae, Rhyncaphytoptidae, Tarsonemidae and Tuckerellidae while the remaining 189 species belong to two families of Mesostigmata (Phytoseiidae and Ascidae) and 7 under Prostigmata (Stigmaeidae, Tydeidae, Cheyletidae, Anystidae, Cunaxidae, Bdellidae and Erythraeidae are important predators. Among the phytophagous forms, Eriophyoidea is the largest worked out group in which 360 species under 67 genera are known and of those the majority are endemic, may be because these mites are highly host specific. This is followed by Tetranychidae, the most important plant pests (100 spp., 20 genera) and Tenuipalpidae (65 spp., 10 genera). Tarsonemidae and Tuckerellidae are very poorly worked out. Among all those families, there are as many as 30 species that are important agricultural pests in our country. Among predatory mites, phytoseiid mites are the best worked out (over 150 spp., 10 genera) as they are potential predators of mite pests as well as small insects and nematodes. The other predatory groups have not received adequate attention as only a very few species in each family are known which does not constitute even 20% of the fauna likely to occur in India. So far as well worked out groups are concerned, there is a scope for further addition of another 20–30% more if surveys are conducted in some of the unexplored areas like NE hill region, Andaman and Nicobar and Lakshadwip group of Is., Madhya Pradesh, Rajasthan and Kashmir valley.

Soil associates (Prostigmata) : Practically nothing is known about soil prostigmatids although they are no less abundant specially in soil rich with humus. So far, through one stray study from Bihar, only 12 species have been recorded while nothing is known from rest of the country. Because of very tiny nature and having soft, white coloured bodies, these mites evade attention of soil acarologists and even there are many who mistake these as juveniles of other dominant soil inhabiting forms like mesogtigmatids, cryptostigmatids, etc. Hence, a vast scope exists to work in this group.

Invertebrate associates : Among the mites associated with insects, those parasitising the honey bees both externally as : Laelapidae : *Euvarooa, Tropilaelaps, Varooa* and internally as Scutacaridae : *Acarapsis* have received serious attention because of being important pests of bees which often kill the entire colonies. A good amount of work has been done both on taxonomy and other basic aspects like morphology, anatomy, biology, behaviour, etc., and applied aspects like control. Some of the relevant works have been reviewed under historical resumé. Besides, reports are also on mites associated with Orthoptera (Romeschandra and Mittal, 1981; Mohansundaram & Chinniah, 1990), Coleoptera (Chinniah and Mohansundaram, 1990), Lepidoptera (Prasad), Hemiptera (Krantz and Khot, 1962, Rewat, 1981), Diptera (Chirwatkar & Sharma, 1990), Pseudoscorpion (Sudarsanam and Murthy, 1990) and Bivalves (Pal & Majumder, 1990). Through these only a fragmentary knowledge about mite fauna of invertebrates has been collected. Majority of the species recorded so far belong to families Erythraeidae, Pyemotidae, Podapolipodidae, Tarsonemidae and Trombidiidae under Prostigmata; Ameroseiidae, Podocinidae, Otopheidomenidae, Laelapidae among Mesostigmata and Acaridae and Saproglyphidae among Astigmata. The distribution of majority of the species is restricted to India only. Since most of the insect groups as well as other invertebrates like millipedes, scorpions, pseudoscorpions, molluscs, etc., have not been examined thoroughly and as they are known to harbour mites, it is expected that more thorough surveys, if made, will yield many more species.

Vertebrate associates : From the previous review it is clear that this group has received wide attention since the beginning of the acarological works in the country and as many as 327 species under 40 families and 107 genera are so far known. The major families that are involved are : Prostigmata : Trombiculidae (chiggers), Pterygosomidae (lizard mites), Cheyletidae, Demodicidae (follicular mites), Myobiidae (hair mites), Pymotidae, Tarsonemidae (itching mites), Cheyletiellidae, Syringophilidae, Harpirhynchidae (hair mites); Astigmata : Analgidae, Dermoglyphidae, Falculiferidae (feather mites), Epidermoptidae (skin mites), Cytoditidae (air sac mites), Psoroptidae and Sarcoptidae (menge mites), etc., and among Mesostigmata: Dermanyssidae, Macronyssidae, Laelapidae, Raillietidae (all blood suckers), Spinturnicidae (bat mites), Rhinonyssidae (nasal passage mites), etc. The most dominant one is Trombiculidae which is known by 166 species. Among the vertebrates, the maximum emphasis has been laid on mite fauna of birds (poultry birds, caged birds and wild birds), rodents, domesticated animals, reptiles (snakes, lizards), amphibians (frogs) and human beings. These mites parasitize the vertebrates and while sucking the blood, inject some pathogenes, microbial organisms like bacteria, spirochaetes, protozoans, rickettsia, etc., causing virulent diseases which may cause heavy mortality. The trombiculids caused great concern to U.S. Army because of posing serious health hazards causing Typhus during and after World-War II that led to the establishment of U.S. Army Typhus Commission, Scrub-Typhus Research Laboratories, British War Office Unit and all these helped considerably to explore this group of mites. The number of species known during various times are 63 (Audy, 1954), 93 (Prasad, 1974), 123 (Kulkarni, 1978) and 166 upto the present time. Next to this, the mites of the families Psoroptidae, Sarcoptidae, Analgide and Dermanyssidae are of importance. The Pyroglyphidae causes bronchial asthma, rhinities and other respiratory allergies. Although a good amount of informations are available on mites of this group but yet more surveys in general and from birds, reptiles and amphibians in particular are needed which will help in further addition to the fauna.

Storage associates : There is hardly any granary or storage house which is not occupied by diverse groups of mites. Of these, some are grain feeders, some are fungivorous, a few are predators and others are coprophagous. Among Astigmata, the members of the families Acaridae (*Acarus, Lardoglyphus, Rhizoglyphus, Tyroborus, Tyrophagus*), Glycyphagidae (*Glycyphagus, Lepidoglyphus*), Carpoglyphidae (*Carpoglyphus*), among Prostigmata, Cheyletidae (*Cheyletus*) and among Mesostigmata, Ascidae (*Lasioseius*) and Uropodidae (*Fuscuropoda*) are some of the mites to be available in any storage house. Some of them (Astigmata) feed upon the grains or other stored products and damage their qualitative value while others like Cheyletidae feed upon these injurious mites. Although 71 species belonging to 45 genera under 18 families are known but these are mostly from stored grains while either nothing or very little is known from other storage like drugs, leather, pulses, spices, various farinaceous products, dry fishes, etc. from major parts of the country. Therefore, it is obvious that such study will prove profitable in exploring mite fauna from these habitats. The majority of the so far reported species also occur on other parts of the world and show very little or no endemism at all.

Nest associates : Nest fauna includes mites belonging to Prostigmata, Astigmata, Mesostigmata, Cryptostigmata and Metastigmata but the first three are most dominant and the other two are very infrequent. Mites of the genera *Ornithonyssus, Macronyssus, Steatonyssus, Laelaps* (all under Mesostigmata) are blood feeders and their occurrence in nests is accidental being dropped into nest form host body (birds) while fluttering of wings. The members of the families Acaridae, Glycyphagidae (under Astigmata) and Tarsonemidae (under Prostigmata) are probably fungus feeders while majority of the others specially those belonging to Bdellidae, Stigmaeidae, Cunaxidae, Raphignathidae, Tydeidae (all under Prostigmata) are predators feeding upon the acarid mites. Some mites as Tetranychidae, Tenuipalpidae (Prostigmata) which are plant mites and have also been recorded in nests probably got entry there through nesting materials like leaves, twigs, etc, while some such mites as Ameroseiidae, Macrochelidae (Mesostigmata) infested nests through the insects (where these mites remain as phoretic) which occur in nests either independently i.e., they visit nests themselves or they are brought there by the birds for feeding to their young ones. Excepting one, all the studies so far conducted are from nests of 16 spp. of birds and only one is from squirrel nest. The major study was done in West Bengal and only one was from Pune. Therefore, nothing is known from remaining parts of the country as well as from nests on major bird species. A conservative estimate will show that less than 25% of the nest mite fauna is known. Considering this, it appears that this environ shows promise for the future workers and exploration of fauna not only from bird nests but also from nests of rodents will unravel the acarine faunal diversity.

House dust assocites : By now it is well documented that house dust is an important source of inhalant allergin causing bronchail asthma, rhinities and several respiratory allergies and mites of the family Pyroglyphidae (*Dermatophagoides, Euroglyphus, Pyroglyphus*) under Astigmata are intimately associated in producing these allergies. Therefore, mite fauna of this habitat has drawn attention not only of acarologists but also of medical scientists and a total of 57 species have been recorded in dust. The order Astigmata constitutes as the largest group being represented by 27 species (6 families, 20 genera) and three of those, as earlier stated, are the actual causative agents for the allergies. Among the remaining mites, some are predators (Bdellidae, Cunaxidae, Stigmaeidae – under Prostigmata), some are saprophagous/fungivorous while the occurrence of others in house dust is accidental. It may be noted that there is a striking similarity in fauna composition of house dust and storages as both the environs have almost the same groups of mites. In a broad sense, the fauna of bird nests also shows similarity with that of storages and house dust except the occurrence of the blood sucking forms which are found only in nests and not in the other two habitats. From the knowledge already available, it is estimated that still another 25% remains to be discovered if further explorations throughout the country are made. Excepting a couple of genera and species of Astigmata, the majority are cosmopolitan while in case or Prostigmata, the species are mostly endemic.

Water associates : As has already been mentioned, the members of Prostigmata are the only ones which are available in water and so far 216 species under 57 genera and 23 families are known from Indian water. The majority of the species are endemic. Some of these also are known to parasitise bivalves and a few act as biocontrol agents of dipteran larvae. Since the water mite fauna is very rich and a high degree of faunal diversity exists, it is obvious that more intensive studies will add further to our knowledge.

Estimation of Taxa

Total number of species, genera and families groupwise is given in Table–1. The family wise break up of species and genera in each order is given in Tables 2-4.

TABLE 1 Total number of families, genera and species

	Family	*Genera*	*Species*
Prostigmata	52	261	1093
Astigmata	28	72	140
Mesostigmata	17	61	247
	97	394	1480

TABLE 2 Prostigmata : Familywise break up of genera and species

	Family	*Genera*	*Species*
1.	Anisilsiellidae	6	10
2.	Anystidae	2	2
3.	Aturidae	4	15
4.	Axonopsidae	8	28
5.	Bdellidae	5	8
6.	Cheyletidae	15	31
7.	Cheyletiellidae	3	4
8.	Cryptognathidae	1	1
9.	Cunaxidae	5	14
10.	Demodicidae	1	3
11.	Eriophyidae	57	330

	Family	Genera	Species
12.	Erynetidae	1	2
13.	Erythraeidae	8	29
14.	Eupodidae	1	1
15.	Eylaidae	1	2
16.	Halacaridae	1	1
17.	Harpagopalpidae	5	38
18.	Harpirhynchidae	1	2
19.	Hydrachnidae	1	7
20.	Hydrodromidae	2	5
21.	Hydrovolziidae	2	3
22.	Hydrophaitidae	2	3
23.	Hygrobatidae	4	22
24.	Iolinidae	2	2
25.	Lebertiidae	2	3
26.	Limnesiidae	2	7
27.	Limnocharidae	2	2
28.	Mideopsidae	1	4
29.	Myobiidae	2	4
30.	Pioniidae	2	6
31.	Podapolipodidae	2	3
32.	Protziidae	3	9
33.	Pterygosomidae	3	11
34.	Pyemotidae	3	8
35.	Raphignathidae	2	4
36.	Rhyncaphytoptidae	10	30
37.	Scutacaridae	2	2
38.	Sperchonidae	1	3
39.	Stigmaeidae	7	15
40.	Syringophilidae	1	5
41.	Tarsonemidae	5	10
42.	Tenuipalpidae	10	65
43.	Tetranychidae	20	100
44.	Thermacaridae	1	1
45.	Thyasidae	2	2
46.	Torrenticolidae	2	20
47.	Trombiculidae	23	166
48.	Trombidiidae	5	6
49.	Tuckerellidae	1	3
50.	Tydeidae	4	11
51.	Unionicolidae	3	22
52.	Hungarohydracaridae	2	8
		261	1093

TABLE 3 Astigmata : Familywise break up of genera and species

	Family	*Genera*	*Species*
1.	Acaridae	10	21
2.	Alloptidae	1	2
3.	Analgidae	7	16
4.	Anoetidae	2	5
5.	Avenzoaridae	2	4
6.	Carpoglyphidae	1	2
7.	Chortoglyphidae	1	1
8.	Cytoditidae	1	4
9.	Demoglyphidae	2	4
10.	Epidermoptidae	3	4
11.	Falculiferidae	1	2
12.	Freyanidae	2	2
13.	Glycyphagidae	9	17
14.	Knemidocoptidae	1	2
15.	Kramerellidae	2	2
16.	Lardoglyphidae	1	1
17.	Listrophoridae	1	1
18.	Myalgesidae	1	1
19.	Proctophyllodidae	2	7
20.	Protolichidae	1	1
21.	Psoroptidae	2	3
22.	Pterolichidae	5	7
23.	Pterophagidae	1	2
24.	Pyroglyphidae	4	9
25.	Saproglyphidae	4	8
26.	Sarcoptidae	3	10
27.	Syringobiidae	1	1
28.	Teinocoptidae	1	1
		72	140

TABLE 4 Mesostigmata : Familywise break up of genera and species

	Family	*Genera*	*Species*
1.	Ameroseiidae	3	7
2.	Ascidae	7	18
3.	Dermanyssidae	3	4
4.	Digamasellidae	1	1
5.	Eviphididae	1	2
6.	Laelapidae	11	20
7.	Macrochelidae	2	3

	Family	Genera	Species
8.	Macronyssidae	5	17
9.	Otopheidomenidae	3	3
10.	Parasitidae	1	1
11.	Phytoseiidae	10	150
12.	Podocinidae	2	2
13.	Rhinonyssidae	3	3
14.	Rallietidae	1	1
15.	Spinturnicidae	5	11
16.	Urodinychidae	1	1
17.	Uropodidae	2	3
		61	247

Analysing the data given in Tables it appears that the maximum number of species is known in Prostigmata because it contains species that are of significant economic importance. Since no attempt has ever been made to estimate the world fauna in majority of the families barring a few like Phytoseiidae (approx. sp. 1000), Tenuipalpidae (apporox. 580 spp.), it is very difficult to throw any light on majority of the families as to how much of the world fauna is represented from the Indian subcontinent. Likewise, as majority of the adjoining parts of the continent still remain to be explored (except plant mites) and whatever distributional data available are patchy, it is rather risky, at least at this stage, to make any comment about the degree of endemism shown by the Indian genera and species in general. However, some groups like water mites and eriophyids and may be tenuipalpids also which show high degree of endemism at species level and in eriophyids it is fairly high at generic level also. The Phytoseiidae, another well worked out group, also shows endemism by 40% in species level and 20% in generic level. In Trombiculidae, the genera are well distributed. Majority of the genera in Astigmata known from India are cosmopolitan.

Classified Treatment

Astigmata

It includes 28 families, 72 genera and 140 species. Members of this group are mostly inhabitants of house dust, storages, some are ectoparasites of vertebrates and a few occur in bird nests. The families Acaridae, Glycyphagidae, Saproglyphidae, Chortoglyphidae, etc. are represented in storages, house dust and bird nests while other like Cytoditidae, Dermoglyphidae, Falculiferidae, Knemidocoptidae, Listrophoridae, etc. are parasites. The environ wise major works in this group are cited below :

Storgae associates : Pillai (1956) described a new species of *Glycyphagus*. Hughes (1961) listed the stored grain mites known from India. Vijayambika & John (1973–81) elaborately dealt with morphology, histology of *Lardoglyphus konoi*. Cicilykutty & John (1981) studied the dry fish mite, *Suidasia medanensis*. Mathur (1979) and Mathur & Mathur (1983) recorded species of *Suidasia*, *Tyroborus*, *Austroglycyphagus*, *Glycyphagus* from storages in Haryana. Nangia & ChannaBasavanna (1989) reported 10 astigmatid mites belonging to genera *Acarus*, *Caloglyphus*, *Lardoglyphus*, *Rhizoglyphus*, *Tyrophagus*, *Thyreophagus*, *Tyroborus* and *Tyrolychus*.

Dust associates : Dar & Gupta (1979) reported several astigmatid mites from house dust. Ranganath *et al.* (1982) described new species of Acaridae and Saproglyphidae. Krishna Rao *et al.*

(1981) reported species of Chortoglyphidae, Pyroglyphidae, Acaridae, Glycyphagidae and Saproglyphidae from dust in Karnataka. Kumar *et al.* (1988), Tandon *et al.* (1988) and Kumud *et al.* (1988) studied the dust mite fauna from H.P., W. Bengal and Haryana, respectively and recorded several species of Glycyphagidae, Acaridae, Saproglyphidae, Pyroglyphidae, Carpoglyphidae, etc.

Vertebrate associates : Abdussalam (1939) described a new species of *Rivoltasia* from chicken. Fain & Bafort (1964), Fain (1964), Sen & Fletcher (1962), Misra *et al.* (1972) recorded several species of Cytoditidae and Sarcoptidae. Mitchell (1970) reported species of *Teinocoptes*. Naik (1935-1938), Sen (1932), Sen & Fletcher (1962) reported several species of *Sarcoptes*. Alwar & Lalitha (1961, 63), Alwar *et al.* (1958), Lalitha & Alwar (1960, a, b, c, 71, 72, 73), Gaud (1961), Gaud & Mouchet (1963), Atyeo *et al.* (1972) made significant contributions on the families Analgidae, Epidermoptidae, Falculiferidae, Pyroglyphidae by reporting or describing new species from several hosts. D'Souza & Jagannath (1980, 82, 86) recorded mites of Analgidae, Pterolichidae, Kramerellidae, Syringobiidae, etc. from different birds. ChannaBasavanna *et al.* (1982) described a new species of *Caloglyphus*. Putatunda (1990) reported a new mite of *Trouessartia*.

Nest associates : Gupta & Chattopadhyay (1979), Gupta & Paul (1985, 1989) recorded species of Glycyphagidae, Acaridae, Analgidae, Pterolichidae, etc. from birds' nests.

Invertebrate associates : Hiregaudar (1956) described a new species of *Myalges* from pigeon fly. Putatunda *et al.* (1984) described 2 new species of *Kuzinia*.

Prostigmata

Altogether 1093 species belonging to 261 genera under 52 families are so far known from India, of these the families Tetranychidae, Tenuipalpidae, Eriophyidae, Rhyncaphytoptidae are exclusively phytophagous, the families Bdellidae, Cunaxidae, Anystidae, Tydeidae, Stigmaeidae, Cheyletidae, Erynraeidae and Raphignathidae are predators of phytophagous mites, some are parasitic and 23 families are aquatic. Important works environ-wise are given below :

Vertebrate associates : Oudemans (1914), Hirst (1915), Ewing (1925, 31), Abdussalam (1939), Radford (1946, 48), Womersley (1952), Womersley & Fuller (1952), Traub (1949), Traub & Evans (1956), Rao & Hiregaudar (1955), Hiregaudar (1957, 58), Audy & Nadchatram (1957), Audy & Womersley (1957), Traub & Morrow (1957), Womersley & Audy (1957), Domrow (1962), Joshee (1960), Mitchell *et al.* (1966), Mitchell & Nadchatram (1966), Verma (1967, 69), Verma & Nadchatram (1971, 1972), Bhat (1971), Kulkarni (1973-1988), Kulkarni *et al.* (1979) made valuable contributions on trombiculid mites and through these many species were either described or reported from India. Hirst (1926) described several new species of *Geckobia* and other genera from Indian lizards. Mitter (1912), Naik (1931, 37, 39), Sen & Fletcher (1962), Das & Misra (1972) studied Demodicidae. Fain (1963, 69) described new species of Erynetidae from birds. New species of various prostigmatid groups were described by Prasad (1975) in *Bharatoliaphilis*, Putatunda *et al.* (1988) in Pygmephorus, etc. Putatunda *et al.* (1989) recorded several species of Pyemotidae, Tarsonemidae, Cheyletidae, Cheyletiellidae, Syringophilidae and Harpirhynchidae from birds.

Invertebrate associates : Mitra & Mitra (1953) described a new species of *Stigmaeus* from Phlebotomus fly. Putatunda & Kapil (1988) described 7 new species of *Cheletophyes* from bees. Peshwani (1960) recorded a species of *Eutrombidium* from grasshopper. Mohansundaram and his co-workers (1990) recorded a number of species of *Locustacarus, Leptus, Pygmephorus, Pyemotes* from insects.

Nest associates : Ramachandra Rao & Rajagopalan (1970) reported species of Trombidiformes, Smariidae, Hydrachnellae, etc. from bird nests. Gupta & Chattopadhyay (1979), Gupta & Paul (1985), Gupta & Paul (1989) reported or described several species of Cheyletidae, Stigmaeidae, Tydeidae, Raphignathidfae, etc.

Dust associates : Gupta & Datta Ray (1976), Krishna Rao *et al.* (1981), ChannaBasavanna *et al.* (1984), Tandon *et al.* (1988), Kumud *et al.* (1988) and Kumar *et al.* (1988) reported several mites of Cheyletidae, Erythraeidae, Cunaxidae, etc.

Water associates : Daday (1908), Viets (1926), Walter (1928), Lundblad (1934), Cook (1967), Nayar (1969), Tomar & Raychaudhri (1981, 1982) dealt with the entire mite fauna from India.

Plant associates : Since a detailed discussion has already been made in the historical resumé as well as it is elaborately given in Gupta (1985, 1986) and Prasad (1974), these are not repeated here.

Mesostigmata

The fauna is represented by 247 species belonging to 61 genera under 17 families, of these, Phytoseiidae, Ascidae, are predators, Uropodidae, Urodinychidae, Digamasellidae, Ascidae occur in storages, nests and remaining are parasites (Spinturnicidae, Raillietidae, Macronyssidae, Laelapidae) of birds and mammals (externally as blood feeders), Rhinonyssidae (internal parasite of nasal passage of birds) while Otopheidomenidae are insect parasites. The important works as per different environs are given below :

Invertebrate associates : Krantz & Khot (1962) described *Treatia indica* from red cotton bug. Prasad (1973) described a new species of *Otopheidomenis* from sphingid moth. D'Souza & Jagannath (1986) recorded *Macrocheles muscidomesticae* from house fly. Bhaskar & Putatunda (1989) dealt with mesostigmatids associated with bees. Vishnupriya & Mohansundaram (1990) reported new *Fuscuropoda* and *Dinogamasus* from insects.

Vertebrate asociates : Hirst (1922) described a new *Liponyssus.* Hiregaudar (1955), Gupta & Basu (1932), Naik (1936) recorded species of *Dermanysssus* and *Ornithonyssus.* Alwar & Lalitha (1960) recorded species of *Androlaelaps.* Hiregaudar & Bal (1956) and Advani & Vazirani (1981) described many species of Spinturnicidae, Macronyssidae and Laelaidae infesting bats. Putatunda *et al.* (1989) reported species of Rhinonyssidae, Blattisocidae, Macronyssidae, from birds.

Nest associates : Gupta & Paul (1985, 89) recorded species of Laepidae, Macronyssidae, Dermanyssidae, Phytoseiidae, Ascidae, Ameroseiidae from bird's nest.

Dust associates : Kumud *et al.* (1988), Tandon *et al.* (1988) and Kumar *et al.* (1988) recorded species of Ameroseiidae, Uropodidae, Dermanyssidae, Parasitidae, etc. from dust.

Plant associates : The relevant works have been reviewed in the historical resumé given earlier as well as are given in detail in Gupta (1985, 1986, 1987) and Prasad (1974).

Current Studies

In ZSI

Work is being carried out on plant associated mites embracing all the three groups and both intensive and extensive surveys are taken up throughout the country to bring out State Fauna volumes. Recently some work has been started from storages in and around Calcutta. Works are also going on nest associated mites and soil Prostigmatid mites as well as mites associated with house dust.

Elsewhere

A concerted effort is being made not only to explore the plant mite fauna of different regions of the country but also to study the biology, ecology, control, etc. of some of the economically important species through the All India Co-ordinated Research Project in Agricultural Acarology, founded by the I.C.A.R. is being operated in 10 centres like Univ. of Agric. Sci., Bangalore and Dharwad; Tamil Nadu Agric. Univ., Coimbatore; Gujarat Agric. Univ., Navasari; Banaras Hindu Univ., Varanasi; Haryana Agric. Univ., Hisar; Rajasthan Agric. Univ., Bikaner; B. C. Krishi Viswavidyalaya, Kalyani and Punjab Agric. Univ., Ludhiana.

Work on plant feeding mites is also being conducted in different agricultural universities/institutes/traditional universities through ad-hoc research projects funded by various funding agencies like I.C.A.R., D.S.T., U.G.C., Kalyani, Calcutta, Tripura and Calicut Univ., TNAU (Madurai), YSPU (Solan), IIHR, IARI, ICRISAT, CPCRI, SEKU, etc. Works on parasitic mites are being carried out in NIV (Pune) (Trombiculid mites) as well as in UAS (Bangalore, Dharwar). Mites associated with stored grains and dust are being tackled at HAU (Hisar), School of Trop. Med. (Calcutta) (dust), DAV College (Chandigarh), YSPU (Solan), etc. Mites associated with invertebrates are being worked out in HAU (Hisar), TNAU (Madurai). At present no centre is known where work is being carried out on water mites.

Expertise

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ACARI : Soil Mesostigmata

Introduction

The mesostigmata is a large cosmopolitan group of acarina which occurs in diverse habitats. The majority are free-living in soil, moss, various litters, compost heaps, decaying plant and animal parts and manure. Many are adapted to life as parasites of vertebrates and invertebrates. The soil inhabiting mesostigmatids are most abundant in the soil and are represented by more than 4000 species under an approximate number of 500 genera.

Mesostigmatid mites range in size from 200 - 2000 μm. The adults possess a number of distinct chestnut-brown shields on the dorsum and venter. The identifying characteristics of this order include: a pair of lateroventral or laterodorsal stigmatal openings at the level of coxae II - IV, a basal palptarsal claw with two or three tines, a pair of horn-like corniculi at the terminus of the hypostome, an unpaired tritosternum and chelate-dentate chelicerae.

The soil mesostigmatids are mostly mycophagous and consume fungi in ground and storage situations. The predaceous ground species feed on small arthropods or their eggs, on nematodes, and occasionally on each other. Many of the predatory mites are used as biotic agents for the control of housefly and other insect pests. They also play an indirect role in the process of humification.

Classification

The outline classification of the Suborder Mesostigmata as proposed by Krantz (1978) is given below:

Class	Arachnida
Subclass	Acari
Order	Parasitiformes
Suborder	Gamasida (Mesostigmata)
Supercohort	Monogynaspides
a. Cohort	Sejina
Superfamily	1. Sejoidea
b. Cohort	Gamasina
Superfamily	1. Parasitoidea, 2. Rhodacaroidea, 3. Ascoidea, 4. Phytoseioidea, 5. Eviphidoidea, 6. Heterozerconoidea, 7. Dermanyssoidea
c. Cohort	Uropodina
Superfamily	1. Thinozerconoidea, 2. Polyaspidoidea, 3. Uropodoidea, 4. Diarthrophalloidea
Supercohort	Trigynaspides
a. Cohort	Cercomegistina
Superfamily	1. Cercomegistoidea
b. Cohort	Antennophorina
Superfamily	1. Antennophoroidea, 2. Aenictequoidea, 3. Celaenopsoidea, 4. Megisthanoidea, 5. Fedrizzioidea, 6. Parantennuloidea

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Historical Resumé

Hermann (1804) first reported soil-dwelling mesostigmatid mite from European soils. Later, C.L.Koch (1836-1841)described soil mesostigmatids from Europe. In the beginning of the twentieth century, acarologists took up studies on the systematics of mesostigmatid mites in an extensive way. The pioneer workers who made valuable contributions in this field are Michael (1880-1884), Berlese (1887-1916), Oudemans (1896-1937), Willmann (1925-1951) and Grandjean (1928-1972). On the contrary, studies on the soil mesostigmatids in India is still in its childhood. It is only in the beginning of the twentieth century, the Mesostigmata of Indian soils attracted acarologists for research.

i) 1901-1947

The first report of soil Mesostigmata from India was made by Ewing (1910). He described three species from the soils of Nilgiri Hills in Tamil Nadu.

ii) 1948-1990

After a long gap of about 50 years after Ewing, extensive study of soil mesostigmatid mites was started in India at the beginning of the year 1965 when S. K. Bhattacharyya, the pioneering acarologist in India, joined the Zoological Survey of India. His first contribution in the field contained the description of one species and record of another species from West Bengal (1965). In the same year Deb and Raychaudhuri (1965) of the University of Calcutta described one species from West Bengal. In subsequent years, Bhattacharyya (1966-1972) made extensive studies on Mesostigmata from the soils of Assam, Arunachal Pradesh, Meghalaya and West Bengal, and described 38 species and recorded 17 species for the first time from India. During this period, Pramanik and Raychaudhuri (1968) described one species from West Bengal and Singh and Mukherji (1971) of Banaras Hindu University reported twelve species as new to science and also added three more species to the list of mesostigmatid fauna of India. During the period from 1978 to 1983, there was no report on the studies of this group of mite, except the record of a new species from West Bengal by Pramanik and Raychaudhuri (1979). Later, in the early eighties, A.R.Datta and R.K.Roy, both of Dibrugarh, Assam, were interested to work on soil inhabiting mesostigmatid mites. Datta (1984) described two new genera, viz., *Forkosclerite* and *Funkotriplogynium*, three new species and new combinations of three known species from Assam. In the year 1988 Datta added another new genus *Krantzolaspina* from Assam. The first record of Mesostigmata from the soils of Bihar was made by Sengupta and Sanyal (1986). Roy (1988) published reports of his extensive survey of soil mesostigmatid mites of Assam, Arunachal Pradesh, Andhra Pradesh, Delhi, Goa, Karnataka, Kerala, Maharashtra, Meghalaya, Nagaland, Orissa, Pondichery, Sikkim, Tamil Nadu, Tripura and West Bengal. The papers included the description of seven new species and ten new records of the mesostigmatid species. In India, this group of mites have not yet been explored thoroughly. So to explore the soil mesostigmatid fauna of the country, extensive and systematic surveys in all the states are urgently needed.

Studies from Different Environs

Singh and Mukherji (1971) while studying the qualitative composition of soil arthropods in five different fields at Varanasi, Uttar Pradesh, reported twelve genera and six species. The populations were low but their distribution were similar. Bhattacharyya (1978) reported one genus, *Macrocheles*, from the soil of Santiniketan, West Bengal, and studied the possible correlation between the mite population and edaphic factors. Singh and Pillai (1981) studied the community structure of soil acarina at Varanasi and recorded five genera of mesostigmatid mites. Sengupta and Sanyal (1986) studied the habitat preference of 15 species of Mesostigmata in Bihar soils. In another study, Sengupta and Sanyal (in press) discussed the ecology of some mesostigmatid species of a paddy field in West Bengal.

Estimation of Taxa

The knowledge of Indian soil Mesostigmata is far from complete and hence it is difficult to assess the taxa accurately. Till date, nearly 110 species under 53 genera and 21 families are known from India. Of these, 43 genera and 68 species are described from India. These have not yet been reported from outside India. A total of 34 species, reported mostly from European soils, are known to occur in Indian soils also. The present status of the taxa shows that nearly 50% of the Indian soil mesostigmatid fauna has been recorded from West Bengal. In the descending order of number of species reported are Assam, Bihar, Arunachal Pradesh, Meghalaya, Uttar Pradesh, Tamil Nadu, Karnataka, Kerala, Tripura, Andhra Pradesh, Delhi, Maharashtra, Pondichery, Manipur, Sikkim, Goa, Madhya Pradesh, Nagaland, Orissa and Rajasthan.

It is evident from the foregoing account that the soil mesostigmata of West Bengal only have been studied to a comparatively greater extent. As regards most other Indian states, this group is either poorly known or yet to be known. So, it is estimated that at least another 300 species, if not more, still await discovery from India.

Current Studies

In the Zoological Survey of India, S. K. Bhattacharyya is currently studying the soil mesostigmatid fauna of different states of India. The review of the family Parasitidae under the "Fauna of India" series is nearing completion.

As has already been mentioned, two other acarologists in Dibrugarh, Assam, are working on the taxonomy of soil mesostigmatid mites of Assam.

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ACARI : Cryptostigmata

Introduction

The cryptostigmatid or oribatid mites are common inhabitants of soil and form a complex group under the Subclass Acari. These mites are frequently known as 'beetle', or 'moss' mites. The Cryptostigmata is a cosmopolitan group of more than 6,000 species under about 800 genera. They show a high degree of diversity in structure, habit and habitat. Most oribatid species are slow-moving, strongly ornamented, and range from 110-300 μm in size.

The common habitats of these mites are soil, leaf-litter, compost heaps, *lichens*, moss, bark of trees, bird nests, caves, including lava caves, nests of small mammals, pasture soil, coniferous taiga forest, arctic tundra, subantarctic zones and sea (Bhaduri and Raychaudhuri, 1981; Sanyal and Bhaduri, 1986).

Oribatids are numerically the most abundant soil acarine fauna. Van der Drift (1951) estimated that soil mites constitute about 80 percent of soil fauna. In India, similar picture has also been obtained through the work of different acarologists.

The adult cryptostigmatids often posses a discrete tracheal system consisting of a series of ducts which open laterally between coxae II-III, or open *via* the acetabular cavities of the legs or through the propodosomal sensory bases *i.e.*, bothridia. The chelicerae are normally chelate-dentate type but occasionally elongate and attenuate. The palpi are simple sensory appendage composed of 3-5 segments. Sexual dimorphism in the Cryptostigmata is obscure.

The cryptostigmatids are primarily fungivorous or saprophagous but also consume algae, bacteria, yeasts and higher plants (Luxton, 1977).

Oribatid mites have drawn the special attention of acarologists because of their direct and indirect effect on man and other animals. The major importance of oribatid mites is related to the decomposition of organic matter resulting in the increase of soil fertility. The decomposition process of forest-litter and the resultant fertility is due mainly to this group of mites. Very few oribatids are known to feed on higher plants. These mites are also suspected to be an agent for the biological control of the serious aquatic weed-pest, water hyacinth. Various helminth-diseases caused by anoplocephaline cestodes in the cattle and other domestic animals are transmitted by cryptostigmatid mites. They also act as predators of soil nematodes. Oribatid mites have also been reported to cause injury to plants. At times, these mites which are present in the house hold dusts act as one of the causative agents for human respiratory allergic diseases.

Classification

According to gross morphological, anatomical and biological features, the Suborder Cryptostigmata is divided into several superfamilies and families. The outline classification proposed by Krantz (1978) is given below :

Class	Arachnida
Subclass	Acari
Order	Acariformes
Suborder	Oribatida (Cryptostigmata)
Supercohort	Macropylides

A. K. Sanyal, Zoological Survey of India, Calcutta.

a) Cohort Bifemoratina

Superfamily 1. Archeonothroidea, 2. Ctenacaroidea, 3. Palaeacaroidea

b) Cohort Ptyctimina

Superfamily 1. Prothoplophoroidea, 2. Mesoplophoroidea, 3. Phthiracaroidea, 4. Euphthiracaroidea

c) Cohort Arthronotina

Superfamily 1. Parhypochthonoidea, 2. Hypochthonoidea, 3. Brachychthonoidea, 4. Phyllochthonoidea, 5. Heterochthonoidea, 6. Cosmochthonoidea

d) Cohort Holonotina

Superfamily 1. Lohmannioidea, 2. Nothroidea, 3. Eulohmannioidea, 4. Epilohmannioidea, 5. Perlohmannioidea, 6. Collohmannioidea

Supercohort Brachypylides

a) Cohort Apterogasterina

Subcohort Polytrichae

Superfamily 1. Nanhermannioidea, 2. Hermannioidea, 3. Hermannielloidea, 4. Liodoidea, 5. Gymnodamaeoidea

Subcohort Oligotrichae

Superfamily 1. Cepheoidea, 2. Carabodoidea, 3. Polypterozetoidea, 4. Zetorchestoidea, 5. Eremaeoidea, 6. Eremuloidea, 7. Damaeolidea, 8. Oppioidea, 9. Hydrozetoidea, 10. Ameronothroidea, 11. Cymbaeremaeoidea, 12. Otocepheoidea, 13. Liacaroidea

b) Cohort Pterogasterina

Superfamily 1. Passalozetoidea, 2. Pelopoidea, 3. Galumnoidea, 4. Microzetoidea, 5. Oribatelloidea, 6. Oribatuloidea, 7. Ceratozetoidea.

Historical Resumé

The first report of oribatid species was made as early as 1804 by Hermann from European soil. Later C. L. Koch (1836-1841) and A. D. Michael (1880-1884) made valuable contributions on the European oribatid mites.

The most extensive and monumental work in the beginning of this century was done by Berlese (1887-1916) and Oudemans (1896-1937). The other pioneer workers whose contributions enriched the knowledge of oribatid taxonomy are Willmann (1925-1951), Grandjean (1928-1972), van der Hammen (1952-1973), Hammer (1952-1979), Balogh (1958-1989), Aoki (1959-1989), Mahunka (1965-1989) and others. Unfortunately, the study of Indian oribatid mites had long been neglected and only in the beginning of the twentieth century this work was initiated, and till date very little work has been done on this group of mites.

i) 1901-1947

The first description and record of cryptostigmatid mites from India was known through the work of Pearce (1906). In the early February of that year, he received from Mr. A. Gage, Superintendent of the Royal Botanic Gardens, Shibpur, Howrah district, West Bengal, several packets of moss collected from Sikkim Himalaya at altitudes varying from 610-2440 m. He described and reported 20 species distributed among 12 genera out of which 12 were already known from Great Britain. The paper also includes the description of a new genus, *Chaunoproctus* and eight new species. Ewing (1910) described two species of oribatid mites from the Nilgiri Hills in Tamil Nadu but the identification was doubtful. Later, Jaco (1933) examined the syntypes of Ewing's species and correctly identified them. Baker (1945) described a new species from Bareilly, Uttar Pradesh.

ii) 1948-1990

Anantaraman (1951) described one new species, *Scheloribates madrasensis*, from the pasture soil, and recorded the species as an intermediate host of the anoplocephaline tape worm, *Moniezia expansa*. Later, Prasad (1965) initiated, for a short period, the study on the soil oribatid mites of Sabour in Bihar, and reported only three mites belonging to three genera.

It is evident from the foregoing account that till 1965 the oribatid fauna of India was studied in a rather piece-meal manner. Truly speaking, late D. N. Raychaudhuri and his student A. K. Bhaduri at the Department of Zoology, University of Calcutta, had initiated for the first time, an extensive study of oribatids of India. They built up an effective school of oribatidologists and made significant contributions to the knowledge of the taxonomy and ecology of oribatid mites. Bhaduri and Raychaudhuri (1967) first reported oribatid fauna of Calcutta and its suburbs, reporting six genera as the first records from West Bengal. In the following year, they recorded seven more species from Calcutta. Further, under the able guidance of D. N. Raychaudhuri, several workers like A. K. Bhaduri, D. K. Chakrabarti and D. C. Deb made extensive studies during the period 1969-1983 on the taxonomy of oribatids of Calcutta, Nadia and North 24-Parganas districts of the gangetic plains of West Bengal, and added a number of species, including new taxa, to the list of Indian oribatid mites. In the early seventies, of the twentieth century D. K. Choudhuri, of the Department of Zoology, University of Burdwan, and his associates initiated the studies on the ecology of soil oribatid mites from the soils of Burdwan district. They studied the population dynamics and the effects of physico-chemical and biological properties of soil on the cryptostigmatid fauna (Banerjee, 1972, 1974*a*, 1974*b*, 1988; Choudhuri and Banerjee, 1975). Later, the work was taken up by Banerjee and Roy (1981) and Ghatak and Roy (1981).

The oribatids of the lateritic soils of Birbhum district, West Bengal, was specially chosen for study by T. Bhattacharya at the Visva-Bharati University, Santiniketan, West Bengal, Bhattacharya, Bhaduri and Raychaudhuri (1974), Bhattacharya (1979), Bhattacharya and Banerjee (1979, 1981), Bhattacharya and Bhattacharya (1981), Bhattacharya, Bhattacharya and Banerjee (1980), Bhattacharya and Joy (1980), Bhattacharya, Joy and Joy (1980, 1981) and Joy and Bhattacharya (1981) worked on the taxonomy, ecology and biology on this group of mite and described and recorded several species, including new to science.

Investigations on the oribatid fauna of Orissa were made by Mishra, Bhaduri and Raychaudhuri (1980) who reported 40 species from Puri district. So far only two species of soil oribatids have been reported from Andhra Pradesh by Raju, Appalanaidu and Rao (1981). The first report of Indian plant-feeding oribatid was made from Andhra Pradesh by Venugopala Rao, Sanyal and Rao (1982). Two species of oribatids were made known for the first time from Maharashtra by Narsapur (1983) and two new species were also described by Sanyal (1984) from the same state. Only one species was recorded from Rajasthan by Reddy, Kumar and Mathur (1978).

The Oribatids from southern India have been studied to a considerable extent by Haq and his associates at the Calicut University, Kerala. Haq and Prabhoo (1976), Haq (1978*a*, 1978*b*, 1979), Haq and Adolph (1980), Adolph and Haq (1982), Balakrishna and Haq (1982, 1984), Ramani and Haq (1984), Haq and Ramani (1984) and Balakrishna (1985, 1986) made significant contributions on the taxonomy, ecology and biology of soil oribatid mites. Mahunka (1985), of the Zoology Department, Hungrian Natural History Museum, Hungary, received a collection of mites made by the entomologists of the Natural History Museum of Geneva during their trip to Kerala. He studied oribatid specimens and described five new genera and ten new species.

Among the northeastern states of India the oribatid fauna of Nagaland was studied by Ghosh and Bhaduri (1978) who reported five species. Bayoumi and Mahunka (1979) of the Hungarian Natural History Museum received rich oribatid material collected by W. Wittmer, Natural History Museum, Basel, during his expedition to India, and described one new species from Meghalaya. Chakrabarti and Roy Talukdar (1979, 1981) and Roy Talukdar and Chakrabarti (1984*a*, 1984*b*) studied eleven species from Cachar, Assam. Misra, Bhaduri and Raychaudhuri (1982) described and recorded five species from Manipur. The oribatids of Tripura have been known through the works of Sarkar (1983, 1984, 1985), Sarkar and Subias (1982, 1983, 1984*a*, 1984*b*), Subias and Sarkar (1982, 1983, 1984)and Bhattacharya and Halder (1984). Sanyal (1989) described 3 new species and recorded a few orbatids from Meghalaya.

Taking the oribatid fauna of the Indian Himalaya into consideration, it is observed that a good number of species are known from the eastern and northeastern Himalayas. The first report of oribatid species was made by Peare (1906) from the Sikkim Himalaya. Bayoumi and Mahunka (1979) described species from Darjeeling and Kashmir. Chakrabarti, Mondal and Kundu (1978, 1979, 1981), Chakrabarti and Mondal (1981, 1983), Mondal (1984*a*, 1984*b*, 1988), Mondal and Chakrabarti (1982) and Mondal and Kundu (1983, 1984*a*, 1984*b*, 1985, 1986, 1988) extensively studied the fauna of Darjeeling hills. Long after the pioneering work of Pearce (1906), Dhali, Bhaduri and Raychaudhuri (1980) gave the second account of the fauna of Sikkim Himalaya. Kardar (1975) and Niedbala (1982) described several new species from the Kashmir Valley. Recently, Sengupta and Sanyal (1990) have initiated a study on the oribatid fauna of the northwestern Himalaya and reported 40 species from Himachal Pradesh. The study on the cryptostigmatid mites in the Zoological Survey of India was started by Sanyal (1978-1990). He made extensive studies on the taxonomy and ecology of oribatids of saline soils of southern parts of West Bengal. He also described and recorded oribatid mites from Maharashtra, Kerala and Meghalaya. Sanyal (1983-1988) extensively surveyed all the districts of West Bengal and prepared a monograph on its oribatid fauna. Sanyal has already surveyed several districts of Uttar Pradesh, Sikkim, Meghalaya, Maharashtra and Tripura. Besides soil oribatids, the plant-feeding species were also studied by Rao, Sanyal and Rao, (1982) and Sanyal and Das (1989).

There has also been occasional reviews done on the work of Indian Oribatei. Most important among these are by Bhaduri and Raychaudhuri (1978, 1981), Sanyal and Bhaduri (1986) have published a checklist on Indian Oribatei.

Ecology and Biology

In a very general way it can be said that major part of researches on oribatid mites deal with soil-dwelling forms. Out of 125 scientific papers, about 120 are concerned with soil oribatids. Most of the studies on oribatid mites were faunistically oriented. Extensive collection were made in the Himalayas and from peninsular India.

The other environs were not thoroughly explored. Only a few attempts were made to explore the oribatid fauna associated with plants (Rao, Sanyal and Rao, 1982; Sanyal and Das, 1989) and bird's nests (Gupta and Chattopadhyay, 1979; Gupta and Paul, 1985, 1989).

Singh and Mukherji (1971) studied the qualitative composition of soil cryptostigmatid mites at Varanasi, Uttar Pradesh. Banerjee (1972-1988). Choudhuri and Banerjee (1975, 1977), Banerjee and Roy (1981) and Ghatak and Roy (1981) made some contributions on qualitative and quantitative aspects of oribatid population in the soils of Burdwan and Hooghly districts of West Bengal. Bhattacharya and his associates (1978-1981) studied the population dynamics of this group of mites and the interrelationship between oribatid fauna and physico-chemical and biological properties of soils of Birbhum district, West Bengal. Sanyal (1980-1990) made extensive studies on the faunal makeup, population structure and its relationship with the edaphic factors like moisture, relative humidity, temperature, pH, organic matter, phosphate, nitrate, and biotic components present in the soil. He also studied the oribatid population in relation to the pollutants in the soil. Singh and Pillai (1981) studied the community structure of cryptostigmatids and reported twelve genera from the soils of Varanasi.

The extensive studies on the breeding biology and feeding of soil oribatids from Kerala were done by Haq and Prabhoo (1976), Haq (1978), Haq and Adolph (1980), Ramani and Haq (1988), Neena and Haq (1988), and others. Bhattacharya and Joy (1978) studied the effect of temperature on the development of *Oppia nodosa.*

Mukherjee, Singh and Singh (1987), Singh, Mukherjee and Singh (1989) and Sheela and Haq (1989) recorded few oribatid species as active agents for the control of water hyacinth.

More than 80% of cryptostigmatid species live in soil. But there are also records of the species from plant and water. In India, these two most important habitats have not yet been explored thoroughly.These, therefore, need a thorough study.

Extensive and systematic survey is required to be undertaken in all the states of India except perhaps West Bengal.

Estimation of Taxa

As cryptostigmatids are found in different types of ecological conditions, a good deal of divergence is noticed in their organisation and consequently we find large number of genera and species. Thus, till date, against an estimated total of about 159 families in the Suborder, 64 families are represented in India, by a total number of 328 species and subspecies under 164 genera. Of these species of oribatid mite, 10 genera and 142 species are described as new to science from India and till date their distribution is restricted to this country. The distribution of oribatid families, genera and species in different states of India shows that 60% of the Indian oribatid fauna is recorded from West Bengal. The second highest number of species occurs in Himachal Pradesh. The other states in descending order of number of species are Orissa, Kerala, Uttar Pradesh, Tripura, Sikkim, Meghalaya, Assam, Kashmir, Nagaland, Manipur, Maharashtra, Tamil Nadu, Bihar, Andhra Pradesh and Rajasthan. Our knowledge of the Indian cryptostigmatids is still far from complete. As most of the biotopes in India have not yet been thoroughly explored, it is estimated that at least another 500 species, if not more, still await discovery from India. Further researches will surely reveal more information on the distribution of this group in India.

Current Studies

In the Zoological Survey of India, taxonomy and bioecology of cryptostigmatid mites of some states of India, namely West Bengal, Tripura, Meghalaya and Uttar Pradesh, are currently under study. Outside ZSI, serious and extensive researches on cryptostigmatid mites are being carried out at the Calicut University, Kerala. The studies are mostly aimed at taxonomy, biology and ecology.

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ACARI : Metastigmata

Introduction

The ticks are a small group of acarines under the suborder Metastigmata, also known as Ixodids. They occur throughout the world, but are more frequently encountered in tropical and subtropical realms.

The Metastigmata is a small group in comparison to other acarine suborders, comprising approximately 800 species from all over the world. They are grouped into three families, the Argasidae or soft ticks, Ixodidae or hard ticks and Nuttalliellidae (known only from Africa).

The ticks show morphological characters typical of other acari, but their peculiarities and greater size (2,000 to over 30,000 µm) clearly distinguish them from most other acarines. Besides, there are certain characters which are present and distinct throughout the ontogeny of ticks. A hypostome armed with retrorse teeth serves to anchor the tick to its host. A complex sensory setal field, Haller's organ, is located on the dorsal side of tarsus-I in all postembryonic stages, providing sites for contact or olfactory chaemoreception. Other distinguishing features are : a pair of stigmata situated posterior to coxa IV or dorsal to coxa III-IV, palp with only three or four segments, chelicera 2-segmented, digits of chelicerae working in horizontal plane with their dentate faces directed externally.

The differences between the families extend to their structure as well as to their habits. The argasid ticks are non-scutate with leathery integument and capitulum inferior in the nymphs and adults, sexual dimorphisim slight, spiracles small and anterior to coxa-IV and pads, porose areas and festoon absent. The ixodid ticks are scutate with terminal capitulum, sexual dimorphism well marked, spiracles posterior to coxa-IV and pads, porose areas and festoon present. The ticks live as ecto parasites of vertebrates and feed obligatorily on the blood of mammals, reptiles and birds. Some of them are significant pests of man and animals in temperate forests, steppe and prairie habitats, as well as in the harsher tundra of the far north. In temperate and tropical countries, they surpass all other arthropods as transmitters in the number and variety of diseases of man and domestic animals. They cause paralysis and anemia and serve as reserviors and vectors for many infective viruses, rickettsias, bacteria, sporozoans and spirochaetes. Ticks are the main vectors of Kyasanur forest disease in man and monkeys in Karnataka state. Other arboviruses like Kaisodi, Ganjam and Bhanja are also isolated from ticks in India. Ticks are oviparous. The life history passes through egg, larva, nymph and adult stages.

Historical Resumé

The ticks attracted the attention of scientists since the days of Linnaeus (1746-1767). Later, due to their immense medical importance, the progress in the field of taxonomy was made rapidly and culminated in a large number of papers and monographs by such authorities as Cooley (1909-1945), Kohls (1930-1969), Delpy (1934-52), Pomerantzev (1934-1950), Roberts (1934-1970), Theiler (1941-1964), Anastos (1947-1968), Hoogstraal (1950-1985) and others. In the field of biology, experimental physiology and tick ecological technique, we owe much to the notable workers like Philip (1931-1969), Macleod (1932-1962), Gregson (1935-1969), Hitchcock (1943-55), Milne (1943-1952), Lees (1945-1956) and Wilkinson (1953-1969).

The Indian ticks were taken up for research as early as in 1758. Since then they have been studied extensively in different aspects. The important works done on the families of Indian ticks are summarised below.

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Classified Treatment

Family *Ixodidae*

Linnaeus (1758) described *Acarus elephantinus* from India. Later in 1967, he described another Indian species *Acarus indus*. Neumann (1897-1910) in series of papers described ten species from India. Stiles and Hasall (1899) recorded *Boophilus australis* for the first time from India. Warburton and Nuttall (1908, 1909) described two species. In 1911 and 1915 theses two workers alongwith Robinson and Cooper published two comprehensive works entitled *'Ticks : A monograph of Ixodoidea'* Part 2 and Part 3, dealing with the genera *Ixodes* and *Haemaphysalis*, in which two species were recorded for the first time from India. Besides the monographs, Nuttall (1912, 1913, 1916) described two species from Uttar Pradesh and Arunachal Pradesh and recorded one more species from Kashmir Valley. The fourth volume of the book was published by Robinson (1926).

The most extensive and comprehensive study of Indian ixodids was done by Sharif (1928). He listed the Ixodidae occurring in India and recorded altogether 9 genera and 45 species, 4 subspecies and 6 varieties. He also provided informations on the bionomics of *Hyalomma aegypticum*. Further in 1938, Sharif reported diseases transmitted by the Indian ticks and the possibility of their control through biological agents. Sen (1938) published a check-list of Indian ixodid ticks and recorded 35 species under 9 genera from this subcontinent. Spare (1940, 1944) studied the biology of two species.

After a long gap of about fifteen years, the Indian ixodids were again taken up seriously for research by the scientists at National Institute of Virology, Pune. Singh, Geevarghese, Sreenivasan, Mishra, Kaul, Dhanda, Bhat, Kulkarni, Rajagopalan and others (1964-1979) studied taxonomy, ecology and biology of ticks. They described and recorded several species from Uttar Pradesh, Arunachal Pradesh, Himachal Pradesh, Karnataka, Maharashtra, Tamil Nadu and West Bengal.

The Indian ixodid ticks were also extensively studied by Hoogstraal and his co-workers Trapido, Verma, McCarthy, Kohls, Rebello, Elkammah, Mitchell and others (1962-1971). Hoogstraal at the Medical Zoology Department, U.S. Naval Medical Research Unit number Three, Cairo (Egypt) and his co-workers studied the Indian ticks mostly of the genus *Haemaphysalis* collected by the staff members of National Institute of Virology, Pune. They described and recorded several species of ixodid ticks with their distribution and hosts from Bihar, Gujarat, Karnataka, Uttar Pradesh, Kashmir, Rajasthan, Andhra Pradesh, Arunachal Pradesh, Sikkim, Himachal Pradesh and West Bengal. Advani and Vazirani (1981) recorded *Ixodes vespertilionis* as an ectoparasite of bat from Rajasthan.

The interrelationship between ixodid ticks and Kyasanur Forest disease (KFD) virus resulting into the death of monkeys in a forested area of Shimoga district, Karnataka, was first attended by Work and Trapido (1957). They published a preliminary report of investigations on the epidemic disease caused by KFD virus. Later Work (1958) added more informations on KFD. Trapido, Goverdhan, Rajagopalan and Rebello at National Institute of Virology, initiated a study on the qualiltative and quantitative aspects of the ticks ecto-parasitic on monkeys in the KFD area, during the period 1957 to 1961 and in 1964.

Bhat (1988) and Sreenivasan, Rajagopalan and Bhat (1988) studied the ecology of KFD virus and their isolation from ixodid ticks. In another attempt Dhar, Bhusan, Malhotra, Mallick and Gautam (1988) assessed *Theileria annulata* infection in *Hyalomma anatolicum anatolicum*. In the same year Geevarghese and Dhanda (1988) studied the bionomics of three Indian species of *Hyalomma* ticks.

Family *Argasidae*

The study on Indian argasid ticks was started much later than the ixodids, and till date comparatively little work was done on this group of ticks. The first report of Indian argasid

Ornithodoros savignyi was made by Christophers (1906) from South India. Nuttall, Warburton, Cooper and Robinson (1908) recorded *Argas persicus* from Punjab, Maharashtra, Bihar, Andhra Pradesh and Uttar Pradesh. After a long gap of more than a decade, Cross and Patel (1922) recorded *Argas persicus*, *Ornithodoros lahorensis* and *O. savignyi* from Punjab. Naik (1935, 1938) reported the occurrence of *O. savignyi* from Karnataka and Maharashtra. The second record of argasid from Punjab was done by Sen (1935). He made an extensive study on feeding mechanism of *Ornithodoros papillipes* (= *O. tholozani*). Kingston (1936) reported *Otobius megnini* as the first record of argasid tick from Madhya Pradesh. Sen (1938) published a check-list and host index of 5 species and 3 genera of argasid ticks occurring in India, where he also recorded additional distribution data. Sharif (1938) stated that *Argas reflexus indicus* was an important parasite of pigeons all over India. Joshi (1943) reported *O. savignyi* from Rajasthan. Hoogstraal, the pioneer worker on Indian ticks, and his associates McCarthy, Kaiser and Kohls (1956-1968) described two new species *Argas* (*Persicargas*) *abdussalami* and *A.* (*P.*) *robertsi*, and also reported *Argas* (*C.*) *vespertilionis* and *Ornithodoros* (*Alectorobius*) *coniceps* for the first time from India. Sen and Fletcher (1962) extensivesly studied the argasid ticks of Punjab, Gujarat and Madhya Pradesh. They reported *Ornithodoros* (*Pavlovskyella*) *tholozani* and *O.* (*P.*) *savignyi*. Later Dhanda and Rajagopalan (1971) described a new species *Ornithodoros* (*R.*) *chiropterphila* from Karnataka. In the same year Rau and Rao (1971) described another new species *Ornithodoros* (*O.*) *indica* from Arunachal Pradesh. Besides taxonomic investigations, several other works related to ecology, biology and disease relationship were done by a few acarologists. The most important of these are the studies of Rajagopalan, Paul and Sreenivasan (1969) who studied the transmission of KFD virus by *O.* (*R.*) *chriopterphila* and the studies on the life cycle of *O. megnini* done by Jagannath and Lokesh (1988).

The researches on Indian ticks in Zoological Survey of India was started by M. Sharif (1924-1938). He worked on ixodid and argasid ticks of India as mentioned earlier. After Sharif there was no significant work untill Mathai (1951-1963) who described two species of ixodid ticks from India. Subsequently De started researches on this group. He published in 1976 a detailed report on ixodid ticks of Orissa. De, Sanyal and Gupta (1978-1990) have extensively surveyed the ixodid tick fauna of Arunachal Pradesh, Andaman and Nicobar Islands, Orissa, Uttar Pradesh, Tripura, Meghalaya and West Bengal and recorded several species for the first time from these states. Basu, De and Sanyal (1989) reported the tick fauna associated with cattle and buffaloes in West Bengal. In last few years (1983-1987) the staff of Acarology Section of *Z.S.I.* have extensively surveyed the ixodid fauna in all districts of West Bengal, collecting hundreds of specimens, and a monograph is under publication.

The studies on argasid ticks in Zoological Survey of India was done by Advani and Vazirani, at the Desert Regional Station, Jodhpur. They (1981) made an exhaustive work on the ectoparasites of bats in India. While doing this, they encountered a good number of tick specimens belonging to both the families Ixodidae and Argasidae. The ixodid ticks collected from Rajasthan were identified as *Ixodes vespertilionis*. Of the six argasid species reported five were new to science *Argas* (*Carios*) *soneshinei* from Dadra and Nagar Haveli, *A.* (*C.*) *indicus* and *A.* (*Chiropteragus*) *wilsoni* from Rajasthan, *A.* (*C.*) *gujaratensis*, *A.* (*C.*) *hoogstraali* from Gujarat, and one species *A.* (*C.*) *vespertilionis* was added to the faunal list of Rajasthan.

Areas Yet To Be Explored

Although extensive surveys have been undertaken for collection of disease causing species, it is high time to study the tick fauna of economic importance. Further, studies on ecology and biology of Indian ticks need attention. The survey of tick fauna in many of the Indian States has not been done extensively.

Estimation of Taxa

Till date 86 species of ixodid ticks under 9 genera, and 21 species of argasid ticks under 3 genera occur in India. Nearly 33% of tick species are recorded from Karnataka and 30% from West Bengal. The other states represent a lesser number.

As already mentioned, the ixodid ticks are rich both in quality and quantity in comparison to argasid ticks. However, it is assumed that the chances of getting new species under Ixodidae are very little, while a thorough and extensive survey may add a few new and interesting species of Argasidae to the list of Indian tick fauna.

Current Studies

The scientists of Zoological Survey of India are presently studying the taxonomy of ixodid ticks of West Bengal, Tripura, Meghalaya and Uttar Pradesh. Outside ZSI, scientists in the National Institute of Virology, Pune, are extensively studying the taxonomy, ecology and biology of ixodid ticks.

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ARANEAE

Introduction

Jean Baptiste - De Monet, Chevalier De Lamarck, the great French philosophical biologist, named the group Arachnida in 1815, when he divided Linne's heterogeneous group, Insecta, into three classes. The chief external features of Arachnida are the division of the body into two parts - properly called the prosoma and the opisthosoma. The prosoma is composed of a united head and thorax, commonly known as the cephalothorax, and the opithosoma is also called the abdomen. The prosoma of Arachnida is made up of nine segments, sometimes all of them are fused to form a dorsal carapace upon which the eyes are situated. In contrast to this comparative uniformity of the prosoma, there is much greater diversity in appearance of the opisthosoma and of its appendages. It may wholly retain the segmented form or may be unsegmented, and may or may not have several pairs of appendages.

An interesting problem afforded by the Arachnida is that of their evolutionary history. The puzzle is a dual one, the earlier question is the origin of the Arachnida as a class, and the later one is their division into the different orders. The geological records are as follows: The primitive form which can be classed as Arachnida, the Eurypterida, are wholly palaeozoic, their earlier form are found in the upper Cambrian and latter in the Devonian. The most ancient of living forms, the Scorpions, are found in the Silurian. Spiders and Pedipalpi occur in the Carboniferous and all the principal orders of modem Arachnida are present in the Tertiary strata.

A problem is the origin of the Eurypterida during the Cambrian era. According to classical or traditional theory by Lankester and Pocock, the possible ancestor of the Eurypterida is to be sought among the Trilobites, the dominant organism of the Cambrian.

Trilobites

Limulava

Eurypterida

Synxiphosura — Palaeophonus

Xiphosura — Scorpiones

The Arachnida living today are grouped into ten orders :

1) Araneae : Spiders.
2) Opiliones : Harvestmen.
3) Pseudoscorpionida : False-scorpiones.
4) Pedipalpida : Tailless whip-scorpiones.
5) Scorpionida : Scorpiones.
6) Solpugida : Sun spiders.
7) Xiphosura : King crab.
8) Microthelyphonida.
9) Richinulei.

B. Biswas, Zoological Survey of India, Calcutta and U. A. Gajbe, Zoological Survey of India, Jabalpur.

10) Acari : Ticks and mites.

Brief characters of these are given as follows :

Araneae : Abdomen jointed with the cephalothorax by narrow pedicel. Abdomen provided with spinnerets.

Opiliones : Harvestmen- spider-like body; pedipals small, not chelate; chelicera not bearing spinnerets; two median eyes provided with tubercles, present on cephalothorax.

Pseudoscorpionida : One or two pairs of lateral eyes present on cephalothorax; chelicera bearing spinnerets; pedipalpi large and chelate; body scorpion-like.

Pedipalpida : Large to medium in body size; caudal appendage long,short or absent; first pair of legs long and modified into feelers, each provided with a rounded tip *inserted* of claws.

Scorpionida : Abdomen with a broad tail-like prolongation terminating in a poisonous sting; pectines always present on the underside of the base of abdomen; pedipalp stout and chelate.

Solpugida : Chelicera enormous in comparison to body size; racquet organ present on the underside the last pair of legs; pedipapls leg-like without claws; abdomen may have narrow prolongation but never provided with sting.

Xiphosura : Opisthosoma hexagonal, broadly pointed to prosoma; chelicerae of three segments, small and chelate; peripalpi not different from ambulatory legs. [King crab (*Limulus*) has been used by the americans as food for both pigs and poultry, and in some areas it is believed that this food makes the hens lay more eggs. It is also reported that film industry developed from the carapace of king crab].

Microthelyphonida : Minute in body size; caudal appendages long and many-segmented; first pair of legs long but not modified as feelers and each bears claws at the tip.

Richinulei : Cephalothorax provided with movable hood (cucullus) in front; eyes absent; third pair of legs in males modified as copulatory organs.

Acari : Mouth parts contained in a discrete anterior gnathosoma; portion of the body on which the legs are inserted (the podosoma) broadly joined to the portion of the body behind the legs (the opisthosoma) to form the idiosoma.

For the Orders Solpugida, Pedipalpida, Opilionida, Pseudoscorpionida, Xiphosura, Microthelyphonida, Richinulei no subsequent comprehensive work has been published after the publication of the 'Fauna of British India' volume by Pocock (1900), where 25 species of pedipalps and 17 species of solifugids are recorded. Gravely (1910-1935) added to our knowledge of these animals to some extent. Tikader (1987) has enhanced our knowledge on ten orders of Arachnida in 'Handbook of Indian spiders'

Spiders are important components of life of India's vast and diversified land. They are widespread, found in all types of habitats and occupy all but a few niches. Spiders may be found near the edge of water-bodies, on the ground, in underground caves and on top of the mountains. In fact, jumping spiders have been collected even from Mount Everest region (22,000 feet), the highest elevation at which any animal has ever been found. It is recorded that ballooning spiders have been collected from air-planes at an elevation of 5000 feet. Some spiders like Pholcidae, Oecobidae, Heteropodidae and Filistatidae live inside human habitations, and others frequent the walls outside. Almost every plant has its spider fauna, as do the dead leaves on the forest floor. They may be found under the bark, under stones, under fallen logs - these being only a few examples of their various habitats. There may be different species of spiders even in a small area, as for example nearly 600 species of spiders are known from Connecticut, a very small state of U.S.A. Some ground spiders like *Geolycosa* and trap-door spiders of the Western Ghats dig holes in the ground and remain there during their whole life, except for a short period when the male ventures out to seek a mate. The silk-lined tunnel of *Atypus* extends partly into the ground and partly along the surface of a tree. The wolf-spiders, mainly *Lycosa* and *Hippasa* may make use of shallow lobes in which they hide. Many spiders like Uloboridae, Pholcidae prefer dark and shady places, where the humidity is high. Some *Pardosa* and *Lycosa* species are found along the edge of streams and ponds, running over the water surface quickly, and in an emergency they can dive into water. *Araneus* and *Tetragnatha* species also prefer water sources but are usually found on the shrubs, which overhang the ponds or streams. Many crab-spiders like *Thomisus* and *Misumena* live among flowers, waiting in ambush for insect visitors. It was observed that crab-spiders change their colour according to that of the flowers. *Tibellus, Thanatus* and *Oxyopes* run along grasses; clubionids, salticids hunt on leaves. Hersilid spiders live on walls of houses and on tree trunks. They are usually dark in colour, in resemblance to tree or wall on which they occur. The only social spider *Stegodyphus sarasinorum* Karsch, has attracted the attention of many naturalists in India. They built their nest in the foliage of *Acacia arabica* or *Zizyphus* sp. Many species are found on tall grass, on bushes and trees. Some run over the branches and trunk and hide under loose bark and in crevices.

Spiders have long been listed among animals that are able to reproduce parthenogenetically. After laying a mass of eggs, the female covers them with a silken sheet and molds the mas into the egg sac characteristic of the species. The number of eggs laid by different spiders varies enormously. The essential work of the female is over as soon as eggs are laid and enclosed in some kind of silken sac. This act frequently represents the parental care. Spiders undergo a development within the egg that is comparable to that of other arachnids. The embryo spider gradually takes form, outside vast sphere of yolk that makes up most of the egg. On the generalized part, which will become the cephalothorax, appear little buds and gradually become differentiated into the chelicerae, palpi and the legs. A şimilar series appear on the abdominal portion. At rather definite intervals in its development the spider casts off the bounds of its stiff outer covering and eject itself for life in a more advanced stadium.

Currently Araneae have attracted the attention as a source of homeopathic as well as allopathic medicines. There are several species from which venom is extracted. Spider venom is the source of several drugs.

Spiders are often confused with insects. However, these can be easily diagnosed and separated from insects on the following characters :

1) Body divided into two unsegmented parts - cephalothorax (or head) and abdomen.

2) Cephalothorax has four pairs of legs and a pair of six segmented pedipalps, modified in the male for sperm transportation.

3) Wings absent; eyes simple, two or eight in numbers.

4) Respiration by book lungs and genital pore on the ventral side near anterior end of abdomen.

5) Silk apparatus always present, opening at hind end of abdomen below anus.

6) Poison apparatus opening on fangs of chelicerae.

7) Development direct, spiderlings resemble their parents.

Historical Resumé

Two of the earliest contributions on Indian spiders were by Stoliczka (1868) and Karsch (1873) who reported many interesting species from Sri Lanka and Minicoy. Simon (1887-1906) recorded many species from the Himalaya, and Andaman and Nicobar Islands. Thorell (1895) published a descriptive catalogue of about 200 species of Burmese spiders. Pocock (1900) recorded 200 species from India, Burma and Sri Lanka in the "Fauna of British India India, Arachnida" He concentrated mainly on the large-sized spiders available on the ground as well as orb-webers. Sheriff (1919, 1929) and Reimoser (1938) described numerous interesting species of spiders from southern India.

Caporico (1934-1935) described some species from Karakorum (Himalaya). Gravely (1912-1935) added considerably to the knowledge of Indian spiders, particularly of families Lycosidae, Ctenidae, Clubionidae, etc. A number of species from Lahore were described by Dyal (1935). Narayan (1925) gave interesting accounts of many ant-like spiders of the family Salticidae. Contributions made by Sinha (1951-1952) on Lycosidae and Argiopidae may also be mentioned as important. Recent studies on the families Thomisidae, Lycosidae, Gnaphosidae, Theridiidae, Scytodidae, Araneidae (= Argiopidae), Oonopidae, Clubionidae, Filistatidae, Uloboridae, Amaurobiidae, Dictynidae, Pholcidae, Salticidae, Linyphiidae, Tetragnathidae, Hersilidae, Oxyopidae, Pisauridae, Theraphosidae, Heteropodidae, etc. have been made by Tikader (1960-1987). Biswas (1987) worked on the spiders of Orissa reporting on the families Araneidae, Gnaphosidae and Salticidae. Majumder and Tikader (in press) have studied clubionid spiders from India.

Tikader and Gajbe (1973-1979) described many species of the Gnaphosidae and Platoridae. Gajbe (1981-1989) described many interesting species of Gnaphosidae from India, and Thomisidae Mimetidae, Oxyopidae, Uloboridae from Madhya Pradesh. Patel (1973-1989) worked on the spider fauna of Gujarat. Sadana (1973-1989) published some papers on the families Salticidae and Lycosidae from Punjab. Tikader and Biswas (1981) published an occasional paper on the spider fauna of Calcutta and its vicinity, and recorded 99 species under 47 genera of 15 families. Biswas (1982-1989) recorded many interesting species of the families Salticidae, Clubionidae and Gnaphosidae from West Bengal, Tikader (1980) under 'Fauna of India, Spider Part 1, Family : Thomisidae' reported 117 species under 25 genera of the family Thomisidae (crab-spider); Tikader & Malhotra (1980) under 'Fauna of India, Spider Part 2' reported 97 species under 9 genera of the family Lycosidae (wolf spiders). Tikader (1982) under 'Fauna of India, Spiders Volume 2, part 1 and 2' reported 142 species under 21 genera of the family Araneidae and 110 species under 21 genera of the family Gnaphosidae. Tikader & Bal (1980-81) described many species of Araneidae and published an occasional paper on some orb-spiders. Tikader & Gajbe (1973-79) described many species of the family Gnaphosidae and Platoridae. Gajbe (1981-89) reported many species of the family Gnaphosidae from Madhya Pradesh and other parts of India. Patel (1973-1989) reported many species of different families from Gujarat. The karyological studies on some Indian spiders were investigated by Mittal (1976-1986).

Studies from Different Environs

The information on Indian terrestrial spiders is scattered. In the beginning, studies on these spiders were faunistically oriented. Extensive collections were made in the Himalayas starting from the Pir Panjal Range on the west to the Dafla Hills, Khasi and Jaintia Hills and Sikkim in the east. Collections were also made from the peninsular India, especially from the Western Ghats. All the collections were studied by various arachnologists during the pre-independence period. These studies have culminated in the publication of one volume under the 'Fauna of British India' series, and a number of papers.

Araneae fauna collected by Zoological Survey of India has been extensively worked out in recent years from different parts of India : West Bengal, Assam, Arunachal Pradesh, Meghalaya, Gujarat, Maharashtra, Sikkim, Andaman-Nicobar Island and Orissa.

i) Fauna of Andaman and Nicobar Islands - The Araneae of Andaman and Nicobar Islands ecosystem have been described by various arachnologists such as Simon (1885), Thorell (1891) who published various papers on the Arachnid fauna of these islands. Recently, Tikader (1977) studied the spider fauna of Andaman and Nicobar Islands. His study was undertaken with a view to describing the species occurring in these island and also comparing the distribution of spider fauna of these islands with those of the adjoining Indian mainland.

ii) Fauna of Sikkim - It was studied by Tikader (1970) which deals with the spiders from East Sikkim, West Sikkim and Northern part of West Bengal (between lat., 27.5 and 20.9 long. 87.56 and 90.5) covering an area of about 7428 square kilometers. These areas are largely covered by evergreen forests. The study is based on the collections made by B. K. Tikader, as a member of the Indo-Swiss Zoological Expedition, 1959. Altogather 65 species, contained in 33 genera, distributed in the families Uloboridae, Homalonychidae, Theridiidae, Linyphidae, Argiopidae, Thomisidae, Aglenidae, Hahniidae, Pisauridae, Lycosidae and Oxyopidae have been dealt in this paper. Of these, 50 species are new to science.

iii) Araneae of Deccan area - One of the earliest fields of Stoliczka (1869) who reported many interesting species from Bombay, Madras and southern India. Sheriff (1927-1951) has described a number of interesting species, particularly from the Deccan. Gravely (1921-1935) had contributed considerably to our knowledge of spiders of this region. Narayan (1915) had recorded the occurrence of several remarkable forms of ant-like spiders of Salticids in the Deccan area. Recent studies of Sinha (1951-1952) on the families Lycosidae and Argiopidae need also to be mentioned as important additions to our knowledge of Indian Arachnology. More recently, Tikader (1960-1967) has described 164 species of spiders from the Deccan, under the families Araneidae, Lycosidae, Clubionidae, Avicularidae, Heteropodidae, Sparassidae, Dictynidae, Dipluridae, Erigonidae, Filistidae, Oecobidae, Oxyopidae, etc.

iv) Fauna of Orissa - Biswas (1987) has described 29 species of spiders from Orissa under the families Araneidae, Gnaphosidae and Salticidae.

Estimation of Taxa

So far 104 families of spiders have been recognised from the world. Approximately, 35000 species of spiders have been named from the world, representing what is believed to about one fourth of the total number of species supposed to be present. A total of 1015 species belonging to 236 genera under 44 families are so far known from the Indian subcontinent. The National Zoological collections of India comprise about 1250 species belonging to 43 families and collected from different localities of India and other countries.

The family-wise account of Araneae of Indian subcontinent is as follow :

Sl. No.	*Family*	*No. of Genera*	*No. of Species*
1.	Agelenidae	6	10
2.	Amaurobiidae	1	1
3.	Araneidae	21	101
4.	Atypidae	1	1
5.	Aviculariidae	2	2
6.	Barychelidae	5	8
7.	Clubionidae	15	84
8.	Ctenidae	1	13
9.	Ctenizidae	5	14
10.	Dictynidae	1	12
11.	Dinopidae	1	1
12.	Dipluridae	2	3
13.	Eresidae	2	9
14.	Filisatidae	1	8
15.	Gnaphosidae	21	80

Sl. No.	*Families*	*Genera*	*Species*
16.	Hahniidae	1	3
17.	Hersilidae	3	12
18.	Heteropodidae	8	65
19.	Homalonychidae	1	1
20.	Linyphiidae	4	12
21.	Loxoscelidae	1	1
22.	Lycosidae	9	115
23.	Lyssomanidae	3	4
24.	Oecobiidae	1	2
25.	Oonopidae	3	10
26.	Oxyopidae	2	32
27.	Palpimanidae	2	3
28.	Pholcidae	4	6
29.	Platoridae	1	4
30.	Prodidominidae	2	2
31.	Psechridae	2	9
32.	Salticidae	25	87
33.	Scytodidae	1	12
34.	Selenopidae	1	6
35.	Senochilidae	1	1
36.	Tetrablemmidae	1	1
37.	Tetragnathidae	2	22
38.	Theraphosidae	9	52
39.	Theridiidae	19	40
40.	Thomisidae	25	115
41.	Uloboridae	2	15
42.	Urocteidae	1	1
43.	Zodaridae	7	14
44.	Pisauridae	10	11
		236	1015

Classified Treatment

The classification now generally followed by almost all archanologists of the world is based essentially on that proposed by Pentrunkevitch (1928) in his *Systema Aranearum*. Among the very numerous monographs dealing with the comprehensive natural History of spiders in general, that of Walckenaer (1806-1837) may perhaps be considered as an extremely valuable contribution. Simon (1892-1897) did a monumental work on taxonomy of spiders. It is a most valuable contribution towards the science of Arachnology of the world. Arachnologists are fortunate in having two major bibliographic work concerned with world spider fauna. One is Roewer's 'Katalog der Araneae' in which are listed in essential completeness the spider representation from the entire world. An even more ambitious and scholarly work is the "Bibliographia Araneaorum" of Pierre Bonnet of the University of Toulouse in which are listed almost all spider representation from the entire world. From these sources and from supplementary catalogues, it has been possible to glean reasonably accurate information on the distribution of spider fauna of the world.

Families and higher categories of spiders are as follows

Order Araneae

Suborder Orthognatha

Mesothelae (Atypical tarantulas)

Families

1. Liphistiidae Thorell, 1869
2. Antrodiaetidae Gertsch, 1940
3. Mecicobotheriidae Holmberg, 1882
4. Atypidae Thorell, 1870 *

Opisthothelae (Typical tarantulas)

Families

5. Theraphosidae Thorell, 1870 *
6. Paratropididae Simon, 1889
7. Pycnothelidae Chamberlin, 1917
8. Barychelidae Simon, 1889 *
9. Migidae Simon, 1892
10. Dipluridae Simon, 1889 *
11. Ctenizidae Thorell, 1887 *
12. Actinopodidae Simon, 1892

Suborder Labidognatha

Hypochiloidea

Families

13. Hypochilidae Marx, 1888
14. Gradungulidae Forster, 1955

Neocribellate

Families

15. Filistatidae Ausserer, 1867 *
16. Oecobiidae Blackwall, 1862 *
17. Eresidae Koch, 1851 *
18. Dinopidae Koch, 1851 *
19. Uloboridae Thorell, 1869 *

20. Dictynidae Cambridge, 1871 *
21. Amaurobiidae Thorell, 1870 *
22. Psechridae Simon, 1890 *
23. Tengellidae Dahl, 1908
24. Zoropsidae Bertkau, 1882
25. Acanthoctenidae Simon, 1892
26. Amphinectidae Forster, 1973
27. Neolanidae Forster, 1973

Ecribellate

Haplogyne (Primitive hunters and weavers)

Families

28. Sicariidae Keyserling, 1880
29. Scytodidae Blackwall, 1864 *
30. Loxoscelidae Simon, 1890 *
31. Diguetidae Gertsch, 1949
32. Plectreuridae Simon, 1893
33. Caponiidae Simon, 1890
34. Oonopidae Simon, 1890 *
35. Stenochilidae Thorell, 1873 *
36. Tetrablemmidae Cambridge, 1873 *
37. Pacullidae Simon, 1894
38. Ochyroceratidae Fage, 1912
39. Leptonetidae Simon, 1890
40. Telemidae Fage, 1913
41. Textricellidae Hickman, 1945
42. Dysderidae Koch, 1837
43. Segestriidae Simon, 1893

Entelogyne

Trionycha (Higher web-weavers)

Families

44. Pholcidae Koch, 1851 *
45. Symphytognathidae Hickman, 1931
46. Theridiidae Sundevall, 1833 *
47. Nicodamidae Simon, 1898
48. Nesticidae Simon, 1894
49. Hadrotarsidae Thorell, 1881

50. Linyphiidae Blackwall, 1859 *
51. Micryphantidae Bertkau, 1878
52. Theridiosomatidae Simon, 1881
53. Araneidae (= Argiopidae) Latreille, 1806 *
54. Tetragnathidae Menge, 1866 *
55. Agelenidae Koch, 1837 *
56. Argyronetidae Thorell, 1870
57. Desidae Pocock, 1895
58. Hahniidae Bertkau, 1878 *

Three-clawed hunters

Families

59. Hersiliidae Thorell, 1870 *
60. Urocteidae Thorell, 1869
61. Mimetidae Simon, 1881
62. Arachaedae Koch, 1854
63. Mecysmaucheniidae Simon, 1895
64. Zodariidae Thorell, 1886 *
65. Palpimanidae Thorell, 1870 *
66. Pisauridae Simon, 1890 *
67. Lycosidae Sundevall, 1833 *
68. Oxyopidae Thorell, 1870 *
69. Senoculidae Simon, 1890
70. Toxopidae Hickman, 1940

Dionycha (Two-clawed hunting spiders)

Families

71. Ammoxenidae Simon, 1893
72. Platoridae Simon, 1890 *
73. Gnaphosidae Pocock, 1898 *
74. Prodidomidae Simon, 1884 *
75. Homalonychidae Simon, 1893 *
76. Cithaeronidae Simon, 1893
77. Clubionidae Wagner, 1887 *
78. Anyphaenidae Bertkau, 1878
79. Amaurobioididae Hickman, 1949
80. Zoridae Cambridge, 1893
81. Ctenidae Keyserling, 1877 *
82. Heteropodidae Thorell, 1873 *

83. Selenopidae Simon, 1897 *
85. Philodromidae Thorell, 1870
86. Aphantochilidae Thorell, 1873
87. Salticidae Blackwall, 1841 *
88. Lyssomanidae Peckham & Wheeler 1888 *

Families marked with an asterisk (*) are represented in India.

Current Studies

In the Hdqrs. of Zoological Survey of India, systematics and distribution of Araneae (spiders) of West Bengal are currently under study. Our knowledge is far from satisfactory and hence a revision of some families has been taken up. Studies on 20 families have been completed. Keys for the genera and species of these families have also been prepared.

At Central Regional Station, Jabalpur, the spiders of Madhya Pradesh are under study. Revision of some families like Thomisidae, Araneidae, Lycosidae, Gnaphosidae have been completed and of some other families like Oxyopidae is taken up.

Outside Z.S.I. no serious research on spiders is carried out. In a few universities, namely, Bhavnagar University, Bhavnagar; Panjab University, Chandigarh. Punjab Agricultural University, Ludhiana etc., studies on spiders are being conducted. These studies are aimed at taxonomy, ecology and karyology.

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PHORONIDA

Introduction

Phoronids, so far known, are limited to shallow waters of tropical and temperate zones. They are best known along the European coasts as the marine littoral fauna and are better known than elsewhere.

The first scientific notice of the phylum was after the finding of J. Muller (1846, 1847) of a characteristic swimming larva which was mistaken as an adult form and named as *Actinotrocha branchiata*. Gegenbaur (1854) correctly recognised it as a larval stage. Adult phoronid was discovered by Wright (1856) and gave the name *Phoronis* (from Greek mythology) without any idea of their relationship to the actinotroch larva. Kowalevsky (1867) studied the metamorphosis actinotroch larva and realised that it is the larval stage of Wright's worm *Phoronis*. The name Phoronida for the group was coined by Hatschek (1888) and was differently spelt by Lang (1888) as Phoronidea. The former name was adopted by Hyman (1959) who placed it in the rank of phylum.

The Phoronida are tubicolous, vermiform coelomates, with a terminal lophophore in the form of a horse-shoe that embraces the mouth, with recurved digestive tract having an anal opening near the mouth, with a closed circulatory system and a pair of metanephridia.

The Phoronida are slender solitary worms that inhabit leathery tubes, glued with particles of foreign matter. A number of individuals are commonly associated together, their tubes being twisted around one another; but their bodies are separate. The most conspicuous feature of the animal is its terminal crown of tentacles or lophophore, consisting of a single row of tentacles borne on a double ridge of body wall, curved into crescentic shape. Mouth lies between two ridges of the lophophore. The anus is dorsal and outside two lophophore, at the summit of a median longitudinal ridge. The body is elongated aborally and may attain a length of about 20 cm. Phoronids are hermaphroditic or dioecious.

The Phoronida are exclusively marine and are found sparingly over a wide geographical range but are apparently absent from polar and subpolar waters. They are limited to the upper littoral zone (above 50 m) and no record from deep sea till date is available. They range from very small about 6 mm long with 18 to 25 tentacles to about 200 mm with around 1600 tentacles. Species living in sandy bottom have separate, perfectly cylindrical, erect tubes, covered with fine sand grains. In some species, the tubes of the aggregation may form an inextricable tangle adherent to shells, pilings, and the like and in others the membranous tubes enclosing the worms are themselves enclosed in burrows of mollusk shells or calcareous rock. Most remarkable habitat has been observed in *Phoronis austrialis,* whose delicate transparent tubes occupy the interstices of the cnidarian *Cerianthus* and when the host with draws inside its tube, the phoronid is seen radiating in the expanded strate from the aperture. Phoronids exhibit great power of regeneration, when kept in laboratory aquaria, often casting their tentacular crowns and regenerating new ones.

Historical Resumé

The knowledge of phoronids from the Indian coast is very poor. The pioneering work on this particular group comprising only a couple of species from India, however, dates back to the earlier part of this century. Gravely (1927) explored, at least, one undetermined species of *Phoronis* from the Porites Bay of Krusadai Island in southern India. Subsequently, Nair and Shaw (1956) recorded *Phoronis australis* from the Beyt Island of Okhamandal in western India while Ganguly and Majumder (1967) described *Phoronis bhaduraii* from Digha, Midnapore district in eastern India. The

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record of *P. australis* in the Beyt Island by Nair and Shaw was confirmed by Haldar (1981).

Estimation of Taxa

There are 11 known species assigned to two genera, *Phoronis* and *Phoronopsis*. Genus *Phoronis* is identified by the absence of the epidermal collar fold below the lophophore where as in the genus *Phoronopsis* it is present.

Emig (1982) reviewed the biology of Phoronida and provided a list of species as follows:

Genus *Phoronis* Wright, 1856

P. australis Haswell, 1883 (includes *P. buskii)*

P. bhaduraii Ganguly & Majumdar, 1967

P. hippocrepia Wright, 1856 (includes *P. caespitosa, P. capensis, P. gracilis, P. kowalevskii)*

P. ijimai Oka, 1897 (includes *P. vancouverensis*)

P. muelleri Selys-Longchamps, 1903

P. ovalis Wright, 1856

P. pallida Silen, 1952

P. psammophila Cori, 1889 (includes *P. sabatieri* & *architecta*)

Genus *Phoronopsis* Gilchrist, 1907

P. albomaculata Gichrist, 1907

P. californica Hilton, 1930

P. harmeri Pixell, 1912 (includes *P. pacifica, striata* & *viridis*)

Distribution pattern of Phoronida in India

Region	*No. of species*
Gujarat including Gulf of Kutch	1
Tamil Nadu, including Gulf of Mannar	1
West Bengal	1

As per the available information on 3 species known from India, *Phoronis australis* is found in the tubewall of cerianthids, *P. psammophila* lives in the soft substratum and *P. bhadurii* occurs in compact sandy substratum.

Besides taxonomy no other information on this group, except Haldar's (1981) contribution on the ecology and systematics of *P. australis* is available.

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MARINE BRYOZOA

Introduction

Bryozoa, also called Polyzoa or Ectoprocta are lophophorate, aquatic, sessile, colonial, coelomate invertebrates with a recurved digestive tract bringing the anus near, but outside, the mouth. They have no special respiratory, circulatory or excretory organs. The supporting exoskeleton may be cuticular, gelatinous or commonly calcareous. The colonies of bryozoa may be vine like, encrusting as single or multiple layers, nodular, straggling, arborescent or pliacent; rarely they are discoid and non-attached. Colonies may comprise a single feeding zooid or hundreds, or thousands or even a million. Size ranges from a few square millimeters to even 100 sq. cm. in area or 1 mm in length. In texture they may be soft, gelatinous, flaccid or rugged. In the field, they could be easily mistaken for hydroids, sea weeds, ascidians or corals.

The phylum contains some 20,000 described species of which nearly 3,500 - 4,000 species are extant. A few bryozoans inhabit freshwater (Phylactolaemata), but most are marine (Gymnolaemata and Stenolaemata). They occur at all latitudes, surfaces and depths, greatest bundance being in the intertidal and shallow waters of the continental shelf that terminates at a depth of around 200 m or a little more. Earliest known bryozoans are from Upper Cambrian. Several species are preserved as fossils and many geological formations are well characterised by the bryozoa. However, their stratigraphic value is often underestimated and just beginning to be exploited in petroleum research. In the distant Ordivician seas of the Lower Palaeozoic, some 500 million years ago, they were known to form extensive reefs. In modern times, extensive bryozoan reefs have been reported off only a few areas like Bahama and Tasmania which are significant nourishing areas for commercial fish. Bryozoa are among the most commonly encountered, interesting but often overlooked organisms in littoral communities. Predominantly they are cryptic in their habitat inhabiting undersurfaces of rocks, gullies, crevices, etc., and also colonise extensively the algae as well as a variety of hard substrata (rocks, shells, corals, etc.). Some of them, however, also serve as important substrata for other epizoic organisms. Perhaps the greatest importance of bryozoa in shallow waters concerns their role in marine biofouling, a problem of immense economic importance. They are among the most abundant, diverse and consistently persistent groups of marine fouling organisms. Although not contributing significantly to the fouling biomass, they seem to play a very subtle role in the fouling process. Their ability to tolerate copper paints, which are unfavourable for most of the other organisms (and thus providing toxic-free surfaces for other settlers) and association with sulfate reducing bacteria are of special importance in this context. Some species are capable of penetrating wood in the same manner as marine fungi and a few species can bore into shells and other calcareous materials.

In recent years, a number of bioactive compounds have been isolated from bryozoa that possess anti-septic, anti-bacterial and anti-carcinogenic properties promising some exciting possibilities with medical and pharmaceutical applications. Studies also suggest that bryozoa are a potentially valuable, hitherto unexploited, biological resource in environmental impact studies, and some species appear to be very useful indicators for metal pollution, etc.

For all their commonness and importance enumerated above, study of bryozoa has received only scant attention in the past and the group was traditionally regarded as only a 'minor phylum', even though with 20,000 species it actually occupies an intermediate position in the hierarchy of animal phyla in respect of species representation. Faunistic studies are missing from several areas and conspicuous gaps exist in the recorded distribution of several species. They were generally overlooked or ignored in most of the marine biological surveys/studies, probably because their colonies are not conspicuous or spectacular and also their cryptic habitat and general appearance when dried.

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Non-specialist biologists may recognise no more than a few species, while among specialists, the higher categories are not always well understood as many families, genera and species are inadequately characterised. Original descriptions of even the common species "are too incomplete, too general, and do not always include really distinguishing characters" The study also is burdened with a large and fantastic terminology which is sometimes ambiguous and obscure both in application and derivation. The difficulties are aggravated by generally poor accounts in text books and lack of a modern monograph for identifications. Bryozoan biology is rich in enigmatic features and provide ample opportunities for gross misinterpretations. The phylum name itself is the subject matter of seemingly endless controversy. They were first called Polyzoa in antiques and later on as Bryozoa or Ectoprocta. The majority of bryozoologists accept the term bryozoa as a phylum name to indicate only the ectoprocta, but some specialists, insist on using ectoprocta to avoid any confusion. As with the phylum name, there are disagreements concerning the composition of even the higher taxonomic subdivisions.

They were long divided into 2 classes (Phylactolaemata and Gymnolaemata) but now into 3 (Phylactolaemata, Gymnolaemata and Stenolaemata). Infroaordinal classification of especially Cheilostomata, the most diverse order of Bryozoa, has always proved difficult and for convenience either grouped into suborders (possibly quite artificial) and of late as superfamilies. In the absence of clear morphological types and because of their polyphyletic nature, large groups such as Ascophora are best treated as families directly.

Many issues regarding classification of bryozoa are yet to be resolved, and in the past many 'schemes' have been proposed. The most widely used are those adopted from Harmer (1915-57); Osburn (1947, 1950, 1952, 1953) and Cook (1968). In view of the large number of 'artificial groupings' recognised in earlier 'schemes', bryozoan classification has recently been subjected to considerable revision and the one presented in this report (Table 1) is the most widely accepted currently, although a few continue to adhere to older schemes.

TABLE 1

Classification of Bryozoa

Phylum	Class	Order	Suborder	(D) Division/ Superfamily(S.F)		Approx. No. of families
BRYOZOA	Phylactolaemata (freshwater)					
	Stenolaemata	Cyclostomata		(D)	Tubuliporia	8
					Articulata	1
					Cancellata	6
					Rectangulata	1
					Fasciculina	3
					Ceriopria	2
		*Cystoporata				
		*Trepostomata				
		*Cryptostomata				
	Gymnolaemata	Ctenostomata	Carnosa		(S.F) Alcyonidiodea	6
			Stolonifera		Walkerioidea	4
					Penctrantioidea	1
					Vesiculariadea	4
		Cheilostomata	Anasca	(D)	Inovicellata	1
					Scrupariina	3
					Malacostega	7
					Coelostega	8
					Pseudostega	2
					Cellularina	8
			Cribrimorpha			2
			Ascophora			54

* Extinct not dealt in detail

Historical Resumé

i) Pre-1900

A perusal of literature on the group reveals that early studies were mostly conducted by naturalists at the turn of the century, the field was benefited by a small cadre of predominantly European specialists who are still recognised as giants in bryozoology. Much of their work was from temperate localities and they generally believed that the tropics were specifically unfavourable for the growth of bryozoans' Many tropical areas remained unexplored during the period preceding 1900 and Bryozoa were virtually unknown from the Indian region till about 100 years ago. Important publications prior to 1900 include the work of Hincks published in 1884 and 1887. In the 1884 publication he described 6 species from India, Singapore and Sri Lanka (Ceylon); in the 1887 publications 7 more species were added from Mergui Archipelago.

ii) 1901-1947

This period witnessed the publication of 3 of the 4 volumes of Sir Sidney F. Harmer's studies on bryozoan material (Harmer, 1915, 1921, 1934), based on the examination of the rich collections of the 'Siboga Expedition', carried out by the Dutch from 1899 to 1900 under the direction of Dr. Max Weber. The fourth volume, on Ascophora, was completed from his unpublished drafts and with notes by Anna B. Hastings of the British Museum, and published posthumously in 1857). Some 510 species and subspecies were dealt with by Sir Sidney in this work, which is considered a *magnum opus* on bryozoan studies in the tropical Indo-Pacific. The study has also convincingly proved the view that tropical regions are poor in bryozoa as a fallacy. Although the material examined by Harmer does not include samples directly from India, many species from the region described by other early investigators were cited and synonymised. Reference to this important work is a must for all bryozoan studies from not only the Indian region, but the entire tropics. The main contributors during this period were Thorneley, Annandale and Robertson. Thorneley (1950) described/listed 116 species. The material was collected by Prof. Herdman at Sri Lanka. Of these, 31 had already been recorded from Indian seas, 32 from Australian waters, 3 from the China seas and waters of east, west and south Indian Ocean. She established 16 new species and 1 new family. In the 1907 publication, she reported on the collections of R.I.M.S. "Investigator" kept in the Indian Museum. The report has 81 species among which 4 are new to science. Annandale's studies (1906, 1912) are mainly confined to brackishwater and freshwater forms. He described 8 species from the brackishwater along the coast of India. The report of Robertson (1921) in which 95 species including 9 new species and a new variety were listed perhaps constitutes the most comprehensive of the Indian works in this phase of bryozoan studies. These early works have clearly established that a rich and varied bryozoan fauna exists in the region. It is, therefore, extremely surprising that the group remained virtually neglected during the rest of this period.

iii) 1948-1990

Bryozoa continued to receive scant attention till the late sixties notwithstanding the stepped up activity in marine biological research in the century. They were either totally ignored or referred to only briefly in studies concerning benthic animal communities or biofouling conducted by the investigators from the Universities or Government Research Institutes, although identifications of the species mentioned were of dubious nature.

Fortunately, there seems to have been a revival of interest in the group since the late sixties, i.e., after a gap of nearly four-and-a half decades. Investigators from both the east and west coasts brought out some useful publications, though not on a scale quite in proportion to their commonness and abundance, in this more recent phase of bryozoan studies. The most important contributions in this contemporary phase are the two Doctoral theses by Menon (1967) dealing with bryozoa from selected localities along the southwest and southeast coasts and Satyanarayana

Rao (1975) from the north Andhra coast. The number of species obtained by these investigators were 101 and 65, respectively. Most of the material reported upon by Menon (1967), excepting the species occurring in fouling communities of the Cochin harbour area, were from dredged samples. All the species reported by Satyanarayana Rao (1975) however, were from the intertidal region. The material obtained by Menon was confirmed by Prof. Mawatari, Japan and Satyanarayana Rao's species, by Miss. P.L. Cook of the British Museum, U.K. In addition to taxonomy, attention was also paid to certain aspects of ecology in these works. Some of the results obtained in these works were published by these investigators either individually or in collaboration with their research directors (Menon, 1971; 1972 a,b; Menon and Nair, 1967 a,b; 1969 a,b; 1971; 1972; 1975; Ganapati and Satyanarayana Rao, 1968; Ganapati *et al.*, 1969; Satyanarayana Rao and Ganapati, 1972 a,b; 1975; 1978; 1986). Other notable published accounts on Indian bryozoa in recent years are those of Chaapgar and Sen (1966), Pillai and Santhakumaran (1972), Pillai (1978, 1981), Gupta (1967), Subbarao and Kameswara Rao (1970, 1973), Rao (1972 a,b), Satyanarayana Rao and Balaji (1988), Swami and Karande (1987) and a few others.

Vishwanadham (1987) and Radhakrishnan Nair (1989) have recently completed Doctoral works on bryozoa from Visakhapatnam and south east coast (mainly Porto Novo). The former added 12 species to the 65 species recorded by Satyanarayana Rao from Visakhapatnam and the latter obtained over 30 species from the southeast coast.

Studies from Different Environs

i) Estuarine and Harbour Localities

On the west coast, the species occurring at the Cochin backwaters and harbour were studied by Menon (1971, 1973, 1967) and Menon and Nair (1971). Bryozoans in the fouling communities at Mangalore were mentioned by Menon *et al.*, (1977). Pillai (1978, 1981), Pillai and Santhakumaran (1972), Swami and Karande (1987) investigated the bryozoans at Bombay harbour and vicinity. Studies are also in progress by Wagh and associates at the National Institute of Oceanography, Goa, on the bryozoans in the fouling communities at the Zuari estuary.

East coast

Most of the studies made by Annandale (1907-1921) were from the brackishwater ponds at Port Canning, Lower Bengal from the Chilka Lake area.

Satyanarayana Rao (1975), Satyanarayana Rao and Ganapati (1978) studied the bryozoans (12 species) from Visakhapatnam harbour. Viswanadham (1987) added 9 more species to the list. Bryozoa from Madras harbour were listed in the publications of Daniel (1954), Antony Raja (1959), Ismail and Azariah (1978) and more recently by Nair (K.V.K) and associates (1989) from Kalpakkam area. Satyanarayana Rao and Ganapati (1975) described 9 species from the Godavari estuary, Kakinada and Satyanarayana Rao and Balaji (1988) dealt with the fouling species at Port Kakinada. Nair (1989) investigated bryozoans of Porto Novo waters.

ii) Shelf Sediments/Dredged Material

Most of the bryozoans dealt by the early investigators (excepting Annandale) like Robertson (1921), Thorneley (1905, 1907, 1912) are from dredged samples. Menon's (1975) study of the species from south west and south east coasts of India consists primarily of dredged samples. All the 21 species reported by Subbarao and associates (1970, 1973) are from the shelf sediments (off Visakhapatnam and other eastern coasts).

iii) Open coast-intertidal Bryozoa

Satyanarayana Rao's (1975) work on the taxonomy and ecology of intertidal Bryozoa of the north coastal Andhra Pradesh (covering an area of approximately 270 km from Kakinada in the south to Kalingapatnam in the north) is perhaps the most important contribution on the Bryozoa of this habitat, wherein 55 species were described (in addition to the 12 harbour species). At Waltair-Visakhapatnam coast alone 45 species were collected. Subsequently, 12 more species were added by Viswanadham (1987) taking the total number of identified Bryozoa at Waltair to 57, making the locality one of the richest intertidal areas in terms of identified Bryozoa in the world. Other important contributions to Bryozoa in the intertidal region are those of Graveley from Krusadai Islands (1927), Chaapgar and Sen (1967) from Bombay and more recently Nair (1989) from Porto Novo area.

Other Aspects

Investigations on Bryozoa have not really progressed much beyond the level of identification at most tropical localities and this is also generally true of the Indian fauna. Almost all the studies upto the 70's are taxonomic accounts, barring a few species mostly occurring in fouling communities. In the recent past, some very useful information on the ecology of fouling species was obtained, especially from Visakhapatnam, Cochin and Bombay harbours. Seasonality of recruitment, abundance, growth (of major fouling species) are the aspects generally investigated in this context (Satyanarayana Rao, 1975, Menon, 1971, Swami and Karande, 1987). Menon (1973) also investigated the vertical and horizontal distribution of fouling bryozoans at Cochin harbour. Settling responses to metallic and non-metallic surfaces was studied by Satyanarayana Rao and Viswanadham (1988). Species that received relatively better attention are : *Electra bengalensis* (Satyanarayana Rao and Ganapati, 1978) and *Victorella pavida* (Menon and Nair, 1967).

The only major study dealing with distributional aspects and abundance of Bryozoa from an intertidal rocky shore is by Satyanarayana Rao and Ganapati (1986) from Waltair - Visakhapatnam coast, wherein a distinct 'bryozoan band' was described in the infralittoral of Stepehnson's tripartite zonation system. Satyanarayana Rao (1975) recorded extensive bryozoan growths at Visakhapatnam, some calcareous species (*Steganoporella buskii*, etc.) attaining huge dimensions (of 45 x 30 x 30 x 9 cm). Growth rates of 4 species each were studied by Menon and Nair (1970) and Satyanarayana Rao and Viswanadham (1989) at Cochin and Visakhapatnam, respectively.

Satyanarayana Rao and Ganapati (1980) also studied the epizooites occurring on two species of bryozoa, i.e., *Thalamoporella gothica* var. *indica* and *Pherusella tubulosa* and observed that Bryozoa constitute an important substrata for a variety of organisms providing food, shelter and protection from wave action. Satyanarayana Rao (1975) also documented the biological interrelations of bryozoan communities, algal-bryozoan associations, molluscan-bryozoan associations, etc. Karande and Swami (1988) studied overgrowth competitions amongst 7 species of encrusting cheilostomes at Bombay. Salinity tolerance of two species was investigated by Menon and Nair (1970). The species were : *Victorella pavida* and *Electra crustelenta*.

The breeding periods and seasonality of settlement of 21 species of open coast bryozoa from Visakhapatnam were reported by Satyanarayana Rao (1975). Satyanarayana Rao and Viswanadham (1987) described ancestrulae and early colony formation in 7 species of malacostegan Bryozoans. These authors (Satyanarayana Rao and Viswanadham, 1987) also provided a detailed descriptions of the ancestrula of the Thalamoporellid, *Thalamoporella stapifera* and gave an account of its early astogeny.

Estimation of Taxa

Both Gymnolaemates and Stenolaemates - the two classes of Bryozoa that occur in marine conditions are represented in the Indian collection, the former far outnumbering the latter. This is predictable as Gymnolaemates are by far the most diverse and successful of modern Bryozoa with over 106 families against only 20 of Stenolaemates. Accurate estimates of the number of species occurring in the region is extremely difficult to provide as descriptions of species especially in early works are too incomplete, too general and do not always include really distinguishing characters. Very few species are illustrated adequately and the problem is compounded by the absence of any authentic collections (of identified species) in the National Museums.

Authentic identifications have been made, for about 170 species in recent years, most of them by Satyanarayana Rao and Menon. At least 30-40 species from early works appear to be valid (after synonymistaion). Of the 126 extant families in Gymnolaemata (106) and Stenolaemata (20), at least 40 are represented. Membraniporidae, Electridae, Thalamoporellidae, Bugulidae, Scrupocellariidae, Smittinidae are among the better represented families. The collections include cosmopolitan (e.g., *Aetea anguinea, Bugula neritina*), cricumtropical (e.g., *Membranipora tuberculata, Zoobotryon verticellatum*), but mostly of species typically of the tropical Indo-West Pacific (*Steganoporella sulcata, Thalamoporella hamata, Parasmittina tropica*, etc.). Endemism is rare in Bryozoa, *Membranipora hugliensis*, however, is one such species. In recent years, a number of bryozoans, e.g., *Bugula stolonifera* have been introduced into the Indian waters, through presumably ship fouling.

Current Studies

Bryozoa is not being studied at the Zoological Survey of India for some years now. Outside ZSI, bryozoological research is being carried out in a few centres, i.e., Visakhapatnam and Kakinada (Wood Biodegradation Division-Marine of the Institute) and Andhra University; Kalpakkam (Indira Gandhi Centre for Atomic Research Centre); Porto Novo (Centre for Advanced Studies in Marine Biology) on the east coast; at Trivandrum and Cochin (Kerala and Cochin Universities); Bombay (Naval Chemical and Metallurgical Laboratory); Goa (National Institute of Oceanography) and Wood Biodegradation Division-Marine of the Institute of Wood Science & Technology) on the west coast. While taxonomic work still continues to be the major aspect, of study, studies relating to ecology (especially of fouling species), biology and physiology are gaining attention. The use of bryozoans in pollution studies is currently being investigated at Visakhapatnam.

Guha at the Indian Institute of Technology, Kharagpur and Dwivedy at the Oil and Natural Gas Commission, Dehra Dun are engaged in studies relating to fossil Bryozoa, biostratigraphy and paleoecology.

Our knowledge of marine bryozoa from the Indian region, however, is far from satisfactory and continues to be at the 'alpha' level. Vast stretches of the coast line are yet to be explored, the role of bryozoans in littoral ecology is still to be understood and many aspects of their biology are to be investigated.

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FRESHWATER BRYOZOA

Introduction

Freshwater Bryozoa of Ectoprocta represents one of the most common and àttractive aufwuch communities of the ecosystem. These colonial organisms vary in the number of individuals depending on age of the colony, nutritive status and pollution levels of the water bodies. They display exquisite behavioural responses to environmental stimulii. Ectoprocta is mainly divided into two distinctive classes, Phylactolaemata and Gymnolaemata, of which the former is strictly restricted to fresh waters and the latter is predominantly marine. About 5,000 spp. of marine Ectoprocta and 45-50 spp. of phylactolaematous Ectoprocta inhabit marine and fresh water respectively. The freshwater Ectoprocta frequently occur on submerged stones, on the stems of aquatic plants and other submerged substrates. Despite their common occurrence collection of fresh water Ectoprocta need keen observation, careful collection of the material, proper narcotisation and fixing. These interesting organisms provide exquisite designs and architecture, providing some of the most beautiful biota of the freshwater ecosystem.

Freshwater Ectoprocta are soft-bodied animals enclosed in protective body wall, the zooecium. They have colonized on all possible submerged substrates, each species having its own preferences. They extend from floating substrates to substrates at grèat depths. However, they are most abundant in the littoral region. In the freshwater ecosystem the Ectoprocta play an important role even though their biomass productivity is meagre. These filter feeders under favourable conditions can grow into dominant communities. The interspecific relations of fresh water Bryozoa range from simple association, to having commensalistic and symbiotic relations. These have close associations with bacteria and other invertebrate phyla, like Protozoa, Porifera and Coelenterata. Occasionally these organisms also grow on molluscan shells, leaves and steams of aquatic plants, floating barks and even on pupal exuviae and on tortoise shells etc. Some of the spp. of the freshwater Ectoprocta are known to be used as food by fresh water fishes, but most of the gelationous spp. are not consumed as food but avoided probably due to the epidermal toxins of these organisms.

Historical Resume

The freshwater Ectoprocta attracted scientific attention quite early. Aristotle referred to them as zoophytes. Early biologists including Linnaeus, Allmann and Annandale have preferred the term Bryozoa. Recent workers however prefer the name Ectoprocta.

i) Pre-1900

Study of freshwater Ectoprocta in general was pioneered by Blumebach (1780), Curiver (1798), Davenport (1890a & 1890b), Hancock (1850), Kraepelin (1884), Lamarck (1860), Linnaeus (1767), Oka (1890), Pallas (1768), and Wesenberg Lund (1895). The earlier contributions by these authors were on the gross morphology, structural details and habitat of these organisms.

ii) 1901-1947

As far as Indian fauna is concerned Annandale was the first to draw our attention to the freshwater ectoprocta. Annandale (1901 - 1922) has pointed out diversity of these organisms from numerous localities in British India. Sehoeder (1910) gave an account of freshwater Ectoproct parasites.

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iii) 1948-1990

The recent compilations by Hyman (1958), Maglich (1972), Ryland (1970) and Woolacott and Zimmer (1977) have helped in consolidating the known information on freshwater Ectoprocta. Further, the recent researches of Bushnell (1950-1990), Wood (1972-1990), Rao (1962-1990), Rao and Agarwal (1971), Rao and Diwan (1976-1980), Rao, Diwan and Shrivastava (1976-1980) Rao and Ghosh (1962), Rao & Kulshrestha (1962), and Raviprakash, Rao & Trivedi (1962) have thrown light on the environmental relations of the freshwater Ectoprocta. The ultra-structural aspects were described for the first time by Bushnell & Rao (1974), Rao & Bushnell (1976) & Rao (1976, 1977 & 1978) who have explained the ultra-structural mechanisms of the statoblast binding and germinable capabilities.

The ecological aspects of freshwater Ectoprocts were pioneered by Bushnell (1965a, 1965b, 1965c, 1966, 1972 & 1974), Bushnell and Rao (1974, 1979), Rao (1976 & 1979) and Toriumi (1941, 1956, 1963 & 1970). The physico-chemical factors and their influence on these animal were described by Bushnell (1966 & 1974).

Reports on the biological relationships of ectoprocta were attempted by a number of workers elsewhere. But in India their associations with plants and sponges were recorded by a few workers (Annandale, 1991; Shrivastava, 1959; Kulashrestha, 1962-64; Rao and Kulashrestha, 1962-64).

The pollution ecology of freshwater Ectoprocta have attracted attention of several workers. In India, Rao & Diwan (1977) have described the effects of high organic pollution on Ectoprocta. A detailed account on water quality monitoring with freshwater Ectoprocta as indicator was described by Rao *et al.* (1986).

Institutional Research

Studies on Indian freshwater Ectoprocta were initiated by Annandale, who published several reports on freshwater Ectoprocta (1901-1922). His monograph on freshwater Ectoprocta (1911) is a pioneering work as far as Indian fauna is concerned. His work was supplemented by Rao (1940), Seshaiyya (1934) and Rao (1961-1963). The last mentioned author reported on freshwater Bryozoa of Rajasthan (Rao, 1972). Subsequent to this period, not much attention was given to this group by the scientists of the Zoological Survey of India.

Studies from Different Environs

Information on Indian freshwater Ectoprocta is meagre and is scattered in about 50 references involving more than 10 scientific journals. About 10 scientific investigators have contributed towards our knowledge of freshwater Ectoprocta while the marine Ectoprocta have comparatively attracted more attention.

Indian freshwater Ectoproct study dealt by Annandale (1911) are faunistically oriented and so are the reports of Rao (1940) and Rao (1972). subsequent investigations of Rao resulted in report of the Narmada Bryozoans in 1973. Later several freshwater Bryozoan reports have been published from the state of Madhya Pradesh by Rao and his associates. Some of the new spp. described by this group include the distributions of *Swarupella andamanensis, P. ganapati* and *Hyalinella diwaniensis.* First records of *P. casmiana, P. repens* and *Hyalinella minuta* in India from the state of M.P. have also been made by this group. Exclusive ecotypes resulting in honeycomb growths of *P. casmiana* and *Hyalinella minuta* are also reported. Rajtilak has reported *P. tanganyikae* from his Himalayan survey. During the last two decades the Bryozoa of Madhya Pradesh have received considerable attention. Materials of *Lophopodella* and *Pectinetella* have also been dealt by Rao and his associates. The significance of solerotisations in the environmental relation of the freshwater Bryozoa was reported for the first time. This factor is extremely important in explaining the survival strategies of these organisms. The origin of this sclerotized structures, the septa, the statoblast and the septal accessories of sclerotization and encrustation were explained and the significance of freshwater Bryozoan resistance to challenging environmental conditions are explained. Tolerance and importance of these as pollution indicator organisms has also been pointed out (Rao, 1986, 1987).

Examination of Taxa

The family wise breakup of freshwater Ectoprocta in India and adjacent countries.

Class	*Family*	*Genera*	*Genera Known only from India*	*Sps. known only from India*
Phylaoto-laemata	Fredericellidae	*Fredericella*	*Swarupella*	*Swarupella andamanensis*
	Plumatellidae	*Plumatella*		*Plumatella ganapati*
		Hyalinella		*Hyalinella diwaniensis*
		Varunella		*Varunella Indorana*
		Stolella		
		Stephanella		
	Lophopodidae	*Lophopodella*		
	Pectinatellidae	*Pectinatella*		
Gymnolaemata	Hislopiidae*	*Hislopia*		

* Another family, Cristatellidae is not represented in India.

Indian freshwater Ectoprocta is as confusing as the world freshwater Ectoprocta Fauna, as far as their systematics are concerned. More collections of material are needed for confirmation of each of these species. New species described recently have to be reexamined critically and their records from more localities would help to confirm their specific status. Ecological studies on freshwater Ectoprocta will throw light on the vast plasticity and environmental relations of this group. Both the phylactolaemate and gymnolaemate ectoprocta of India show more diversity than hitherto conceived.

Classified Treatment

The systematics of freshwater Bryozoa is one of the most controversial amongst the invertebrates. The following information presented includes the widely accepted version of this group.

Class Phylactolaemata

Family Fredericellidae

The family includes one species.

Fredericella sultana

F. sultana is most common in Indian freshwaters.

Family Plumatellidae

Genus *Plumatella*

This represents one of the most plastic genus of this family. Out of the 132 species occuring in this genus some are still of doubtful nature, while the spp. like *P. emarginata*, *P. casmiana* and *P. repens* probably represent polytypic species, while *P. fruticosa*, *P. javanica*, *P. ganapati* are sparingly distributed. Several freshwater Ectoprocta taxonomists like Dr. F. Wiebach, Dr. Anna Hastings, Dr. M. D. Rogick, Makato Toriumi, J. H. Bushnell, K.S. Rao and Timothy Wood suggested the need for a total reconsideration of the entire genus. Several species described by Annandale of this genus have been synonymized. The systematic review of freshwater Bryozoa by Allman is not of much importance in the present day freshwater Bryozoan systematics. Systematic reviews written by Wiebach and Rogick and Lacourt also have limited value because of multiple ecotype materials, existing in each species of freshwater Bryozoa, *Plumatella fungosa, P. toenensis, P. evelinae, P. caryalhoi* have not been recorded from India. Genus *Varunella* is represented in India by two species. The *Varunella coronifera* which is quite common and the species *V. indorana* which is exclusively restricted to Indian subcontinent. *Swarupella andamanensis, P. ganapathi* and *H. diwaniensis* are the other species reported exclusively from the Indian subcontinent, besides the cosmopolitan *H. punctata* and *H. minuta*.

Family Lophopodidae is represented by a single genus *Lophopodella* in which two species occur in the Indian subcontinent, *L. carteri* and *L. himalayana*.

Family Cristatellidae has not so far been recorded from India, while family Pectinatellidae have been represented by single species *Pectinetella gelationosa*. *P. magnifica* has not so far been recorded from India.

Among the class Gymnolaemata a single family Hislopidae is represented in freshwaters. Out of the six spp. of genus *Hislopia* only two *H. lacustris* and *H. moniliformis* are represented in the Indian subcontinent. The recent observations of Rao and Choubey shows the polytypic nature of *H. lacustris*.

Current Studies

Currently no study on freshwater Bryozoa is being undertaken in the Zoological survey of India. In the entire country School of Studies in Zoology, Vikram University, is only place where freshwater Bryozoan taxonomy and ecology are dealt with in depth. Presently collections from Uttar Pradesh, Andhra Pradesh, Madhya Pradesh and Rajashthan are understudy. These include both the groups of Phylactolaemata and Gymnolaemata.

Our knowledge of Indian freshwater Bryozoa is far from satisfactory and revision of several genera and families have to be taken up. Good potentialities of Biomedical nature exists but unfortunately none of the freshwater Bryozoan spp. have been undertaken for such a study. Recently the importance of this group has increased as they have been pointed out as bioindicators of various levels of pollution.

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ENTOPROCTA

Introduction

Entoprocta are pseudocoelomate organisms which are stalked or sessile with the anus opening inside the tentacular circlet. The tentacles are cillated and nonretractile but can be folded into the vestibule forming a calyx. The systematic position of these organisms was for a long time contorversial but their embroyological evidences have undoubtedly relegated them to the pseudocoelomate group. These are bilaterally symmetrical with a "U" shaped alimentary canal and a flame-bulb-type of excretery system. Entoprocta have remarkable power of regeneration by budding. Some members are hermophrodite while others are unisexual. Most of them are marine or brackish water, but the single family Urnatellidae is freshwater. Not much work has been done on this group and their exact role in the freshwater ecosystem has yet to be determined.

Historical Resumé

Leidy (1883) and Keferstein (1863) have referred *Urnatella* and *Loxosoma* to the phylum Bryozoa, although they were aware of the differences between the two genera. Nitsche in 1870 proposed to divide Bryozoa into two groups, Entoprocta to include the genra *Pedicellina, Uranatella* and *Loxosoma* and Ectoprocta to include other known Bryozoans. Presence of the anal opening inside the tentacular circlet is the chief diagnostic feature of this group. Hatschek, (1877) by his embroyological studies has shown that Entoprocta have a much lower grade of organization than Ectoprocta and raised Entoprocta to the status of a phylum. Clarck (1921) recognized the non-coelomate nature of Entoprocta, raised them to the status of a phylum, giving a new name Calyssozoa. All subsequent workers on the group have accepted the phylum status and preferred the name Entoprocta due to priority rules.

Until 1947, despite the controversy, the group was treated as a class in phylum Bryozoa. This group was recorded in India for the first time by Sheshaiya (1944, 1947) who recorded the member of family Urnatellidae, described *Urnatella indica* as a new species from South India. The same species has been figured recently by Tonapi (1980).

Classification

Phylum Entoprocta is mainly divided into 3 families, Loxosomatidae, Urnatellidae and Pedicellinidae. The following table provides a broad classified account of this phylum with examples of common genera.

	Family	*Common genera*
Solitary	Loxosomatidae	*Loxosoma* *Loxocalyx*
Colonial	Pedicellinidae	*Pedicellina, Myosoma christapis, Loxosomatoides, Pedicellinopis, Barentsia, Ascapodaria, Gonypodaria, Arthopodaria.*
Colonial	Urnatellidae	*Urnatella gracilis* *Urnatella indica*

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From the Indian subcontinent Annandale (1908, 1910 & 1916) and Harmer (1885) have described a number of new genera and new species of Entoprocta and Sheshaiya (1944) a single species. The validity of these taxa was upheld by several later investigators abroad.

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BRACHIOPODA

Brachiopoda is a neglected group, very few species having been reported from Indian waters. The earliest Indian work is that of Alcock, 1894 (a new brachiopod) *Terebratula johannisdavisi)* and Joubin, 1906 (*Kingena alcocki*) a new species from Indian seas. Patil (1953) recorded *Lingula* sp. from Karwar coast and the neighbouring Islands. Awati and Kshirsagar (1935) recorded three varieties related to *Lingula anatina* from different localities of the west coast, while Gideon *et al.* (1957) recorded the same species from Dwarka.

Thomas Dawidson's (1886-1888) monographs dealing with 100 species of extant brachipods then known, is definitely the earliest substantial work. Since his death, there has not been any remarkable work and hence his synonymies were in an obsolete and disorderly state. Recently, Muir-Wood (1955) provided an exhaustive bibliography. At present, quite an extensive world literature has accumulated on fossil brachiopods.

For the brachiopods of Indian waters, no contribution has been made excepting a few scattered papers. At present about five species are known from this region. Among the workers may be included-Awati and Kshirasagar (1957) who dealt with the biology of *Lingula;* Sudarsan (1968, 1970) and Chuang (1976), who recorded larval forms along the coasts Arabian Sea and bay of Bengal, respectively. Soota and Reddy (1976) covered the distribution of the genus *Lingula* along the Indian coast.

At present, studied are being conducted in the Survey by Reddy on the taxonomy and ecology of the genus *Lingula.*

Expertise Available

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CHAETOGNATHA

Introduction

The Phylum Chaetognatha contains bilaterally symmetrical, carnivorous, mostly marine and a few estuarine species. They form one of the major constituents of the marine zooplankton and play a prominent role in the food cycle. Chaetognaths are popularly known as "Arrow worms" or "Glass worms" because of the torpedo–like shape and transparent nature of the body. They are well known as indicators of the origin of the watermasses and their movements.

The chaetognaths were first reported by Martin Slabber in 1778 from the Dutch coast and he named them as 'Sea worms' Later, Quoy & Gaimard (1827) gave a brief description on the *Sagitta* species collected from the Straits of Gibraltar. Due to the difficulty of placing *Sagitta* under the then known groups such as annelids, molluscs etc., Leuckart (1854) proposed a separate group Chaetognatha to accommodate the Arrow worms and placed them between nematodes and oligochaetes. The terminology of this Phylum is based on the presence of prehensile hooks on either side of the jaws (Chaetae = setae; gnathos = jaws).

The chaetognaths are hermaphrodites, with delicate, elongate, transparent or opaque body and do not have separate respiratory, circulatory and excretory organs. The body is divided into head, trunk and tail. As this is a small Phylum with only a few species and the differences between the species are not marked, no one has thought of dividing the Phylum into Classes, Orders, Families etc. However, in 1965, Tokioka proposed a new classification for this Phylum as given here:

Phylum CHAETOGNATHA Leuckart, 1854

Class ARCHISAGITOIDEA

Family Amiskwidae (Genus : *Amiskwia*)

Class SAGITOIDEA

Order 1. PHRAGMOPHORA

Family Spadellidae (Genus *Spadella*)

Family Eukrohnidae (Genera *Eukrohnia, Heterokrohnia, Bathyspadella*).

Order APHRAGMOPHORA

Sub–Order CTENODONTINA

Family Sagittidae (Genus *Sagitta*)

Family Pterosagittidae (Genus *Pterosagitta*)

Sub–Order FLABELLODONTINA

Family Krohnittidae (Genus *Krohnitta*)

This new classification for the Phylum Chaetognatha proposed by Tokioka (1965) has not been widely accepted and followed by other taxonomists. As Alvarino (1967) pointed out the highest rank, which might be used in grouping this Phylum, is that of Genus. The species included in each of the genera are separated by means of slight differences, in the position of various morphological structures, which are very closely related to each other. Therefore, further systematic division of this Phylum is not justified. So the Phylum Chaetognatha is divided into nine genera as detailed here:

Genus *Archeterokrohnia* Casanova, 1986

M. Srinivasan, Zoological Survey of India, Madras.

Genus *Eukrohnia* Ritter-Zahony, 1909

Genus *Heterokrohnia* Ritter-Zahony, 1911

Genus *Pterokrohnia* Srinivasan, 1988

Genus *Krohnitta* Ritter-Zahony, 1909

Genus *Pterosagitta* Costa, 1869

Genus *Sagitta* Quoy and Gaimard, 1827

Genus *Spadella* Langerhans, 1880

Genus *Bathyspadella* Tokioka, 1939

So far about 100 species under the above nine genera are known from the different oceans. Though this is a small group, it occupies the second place in the order of abundance among the marine planktonic organisms, copepods being the first group. Further it plays a significant role in the food cycle. They occur in close association with copepods and an increase in the copepod population, is generally followed by proportionate increase in the chaetognath population.

Further, chaetognaths could be used as indicators of watermasses and their movements, because certain species are seen closely associated with particular type of watermass. This association is useful in identifying a particular watermass in a region, where there are several bodies of water in which the salinity differences are not well marked. It has already been established along the Californian coast (Alvarino, 1964). English Channel (Russel, 1935) and west coast of India (Srinivasan, 1976).

Historical Resumé

i) Pre-1900

Prior to the year 1900, very little was known about the chaetognaths from the Indian seas and all the published reports prior to 1900 are about the chaetgnaths of the Atlantic and Pacific Oceans. Though chaetognaths were first reported from Dutch coast in 1778 by Martin Slabber, brief description of the species of *Sagitta* was given by Quoy & Gaimard (1827) based on the samples collected from the Straits of Gibraltar. Then Charles Darwin (1884) reported the *Sagitta* species from the coasts of Brasil, Argentina and Chile. In 1895, Beraneck reported the chaetognaths from the Bay of Amboine (Pacific Ocean) including a new species (*Sagitta bedoti*). In 1897, Aida added there new species of chaetognaths (*S. neglecta*, *S. regularis* and *Krohnitta pacifica*) from the Misaki Harbour.

ii) 1901-1947

Doncaster's (1903) report on the fauna and geography of the Maldives and Laccadives Archipelago is the first significant publication on the chaetognaths of the Indian Ocean. This report describes 11 species including four new species (*S. ferox*, *S. pulchra*, *S. robusta*, *S. septata*). In 1906, Fowler while studying the collections of the Siboga expedition in the Indian Ocean, reported 16 species and provided a complete distributional record of the then known 33 species.

Though several papers were published on the chaetognaths during the beginning of this country, the first comprehensive monograph on the morphology, distribution and bibliography of the Indian Ocean chaetognaths was published in 1911 by Ritter-Zahony. After this monograph, the contributions of Baldasseroni (1915) on the chaetognaths from the Bay of Bengal and Burfield & Harvey (1926) on the 'Sea-Lark' expedition chaetognaths were the prominent ones. Burfield & Harvey (1926) discussed in detail about the horizontal and vertical distribution of the chaetognaths.

Schilp's (1941) report on the chaetognaths collected from the Indian Ocean during the

'Snellius' expedition is another notable contribution on the Indian Ocean chaetognaths. In this account he reported 19 species and discussed the horizontal and vertical distribution of these species.

The first report on the chaetognaths from the west coast was by Lele & Gae (1936) on the Bombay harbour chatognaths. Then a series of papers were published on the chaetognaths of Madras coast (John, 1933, 1937; Subramaniam, 1937, 1940)

iii) 1948–1990

There are not many publications on chatognaths of the Indian Seas during 40s and 50s of this century. The paper published during these two decades are by Varadarajan & Chacko (1943) and Menon (1946) on the chaetognaths from the Trivandrum coast; George (1949, 1952) on the Malabar coast chaetognaths; Chacko (1950) on the Krusadai Island chaetognaths; Rao (1958) and Rao and Ganapati (1958) on the Chaetognaths of the Andhra coast.

Tokioka (1962) gave a resume of the papers published on the Indian Ocean chaetognaths and the species reported from the Indian Ocean. Another important report on the Indian Ocean Chaetognaths is by Alvarino (1962) on the Monsoon expedition chaetognaths collected by R/V ARGO during 1960–1961.

Nair (1967) studied the biomass of the chaetognaths from the Indian Ocean based on the samples collected during the International Indian Ocean Expedition cruises from 1960–1965. Further she has pointed out the variability in the distribution of chaetognaths in the Arabian Sea (1972). In 1973 Nair and Rao reported the occurrence of 19 species of chaetognaths from the IIOE samples collected in the Arabian Sea. Further they have studied the chaetognaths from the Kavarathi Island (1973). In the same year they examined the chaetognaths from the upwelling areas of the Arabian Sea and reported 14 species. They stated that the population maxima of chaetognaths were found not adjacent to the centre of upwelling, but shifted to the fringe of enriched areas.

In 1977 Nair reported the chaetognaths from the Indian Ocean and she discussed the geographical distribution of different species found in the samples. Further in 1978, she studied the bathymetric distribution of 25 species of chaetognaths present in the samples collected during the cruises of U.S. ship Anton Bruun.

Silas and Srinivasan (1968, 1969, 1970) and Srinivasan (1972 a, b) have published a series of papers on the chaetognaths from the Arabian Sea.

In the Zoological Survey of India, studies on chaetognaths from the Indian seas were initiated in 1974 by Srinivasan at the Marine Biological Station, Madras. He has published a series of papers on chaetognaths from the Madras coast and Ennore estuary (1975, 1976, 1977, 1979, 1980).

In 1979, Srinivasan also published a monograph on Chaetognatha incorporating the detailed descriptions of 22 species found in the Indian Seas, a key for the identification of the species, and the discussion on the possibility of using certain species as indicators of upwelling along the west coast of India. He further studied the chaetognaths collected during the expedition cruises of INS DARSHAK (1987), INS KISTNA, RIMS INVESTIGATOR and R. V. VITYAZ (1987); the third Indian Expedition to Antarctica (1988) and cruises 1–44 of FORV SAGAR SAMPADA (1989). In the last referred paper he pointed out that the density of chaetognath population was very rich between Cochin and Mangalore coasts and near the Kandla coast along the west coast of India. Along the east coast of India, the density of the chaetognath population was less than the west coast and certain areas between Madras and Andhra coasts and between Paradip and Bangladesh coast had higher density of chaetognath population than the remaining areas of the east coast.

Studies from Different Environs

In addition to the marine habitat, chaetognaths are also found in the estuarine habitat. Though there are many estuaries along the Indian coasts, chaetognaths are well known only from a few estuaries such as Cochin backwaters (Nair, 1972, 1973, 1975; Srinivasan, 1972) and Mandovi–Zuari estuary (Nair & Selvakumar, 1979) along the west coast and Ennore estuary (Srinivasan, 1972, 1977, 1980; Srinivasan & Raghunathan, 1978; Raghunathan & Srinivasan, 1983), Kakinada estuary (Rao, 1960) and Goavary estuary (Cahdramohan, 1963) along the east coast of India. Among the 100 species known from the World Oceans, only 9 species are so far known from the estuarine waters of India. Even among these nine species only two species, *Sagitta bedoti* and *S. entlata* are commonly seen in estuaries.

Life cycle studies on certain chaetognath species in Cochin backwaters and Ennore estuary (Nair, 1973; Srinivasan, 1980) revealed that the fully matured specimens of *S, bedoti* and *S. enflata* were absent in the estuarine waters, whereas the specimens of all the other sages were found. This may be due the possibility of migration of these adults towards the deeper layers of the estuaries (David, 1955).

An interesting observation noted during these studies is the retarded growth in the total length of the specimens of *S. bedoti* and *S. enflata* (Srinivasan, 1972, 1977) from the Cochin backwaters and Ennore estuary.

Srinivasan and Krishnan (1985) studied the chaetognaths collected during the total solar eclipse from the Plankton samples collected in the coastal waters of Puri, Orissa, and observed the upward migration of chaetognaths along with the other planktonic organisms towards the surface waters. The number of chaetognaths found in the sample collected during the eclipse period was more than the number in the sample collected before and after the total solar eclipse.

Studies on chaetognaths of the Indian seas have revealed that the west coast has been well explored than the east coast. This may be due to the fact the Central Marine Fisheries Research Institute, stationed at Cochin has conducted several regular crusies along the west coast and collected plankton samples along the coast and around the Laccadives. Further the National Institute of Oceanography, stationed at Goa has also collected samples from the Arabian Sea. Along the east coast, only certain coastal areas around the Mandapam, Madras and Vishakhapatnam have been explored so far. The remaining coastal areas along the east coast, offshore waters and the seas around the Andaman & Nicobar Islands are yet to be explored.

Estimation of Taxa

So far about 100 specie of chaetognaths belonging to nine genera are known from the World Oceans and less than 30 species are reported from the Indian Seas. This is probably due to the insufficient sampling from deeper waters of the Indian seas.

Genus–wise breakup of the Chaetognatha known from India seas:

Eukrohnia	...	...	3 species
Krohnitta	...	...	2 species
Pterosagitta	...	...	1 species
Pterokrohnia	...	...	1 species
Sagitta	...	...	18 species
Spadella	...	...	2 species

Classified Treatment

As this is a small Phylum with only 9 Genera and 100 species, generally the entire group is taken up as such for detailed taxonomic studies. Detailed biological studies have been carried out on a few important species. Rao and Kelly (1962) studied the breeding habits of *S. enflata* in the Lawsoris Bay, Waltair and concluded that this species breeds throughout the year, with several peaks of intensive breeding. Srinivasan (1972, 1977, 1980) examined the breeding habits and life cycle of *S. bedoti* and *S. enflata* from the samples collected in the Cochin backwaters and Ennore estuary and reported that both the species were continuous breeders. Nair (1973) also studied the breeding habits of *S. enflata* and *S. bedoti* from the Cochin backwaters and Nair *et, al.* (1975) analysed the bio-chemical composition of *S. bedoti*

Current Studies

In the Marine Biological Station, Zoological Survey of India, Madras, the taxonomy, ecology and distribution of chaetognaths collected during the regular cruises of the Departmental Vessel CHOTTA INVESTIGATOR and the sorted out chaetognath samples received from the Director, Central Marine Fisheries Research Institute, Cochin, collected during the regular cruises of FORV SAGAR SAMPADA in Bay of Bengal and Arabian Sea are being studied.

Expertise Available

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Sachiko Nagasawa, Ocean Research Institute, 1-15-1 Minamidai, Nakano-ku, 164 Japan. [Chaetognath natrial ecology, rhythmic activity, feeding].

Moriyuki Kotori, Hokk. Centr. Fish. Exp. Stn. Yoichi, Hokkaido, 046 Japan. [Biology and ecology of *Paragitta elegans*].

Angeles Alvarino, Southwest Fish. Center, P.O. Box 271, La Jolla, California 92038, U.S.A. [Systematics, anatomy, reproduction, feeding, zoogeography ecology, bethymetric distribution].

George C. Grant, VIMS, Gloucester Point, Virginia 23062, U.S.A. [Distribution, taxonomy, ecology].

Jerry McLelland, Gulf coast Res. Lab, P.O. Box 7000, Ocean Springs, MS 39546, U.S.A. [Deep sea chaetognaths].

Thomas E. Bowman, Nation. Mus. of Nat. Hist. Smithonian Institution, Washington D. C., 20560, U.S.A. [Spadellids].

Harding B. Michel, University of Miami, 4600 Tickenbacker Causeway, Miami, Florida 33149, U.S.A. [Ecology, Zoogeography and life histories].

Helga, Kapp, Zool. Inst. Und Zool. Mus. Martin-Luther-King-Platz 3, 2000 Hamburg 13, Fed. Rep. Germany. [Systematics, zoogeography, vertical distribution and morphology].

Gerd Rehkamper, Anat. Inst. Univ. Koln, Joseph-Stelzmann-Str. 95000 Koln 41, F.R.G. [Central nervous system, morphology].

Wilhelm Hagen, Inst. f. Polarokologie Universitat Kiel, Olshausenstr. 40-60, 2300 Kiel I, F.R.G. [Antarctic chaetognaths].

Ulrich Welsch, Anat. Anst. Univ. Munchen, Pettenkoferstrasse 11, 8000 Munchen 2 F.R.G. [Morphology, systematic position, skin, intestinal tract].

David Convay, Plymouth Mar. Lab. Prospect Place, The Hoe, Plymouth PLI 3HD, England. [Vertical distribution, diurnal and seasonal migration, biomass, production, mainly *S. elegans*].

Quentin Bone, Plymouth Mar. Lab. Citadel Hill, Plymouth PLI 2PB, England. [Muscle structure and function, structure of nervous system].

Kathleen C. Chidgey, Old Odiham Road, Alton, Hants GU34 2EJ England. [Taxonomy and distribution].

Conway Morris, Dep. of Earth Sciences, Univ. of Cambridge, CB2 3EQ Cambridge, England. [Metazoan relationships].

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Vidar Oresland, Dept. of Zoology, Univ. of Stockholm, S-106 91 Stockholm, Sweden. [Distribution, life cycle].

Sifford Pearre Jr. Dept. of Oceanography, Dalhousie University, Halifax, Nova Scotie, Canada b3H 4J1. [Vertical migration, feeding, trophic web relationships].

Jean Paul Casanova, Lab. de Biologie animale, Univ. de Provence, 13331 Marseille cedex 3 France. [Taxonomy, biology, zoogeography].

Michel Duvert, Lab. de Cyt. Univ. Bordeaux, Avenus des Facultes, 33405 Talence-Cedex, France. [Locomotion, muscular contraction].

Alla Kassatkina, Lab. Marine Biology, Zoological Institute, Leningrad 199 164, USSR. [Systematics, ecology, morphology, physiology and zoogeography].

Sigrid Ofner, Zoologie Inst. d. Univ. Althanstr, 14, 1090 Wien, Austria. [Taxonomy, morphology, distribution].

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ECHINODERMATA

Introduction

As conspicuous constituents of marine biota, echinoderms have been known since ancient times and have evoked a large literature. The name Echinodermata which is now applied to such forms commonly known as sea-lilies, starfish, sea-urchins, sea-cucumbers etc., was first used by Jacob Klein (1734) for some echinoids, denoting the spiny skinned organisms. However, Linnaeus (1758) in his *Systema Naturae* ignored the name and included the echinoderms known to him under Mollusca. Later, Bruguiere (1791) separated them from Mollusca and made Echinodermata an order under Vermes. Although the holothurians remained separated from other echonoderms, In 1801, Lamarck for the first time brought holothurians together with other echinoderms but placed Echinodermata under Radiata along with Coelenterata. This association persisted for a long time until Frey and Leuckart (1847) separated echinoderms from Radiata. Since then Echinodermata have been regarded as a distinct phylum.

The echinoderms are characterised by radial symmetry almost invariably with pentamerous organisation of body organs, only holothurians and some echinoids having taken to bilateral symmetry. They are readily differentiated from the similarly radiate phyla by the coelom and higher level of organisation. The most conspicuous feature is their water-vascular system of coelomic nature and its radiating vessels and protruding tube feet or papillae. They further have a calcareous endoskeleton of articulating plates, rigid box-like test or scattered microscopic spicules. The body surface bears soft papillae, warts, calcareous granules or more commonly hard spines from which the name Echinodermata seems to have taken its origin.

The phylum has been divided into three subphyla comprising of 20 or more classes as per different views, of which, only the following six are extant.

Subphylum	Class
Crinozoa	Crinoidea
Asterozoa	Concentricycloidea
	Asteroidea
	Ophiuroidea
Echinozoa	Echinoidea
	Holothuroidea

The phylum can be traced to Cambrian and five of the above mentioned were distinct by Ordovician while the recently discovered Concentricycloidea had probably originated in Jurassic as per the opinion of its authors.

The Crinoidea primarily have a cup-like body called theca from which the branched arms with their lateral pinnules radiate. The sea-lilies have a long jointed stalk with whorls of cirri at each node and live attached to the substratum, while the sea-feathers detach the stalk at the base retaining only the top most whorl of cirri for temporary attachment or crawling and lead a free moving life.

The recently discovered Concentricycloidea are flat discoid forms without distinct arms and with concentrically arranged water-vascular system including the tube feet and supporting skeletal

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structures. This class is so far wholly represented by two living species : *Xyloplax medusiformis* Baker *et al.*, 1986 from New Zealand and *X. turnerae* Rowe *et al.*, 1988 from Bahamas.

The Asteroidea are flattened with a central disc and radiating arms, the latter not distinct in some. The ambulacral grooves are well formed and the metapinnules of Somasteroidea are reduced and highly modified.

The Ophiuroidea have a central disc and long brittle arms distinct from the disc. The paired ambulacral plates are fused into a single vertebra and enclosed together with the ambulacral furrow in box-like segments formed of latgeral, dorsal and ventral arm plates with the tentacle-like tube feet protruding out through pores on the ventral side. The arms are highly branched in many Euryalae.

In Echinoidea the endoskeleton forms a thick rigid box-like test enclosing all the visceral organs. The tube feet protrude out through the pores in the ambulacral plates. The mouth is always on the lower side while the anus is situated above or on the oral side.

The Holothuroidea are oro-anally elongated cylindrical forms with the mouth and anus situated at either end. The mouth is surrounded by highly modified tube feet called tentacles. The endoskeleton consists of scattered microscopic spicules of various forms.

The echhinoderms inhabit all the possible habitats right from the intertidal region up to the abyssal depths of about 10,000 m. of the marine environment. Their size also varies from a few millimetres as in the interstitial holothurians to about 1.38 m. in diameter or 10 kg. in wet weight of certain asteroids or about 2 m. in length in some holothurians. Although the majority are benthic with crawling or burrowing mode of life, the sea-lilies are permanently attached to the substratum and the sea-feathers and abyssal holothurians are habitual swimmers for short distances while certain holothurians are entirely planktonic. The benthic forms inhabit the hard substrata such as rocks and corals or crawl or burrow into the soft sediment. There are also forms which are epizoic on gorgonids and others inhabiting the sponges and algae. Their feeding habits also vary greatly. The regular echinoids feed on algae and certain asteroids scrape microscopic algal covering on rocks. The crinoids and basket stars exclusively feed on the floating micro-organisms by trapping them in mucus or the branching arms. Most asteroids are carnivorous feeding chiefly on molluscs, crustaceans and coral polyps. Some ophiuroids trap the floating organic particles in mucus and convey them to the mouth. Most other echinoderms swallow the organic rich sediment while crawling or burrowing. The echinoderms are dioecious with external fertilization and development through a free swimming planktonic larva characteristic of each group. Viviparity and brood protection are common in cold water inhabitants. Certain species are also known to be protandric. Some rare instances of hermaphroditism have also been reported.

The echinoderms constitute a very important component of the marine benthic biota of all depths. Numerically ophiuroids are the major constituent of some benthic communities, while holothurians contribute to about 90% of the total biomass at abyssal and hadal depths. Because of their characteristic internal skeletal structure, echinodrems are one of the major groups extracting calcium from the ambient waters and contributing to the carbonate sediments of the ocean floor. The boring activity of some sea urchins into the rocks and coral conglomerates causes erosion of the hard substrata contributing to the development of soft habitats. The holothurians with their burrowing and casting habits are comparable to the earthworms as substrate reworkers. The burrowing asteroids and irregular urchins also disturb the sediment considerably.

The varied feeding habits encountered in the group, make use of all types of food available in the environment ranging from attached algae and planktonic biota to the sedentary and burrowing or creeping organisms and organic rich sediments and oozes. In addition, instances of scavenging are also not rare. While this ensures an important place for themselves in the complex food chain of the community, the more disastrous activity is by way of great damage to extensive coral reefs through voracious feeding by the sea-star, *Acanthaster planci* and to the algal beds by various herbivorous echinoids, affecting the community structure drastically and sometimes irreparably.

The ripe gonads of sea urchins and processed body wall of holothurians (*beche-de-mer* or *trepang*) are considered as delicacies in several parts of the world particularly in SE Asia. A very good *beche-de-mer* industry survives in the Gulf of Mannar area with possibilities for extending the same to other localities rich in holothurian resources. Attempts are also on the way to explore the echinoid resources of the Indian seas for a similar exploitation. Sea urchin eggs are also a very handy material in the fields of experimental embryology, developmental physiology, pollution control etc. Recently, echinoderms are being extensively used in the biomedical research for the extraction of various compounds of pharmocological importance.

In addition, dried asteroid specimens and cleaned tests of echinoids with their captivating symmetry and alluring ornamentation serve as decorative pieces. The tests of echinoids are particularly used in making various curios such as paper-weights, lamp shades, ashtrays etc. and as bases for various other curios.

Historical Resumé

Although the first report on Indian echinoderms dates as far back to as 1743, our knowledge of the group greatly increased in the late 19th century with the launching of the Marine Survey programme aboard the R.I.M.S. *Investigator* in 1881 and the almost simultaneous interest shown by the Madras Government Museum in the chank and pearl fishery of the Gulf of Mannar as well as the general fauna of the area, there being very few reports during the intervening period.

i) Pre-1900

It was in 1743 when the first report on Indian echinoderms was made by Plancus and Gualtire from Goa and the next in 1830 by Colliere on the *beche-de-mer*. Subsequently, the accounts of Mueller (1849), Luetken (1865, 1872) and Marktanner-Turneretscher (1887) included a few new species from the Bay of Bengal. In the field of Palaeontology,Stolickzka (1873) reported on the cretaceous echinoderms of South India, while Duncan and Sladen (1883) and Blanford (1887) studied the fossil echinoids of Gujarat and Rajasthan respectively.

The extensive echinoderm collections made by the scientists of Marine Survey through R.I.M.S. *Investigator* from various coastal and offshore areas were studied by several workers. Simultaneously the Madras Government Museum took interest in the fauna of Gulf of Mannar during a study of chank and pearl fishery of the area. Day (1883) first catalogued the echinoderm exhibits from the *Investigator* in the Indian section at the International Fish Exhibition. Alcock (1893-1895), Anderson (1894, 1907), Walsh (1891) reported on the earlier collections of the *Investigator*. Koehler (1897, 1898) first reported on the entire ophiuroid collections. These have been reprinted under *Echinoderma of the Indian Museum* with additional information on subsequent collections in 1899 and 1900. The series was continued for the remaining groups of echinoderms in 10 volumes. While Thurston (1887-1895) of the Madras Government Museum gave and account of the echonoderms and their habitats in the Gulf of Mannar, Bell (1887-1889) reported on the earlier collections of the *Investigator* as well of those of the Madras Museum.

ii) 1901-1947

During this period, echinoderm material arising out of the *Challenger*, *Valdivia* and *John Murray* expeditions from the Indian region were the additions to that of the *Investigator*. Further, Bengal Fisheries Trawler *Golden Crown* also made some echinoderm collections along the coasts of Orissa and West Bengal during her cruises. In addition, scientists from educational and research institutions also contributed to our knowledge of Indian echinoderms. As a result, a number of monographic accounts and check-lists giving an almost complete taxonomic account of Indian echinoderms appeared during the period.

Alcock (1902) gave some general observations on the echinoderms encountered during the cruises of the *Investigator*. Monographic accounts on the different groups have been brought out by several workers on the material of *Investigator, Valdivia, Challenger, John Murray* and *Siboga*. A.H. Clark (1902-1932) reported the Crinoidea of the *Investigator's* collections. Subsequent collections of Ophiuroidea by the *Investigator* and other Indian material were studied by Koehler (1904, 1907, 1910). Complete accounts on the shallow-water and deep-sea Asteroidea were given by Koehler (1909, 1910). Later Koehler (1914, 1922, 1927) reported the Echinoidea in three volumes. The monographic account on Holothuroidea was completed by Koehler and Vaney (1904-1910). In addition, Bomford (1913) and Setna (1930) gave notes on some ophiuroids of the Indian Museum. While Jenkins (1922) made some observations in the shallow waters aboard the *Golden Crown*, and the echinoderms of the Gangetic delta were reported by Annandale (1922).

The echinoderms of Minicoy Island in the Lakshadweep collected during Gardiner's expedition to the Maldive and Laccadive Archipelagoes, were studied by Bell (1902). Unfortunately many of his identifications had to be corrected by later workers. Doederlein (1906) reported a new deep-sea echinoid off Nicobar Islands from the *Challenger's* collection. The monographic and revisionary accounts of Koehler (1904, 1905), Fisher (1911-1930), Doederlein (1915-1930), A.H. Clark (1915-1967), H.L. Clark (1921-1935), Mortensen (1928-1951), Hertz (1930) and John (1948), on the material collected during the *Vaidivia, Siboga*, Philippine and South Pacific expeditions as well as other material included several Indian species.

The echinoderms of Krusadai Island in the Gulf of Mannar and of the Madras beach were documented by Gravely (1927, 1941). There were also a few more reports of new species by Devanesan (1932), Mortensen (1936, 1939) and Nair (1944).

A good number of fossil echinoderms of South India, Khasi Hills, Bagh Beds, Rajasthan etc. were reported by Das Gupta (1921), Splenjer (1923), Rao (1927, 1929), Gee (1931), Chiplonkar (1937, 1939), West (1949) and Barooah (1946).

Studies on ecobiological aspects of echinoderms were also initiated during this period. Aiyar (1936) studied the development of the sea-urchin *Salmacis bicolor*. Aiyar's (1938) continued studies resulted in a memoir on *Salmacis*, the only one of its kind on Indian echinoderms till recent times. Earlier Aiyar and Menon (1934) studied the spicules of two sea-urchins, *Salmacis bicolor* and *Stomopneustes variolaris*. Symbiotic associations of various organisms with echinoderms were reported by Chopra (1931), Mukerji (1932) and Varadarajan (1939) while the parasitic gastropods were dealt with by Koehler and Vaney (1903, 1912, 1925). The occurrence of echinoderm larvae in the plankton off Madras coast was reported by K.S. Menon (1931) and off Trivandrum by M.A.S. Menon (1945).

iii) 1948-1990

Since the publication of the last volume of Echinodermata of the Indian Museum (No. X) by Koehler (1927) and subsequent notes on some ophiuroids by Setna (1930) and a report on the associates by Mukherji (1932), the studies on the Indian Echinodermate at the Zoological Survey of India had come to a stand still until seventies when the studies were again started intensively. However, with more and more Universities and research Institutions recognising the importance of echinoderms in various fields, a large number of works covering a wide variety of aspects of echinoderms appeared during this period. In the field of taxonomy emphasis has been on consolidating and updating the knowledge of regional fauna and revisionary studies in addition to reports of new records and new taxa. On the ecobiology front, the attention has been on the reproductive and biochemical aspects and the *beche-de-mer* resources. There have also been reports on the ecology zoogeography, symbiosis, development, toxicity etc.

Madsen (1951) included in his account, current status and detailed distribution of many deep-sea asteroids of the Indian region collected by the R.I.M.S. *Investigator*. James (1969) catalogued several echinoderms from various Indian localities and elsewhere, present in the reference collections of the Central Marine Fisheries Research Institute and James and Lal Mohan (1969) compiled an exhaustive bibliography on the echinoderms of the Indian Ocean. Clark and Rowe

(1971) in their Monograph included all the shallow-water echinoderms of Indo-West Pacific region with keys for their identification, detailed distribution and a nearly complete bibliography. Important notes were also given by A.M. Clark, (1953, 1967, 1968, 1970), James (1971, 1987), Soota and Sastry (1979) etc.

While Guideon *et al.* (1957) mentioned some echinoderms from the Gulf of Kutch with incomplete identity, only the holothurians were studied by Gopalakrishnan (1969). Sane and Chhapgar (1962) reported 16 species of echinoderms from Bombay of which four have been identified only up to genus. Patil's (1953) report contains only some common forms with incomplete identification, from Karwar coast. Parulekar (1981) reported the echinoderms from Malvan. Whole studying the bottom fauna off Travancore coast, Kurian (1953) encountered four species of echinoderms. Several shallow-water species have been reported from Minicoy by Bell (1902) while Nagabhushanam and Rao (1972) listed a few more species which require confirmation. Sivadas (1977) and Murty *et al.* (1979) reported the crown-of-thorns starfish, *Acanthaster planci* from the Lakshadweep. A thorough study of the echinoderm fauna of the Lakshdweep was made by James (1989) and further updated by Sastry (in press) Mukhopadhyay and Samanta (1983) and Mukhopadhyay (in press).

The fauna of Gulf of Mannar has been well known. Chacko (1956), and Chacko *et al.* (1965) listed the fauna. James (1985) gave an updated list of echinoderms of the Gulf of Mannar. Mukhopadhyay (1988) studied the holothurian fauna of the area. The echonoderms in the Madras Government Museum collected chiefly from Tamilnadu coast were reported by Satyamurty (1976). Some echinoderms of the Kakinada Bay and of Orissa coast were listed respectively by Radhakrishna and Ganapati (1969) and Nagabhushanam and Rao (1969). The echinoderm fauna of the state of West Bengal and of the Hughli-Matla estuary were studied by Sastry (in press) and Mukhopadhyay (in press).

From time to time, James of the Central Marine Fisheries Research Insittute has been reporting on the Indian echinoderms, chiefly from Andaman and Nicobar Islands. James (1983) compiled a list of echinoderms reported from these islands. Julka and Sumita Das (1977), Sastry (1977) and Soota *et al.* (1983) respectively reported some asteroids, echinoids and holothurians from Andaman and Nicobar Islands.

Daniel and Haldar (1974) reviewed the holothurians of the Indian Ocean with special reference to their distribution. James (1980, 1987) reviewed the studies on the echinoderms of the Indian Ocean and of India respectively and in the latter gave the correct identity of species reported by earlier workers such as Bell, Thurston, Gravely etc.(Loc cit)

There have been several studies on the reproductive behaviour, biochemical changes and early development of some echinoderms. Important among them are those of Shetty (1960), Giese *et al.* (1964), Rao (1965, 1968), Rahman (1966, 1968), Krishnaswamy and Krishnan (1967), Krishnan (1967-1970), James (1973) and Krishnan and Mary Bai (1977). Several associates of various Indian echinoderms were reported by Ganapati and Sastry (1972), Rao and Sowbhagyavati (1972), Jones and James (1970), Sastry (1977, 1981), Daniel and Krishnan (1978) etc. The *beche-de-mer* resources, collection, processing, food value, marketing etc. have been dealt with by Durairaj (1982), Jacob (1973), James (1989) and Lal Mohan (1989). James (1983) gave an account of the sea-urchin and sea-cucumber resources with particular reference to Andaman and Nicobar Islands, while Reuben *et al.* (1987) studied the sea-urchin resources of Waltair coast.

The occurrence of echinoderm larvae in the plankton has been studied by George (1953), Prasad (1954) and Meenakshi-kunjamma and Gopalakrishnan (1977).

The fossil echinoderms from Rajasthan have been reported by several workers notably Sahni and Bhatnagar (1955, 1958), Hoffman (1963), Pascoe (1963), Gupta *et al.* (1967) and Gupta (1972). In addition, there have been a few more reports on unidentified fossil echinoderms.

Studies from Different Environs

Echinoderms as a whole inhabit all the possible environs of the marine ecosystem including corals, rocks, shingle beds, sandy shores, muddy bottoms, algal beds, mangroves, estuaries etc. and from the intertidal regions to abyssal depths. There are also some boring, fouling, epizoic and planktonic forms.

Most of the earlier works are of taxonomic and faunistic nature and contain only casual references to the nature of the habitat. Later works contained some information on the general nature of the environment from where the fauna have been collected. There have been only very few works pertaining to the echinoderm fauna with emphasis on the habitat. Rao (1968-1980) and Rao and Misra (1983) studied the taxonomy ecology and zoogeography of the interstitial holothurians. Sastry (1985) compiled a list of echinoderms of the Indian estuaries. Das (1985) reported a starfish from an estuarine region in the Andaman and Nicobar Islands. Some echinoderms from the mangrove habitats of the Andaman and Nicobar Islands have been reported by Das and Dev Roy (1989). Coral inhabiting echinoderms, particularly the crown-of-thorns starfish, *Acanthaster planci* of the Andaman and Nicobar Islands were studied by Mustafa *et al.* (1989), and Pillai *et al.* (1989). Rao and Dev Roy (1985) mentioned some echinoderms of coral habitats of the same areas. The account of Tikader *et al.* (1986) contains references to the habitats of some echinoderms of the Andaman and Nicobar Islands. A detailed account on the different habitats inhabited by several echinoderms of Indian region is however, that of James (1987). He also reported several echinoderms encountered as borers, foulers and epizoans (James, 1988).

The collections of R.I.M.S. *Investigator* included material from both the shallow-water and deep-sea environs. However, later studies in India pertained only to the shallow-water habitats because of their easy accessibility and lack of organized explorations of the deep water elements for taxonomic purposes. With the result, our knowledge of the deep water echinoderm fauna of the Indian region has been confined to what the earlier workers chiefly on the material collected by *Investigator*, reported six decades back. The knowledge on the shallow-water fauna is being updated and consolidated from time to time by James (1969-1989), Sastry (1977-1987 and in press), Soota and Sastry (1979), Soota *et al.* (1983), Mary Bai and Ramanathan (1977), Mukhopadhyay and Samantha (1983), Mukhopadhyay (1988 and in press) etc. Recently a thorough taxonomic study of the echinoderm fauna of the Lakshadweep, West Bengal, Hughli-Matla estuary and holothurians of Gulf of Mannar has been made in the above mentioned works. James (1983, 1985) compiled a list of echinoderms known from the Gulf of Mannar and Andaman and Nicobar islands. However, there have been only partial or scattered reports on the echinoderm fauna of other regions such as Gulf of Kutch, Maharastra, Karnataka, Kerala, Andhra Pradesh and Orissa. There is also dearth of information on the ecobiological aspects of echinoderms, no species having been studies thoroughly. Available information on the regional fauna is summarized below.

Class	*Number of species*			
	Lakshadweep	*Gulf of Mannar*	*West Bengal*	*Andaman & Nicobar Is.*
Crinoidea	1	9	-	28
Asteroidea	19	26	6	79
Ophiuroidea	22	19	7	87
Echinoidea	23	19	5	77
Holothuroidea	32	39	5	88
Total	97	112	23	359

Estimation of Taxa

The echinoderm fauna inhabiting the world oceans has been summarized below.

Extant Classes	*Orders*	*Families*	*Genera*	*Species*
Crinoidea	5	24	164	623
Concetricycloidea	1	1	1	2
Asteroidea	7	35	318	1500
Ophiuroidea	3	17	275	2000
Echinoidea	15	47	230	950
Holothuroidea	6	25	154	1150
Total	37	149	1142	6225

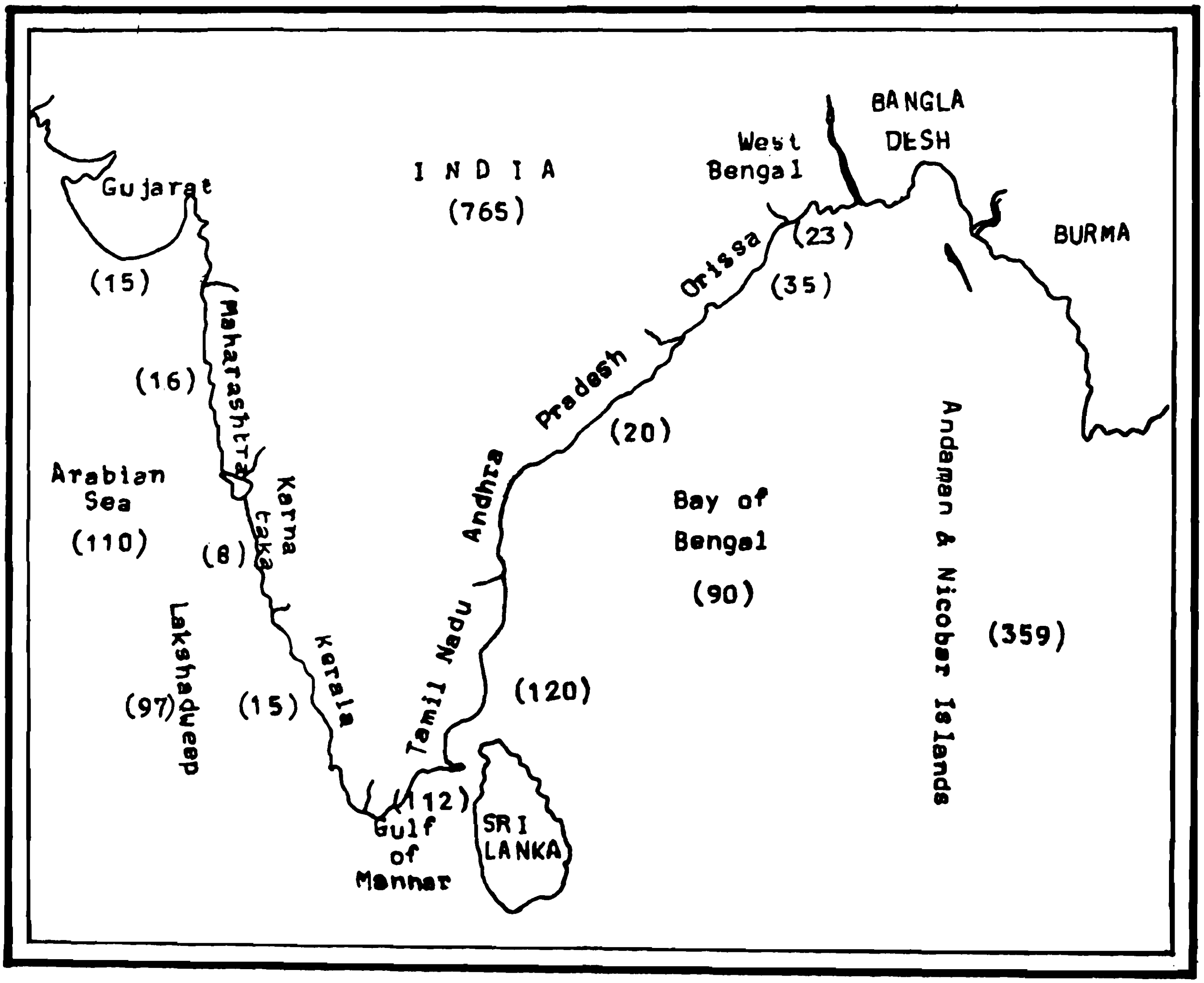
Of the six extant classes of Echinodermata, the class Concentricycloidea is not so far known to be represented in the Indian waters. The other five classes have been reported by a fair number of species. The majority of echinoderms were known by the year 1927 through the extensive collections made by workers on board the R.I.M.S. *Investigator*. Subsequently, there have been some additions to the deep water element by the *Challenger*, *Valdivia* and *John Murray* Expeditions. The shallow-water fauna has been under a thorough region-wise and group-wise study by Dr. D.B. James of Central Marine Fisheries Research Institute and scientists at the Zoological Survey of India. Thus, several additions and revisions of the Indian echinoderms have been made. The following is a compilation of the Indian species based on published as well as unpublished information. The numbers are approximate since delineation of strictly Indian territory is not always possible and is also not meaningful in respect of marine fauna.

Class	Number of Indian representatives		
	Families	Genera	Species
Crinoidea	13	43	95
Asteroidea	20	81	180
Ophiuroidea	15	67	180
Echinoidea	28	79	150
Holothuroidea	14	62	160
Total	90	332	765

The deep water component varies roughly from 35 to 65 per cent in different groups. Most of the shallow-water species inhabit hard coral and rocky habitats. As the echinoderms are in general less tolerant to wide fluctuations in salinity for prolonged periods, only a few species occur particularly during summer months of relatively higher salinity, in or near the estuaries.

Classified Treatment

Most of the earlier studies particularly of Wood-Mason, Alcock, Bell and some of the subsequent works of Clark and Rowe (1971), James (1969) etc. deal with more than one class of Echinodermata and are of purely taxonomic character. These have already been dealt with under the Historical Resume. Only the studies pertaining to other aspects of echinoderms are being mentioned here.



Map of Indian peninsula and islands with approximate number of echinoderm species reported from each region (Arabian Sea including deep water species of Laccadive Sea; Andaman and Nicobar Is. including Andaman Sea; Tamil Nadu including Gulf of Mannar).

Class Crinoidea

Other than taxonomy, only biological associations of crinoids have been reported. Jones and Sankarankutty (1960) reported a pea-crab from *Lamprometra*, while Nayar and Mahadevan (1967) reported occurrence of crinoids on a gorgonid, both from the Tamil Nadu coast. From Waltair coast of Andhra Pradesh, Rao and Sowbhagyavati (1972) encountered several groups of animals particularly myzostomes, crustanceans, polychaetes and molluscs associated with crinoids. Sastry (1981) reported two species of shrimps from the crinoids of Bay of Bengal. James (1987) made some observations on the ecology of some crinoids. James (1988) reported eight species of crinoids encountered as foulers two species of pohiuroids as epizoic on crinoids.

Class Asteroidea

The reproductive and related aspects of *Pentaceraster regulus* were studied by Rahman (1966, 1968) and Rao (1965, 1968). The early development of *Asterina burtoni* was studied by James (1974). Mustafa *et al.* (1989), Pillai *et al.* (1989) and Wood (1989) at Andamans and Sivadas (1977) and Murty *et al.* (1979) at Lakshdweep made some observations on coral habitats with particular reference to the presence of the crown-of-thorns starfish, *Acanthaster planci*. Das (1985), Sastry (1985) and Das and Dev Roy (1989) mentioned the star fish species encountered in the estuarine and mangrove habitats. Various symbionts associated with asteroids were reported by Mukerji (1932), Varadarajan (1939), Rao (1962, 1964) and Jones (1965). Some parasitic gastropods from asteoids were mentioned by Koehler (1909, 1910). James (1988) encountered seven species of asteroids as foulers.

Class Ophiuroidea

Panikkar and Prasad (1952) reported the occurrence of *Ophiocnemis marmorata* along with the coelenterate *Rhopilenema hispidum* at Mandapam. *Ophiomaza cacaotica* is a well known epizoan or even parasitic, on crinoids and sometimes on gorgonids. James (1988) reported the ophiuroids encountered as epizoans and foulers. The swarming behaviour of *Ophiocnemis marmorata* at Ennur backwaters was reported by Evangeline (1966).

Class Echinoidea

Alcock (1902) mentioned some habits of *Echinostrephus molaris* at Lakshadweep. The spicules of *Salmacis bicolor* and *Stomopneustes variolaris* were studied by Aiyar and Menon (1934) and the development of *salmacis bicolor* by Aiyar (1936). The memoir on *Salmacis* by Aiyar (1938) gives a brief account of echinoid classification, common Indian echinoids and also several aspects of echinoid biology with emphasis on *Salmacis*. Shetty (1960) studied the early development of *Stomopneustes variolaris*, while the reproductive and biochemical changes and other related aspects were studied by Giese *et al.* (1964). The effect of starvation on the nutrient reserves in the test, gut and gonads of *Salmacis virgulata* were reported by Krishnan and Mary Bai (1977). The sea-urchin resources were dealt with by James (1983) and Reuben *et al.* (1987). Three species of echinoids which bore into rocks and dead corals and *Salmacis virgulata* encountered as a fouler were reported by James (1988).

Ganapati and Sastry (1972) reported an alpheid shrimp, barnacle, stiliferid gastropod and a gobiid fish associated with *Stomopneustes variolaris* at Visakhapatnam coast. Sastry (1977, 1979) encountered two species of shrimps and a crab associated with sea-urchins of Nicobar Islands. Daniel and Krishnan (1978) reported their observations on the association of the carb *Zebrida adamsii* with *Salmacis virgulata*. Koehler (op. cit.) and Koehler Vaney (1912, 1925) described the parasitic gastropods of sea-urchins.

Class Holothuroidea

The reproductive, biochemical and histochemical studies on *Holothuria scabra* were made by

Krishnan (1967-1970) and Krishnaswamy and Krishnan (1967). The monograph of Mary Bai (1980) on *H. scabra* includes observations on anatomy and regeneration also. Successful induced breeding and development under captivity is the recent interesting contribution by James *et al.* (1988). Biotoxicity and bioactivity of holothurians were studied by Rao *et al.* (1985, 1987). James (1986) suggested the use of holothurian toxin for eradication of unwanted species in the fish farms. Various associations with holothurians were reported by Mukerji (1932), Chopra (1931), Ganapati and Radhakrishna (1963), Nayar and Mahadevan (1965), Jones and James (1970) Jones and Kumaran (1980) and James (1987). The taxonomy and zoogeography of interstitial holothurians were studied by Rao (1968-1983). Since the earlier reports on the *beche-de-mer* industry by Collier (1930) and Hornell (1917) there have been mentions about it in many works. The more recent ones by Durairaj (1982), Durairaj *et al.* (1984), Lal Mohan *et al.* (1987), James (1983, 1986, 1987, 1989) and Narasimham *et al.* (1984) dealt specifically and in detail with various aspects of the industry such as, resources, collection, processing, food value, quality control, marketing, export, conservation etc.

In addition, several papers dealing with reproductive cycles, digestive enzymes, effect of low salinity, and a polychaete associate of *Stomopneustes variolaris*, ecology, zoogeography, echinoderm associates several aspects of *beche-de-mer* industry etc were presented by James, Sastry and others at various symposia and work-shops.

Current Studies

At Zoological Survey of India, mainly taxonomic studies are at present undertaken with emphasis on state-wise faunal accounts. The projects on the echinoderm fauna of the Lakshadweep West Bengal and Hughli-Matla Estuary have been completed. The current projects are on the echinoderm fauna of Gujarat coast and ecology and population dynamics of *Acanthaster planci* at Andaman Islands.

At the Central Marine Fisheries Research Institute, Cochin and its various research stations, James and others are engaged on the taxonomy, zoogeography, ecology and various aspects of sea-urchin and sea-cucumber fishery, resources, and culture.

At other Research Institutes and Universities work on ecobiological aspects of echinoderms is being undertaken.

Outside India, several scientists, particularly from United States of America, United Kingdom, France, Denmark, Belgium, China, Australia, Japan, and New Zealand are engaged in revisionary studies, ecobiological and physiological aspects, pollution monitoring, evolution and classification etc.

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HEMICHORDATA

Introduction

Phylum Hemichordata consists exclusively of marine organisms occurring from tidal areas to great depths with few planktonic representatives. It is divided into three classes, i.e. Enteropneusta, Pterobranchia and Planctosphaeroidea. Our knowledge on this group in India is based on the collections made from the Gulf of Mannar, Madras coast, Andaman & Nicobar Islands, Laccadive Islands and the Gujarat coast.

Historical Resumé

Punnet (1903) described enteropneust worms from Laccadive and Maldive Islands. Menon (1904) working on dredged collections off Madras coast, described three species of which one was new to science. Later, Rao (1955) followed it up to describe several more species from the same area. *Ptychodera flava* from Krusadai Island was made more popular by other workers (but wrongly identified by few as *Balanoglossus*) i.e. Rao (1934), Ramanujan (1935), Devanesan & Varadarajan (1940), Kuriyan (1949) and Rao (1953, 1955 & 1962). Balasubramaniam (1978) described two species of Tornaria from Porto Novo waters. Pillay (1950) described the only enteropneust worm collected form Gujarat coast.

Pillay (1950) identified specimens of enteropneust worms collected from Okha coast. *Glandiceps malayanus* and *Glossobalanus minutus* were identified by Dhandapani from Andaman & Nicobar Islands and Maldive Islands. No samples of either Pterobranchia or Planctosphaeroidea were collected so far by the Zoological Survey of India parties. The Tornaria larvae that were collected during the 46th cruise on board F.O.R.V. *Sagar Sampada* and those that are being collected by RV *Chota Investigator* are being worked out by P. Dhandapani at Marine Biological Station, Madras. Further, Dhandapani during his recent surveys of the Gulf of Mannar, discovered the presence of *Ptychodera flava* (Enteropneusta) both near the Pamban Light House area and the Pullivasal Island.

Jayapaul Azaria, University of Madras conducts bio-chemical experiments on *Ptychodera flava*. Balasubramaniam, CAS for marine biology, Porto Novo, worked on Tornaria larvae. Bjorn Berg, Universidae de Sao Paulo, Brazil, and Staisny, Institute of Van Beneden, Belgium also work on Tornaria. Burdon-Jones, Plymouth Laboratory, England, and Thomas, University of Adelaide, Australia are experts on enteropneust worms. Practically no work on Pterobranchia is being done anywhere in the world.

Areas to be explored

Survey : Dredging should be done beyond 100 m level all over the Indian Ocean and its island waters; efforts should be made to look for hemichordates since this group is not covered adequately from Indian waters.

Taxonomic study

Taxonomic studies on families Protobalanidae, Cephalodiscidae and Planctospaeridae need to be undertaken.

P. Dhandapani, Zoological Survey of India, Madras.

Estimation of Taxa

Class	*No. of families*		*No. of genera*		*No. of species*	
	World	*India*	*World*	*India*	*World*	*India*
Enteropneusta	4	3	12	4	100	12
Pterobranchia	2	Nil	2	Nil	16	Nil
Plactospaeroidae	1	Nil	1	Nil	2	Nil

Expertise

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PROTOCHORDATA

Introduction

Protochordata comprises of two sub-phyla, Cephalochordata and Tunicata. Sub-phylum Cephalochordata has Class Leptochordii. Tunicata has three Classes, *viz.* Ascidiacea, Thaliacea and Larvacea. The protochordates are exclusively marine and occupy various niches in the marine ecosystem. The present status of our group in India is as such based on the work done on the Marine Survey Collections made on board R.I.M.S. "Investigator" , the vessels in the Pearl Oyester fisheries, the collections made by the Central Marine Fisheries Research Institute on board the R. V. Varuna, collections made by the various university laboratories of the maritime states and the collections of the International Indian Ocean Expedition.

Historical Resumé

Cephalochordata : Gray (1847), Thurston (1890), Tattersall (1903) and Foster–Cooper (1903) worked on the samples collected from the Indian Seas, including the Laccadive & Maldive Island collections. Prashad (1934) worked on the collections available in the Zoological Survey of India and described four species. Azaria (1963, 1966, 1967), working on the collections made off Madras coast has described three species.

Tunicata

Ascidiacea : Herdman's (1906) description of ascidians from the Gulf of Mannar was the first on Indian ascidians. Oka (1915), a visiting Japanese Scientist, worked on the deep sea collections made on board R.I.M.S. "Investigator" and described 11 new species belonging to the families Cynthidae, Styelidae, Ascididae and Clavinidae, which included an aberrent deep sea form, *Hexacrobilus indicus.* Das (1936–'45) and Sabestian (1942–59) worked on the ascidian fauna of the Madras coast; the former studied Pyuridae while the latter covered the families Polyclinidae, Peraphoridae, Pyuridae and Styelidae. Prakasam (1978) in his short work, added knowledge to the fauna of Madras coast. Ranganathan (1982–1988) has extensively covered various families of ascidians from his collection off southeast coast of India. From the Bombay coast, Karande (1969) noted six species of ascidians acting as foulers in the harbour. Miller (1988) worked on the ascidians brought by the International Indian ocean Expedition team.

Thaliacea: Bomford (1913) initiated the study on salps collected on board R.I.M.S. "Investigator" and this was followed by Sewell (1926) to complete a monograph. Nair & Aiyer (1943) and Nair (1949) recorded sixteen species of pelagic tunicates (salps & doliolids) collected off Madras coast. Ganapathy & Bhavanarayana (1958) gave a list of pelagic tunicates (salps, doliolids and Larvacea) and pointed out their significance as indicators of ocean currents in Bay of Bengal. Sabestian (1968) described a new encrusting species of *Pyrosoma* from the Arabian Sea. Swarming behaviour of salps were observed by Nagabhushanam (1960) off Andhra coast and by Lal Mohan (1965) off Gujarat coast. Dhandapani (in press) presented a paper in the Symposium on Indian ocean and adjacent seas at Cochin, in which he indicated the presence of fourteen species of doliolids (including new taxa) in the Arabian Sea. Dhandapani (1977) described eight species of doliolids including new records from the Bay of Bengal. Van Soest (1981) has published monograph on Pyrosmatida in which he described several new species from Indian Seas.

Larvacea : Fenaux (1974), working on the International Indian ocean Expedition material, has described many species of appendicularians from the Bay of Bengal. Chandrika (1974) recorded a rare appendicularian of the family Kowlevskidae. Dhandapani (1977) described two new species of Larvacea from the Bay of Bengal.

P. Dhandapani, Zoological Survey of India, Madras.

Dhandapani (1977) has worked out the collections made on board the vessels R.I.M.S. "Investigator", R.V. "Vityaz" and I.N.S. "Kistna" and added two new species of appendicularians, five species of doliolids and one species of Amphioxids as new to Bay of Bengal. Three species of salps and eighteen species of Larvacea have been added as new to National Zoological Collections. The collections of I.N.S. "Dharshak" and those of F.O.R.V. "Sagar Sampada" are being worked out for Protochordata.

In India, Ranganathan (Hindu College, Tuticorin), Jayapaul Azaria (Zool. Dept., University of Madras) and Bhavanarayana (Zool. Dept., Andhra University) continue to work on Ascidiacea, Cephalochordata and Salpida respectively.

Scientists outside India are interested on diversified aspects of the subject, i.e. physiology, embryology, cytogenetics, cytochemistry and computer analysis of the population, etc. Monniot (Museum Nationale de Historie Naturalle, Paris), Patricia Kott (Queensland Museum, Australia), Miller (Marine Laboratory, Scotland), Jefferies, (British Museum of Natural History, London), Tokioka (Seto Marine Biological Laboratory) are interested in taxonomy of ascidians. Godeaux (Institute of Van Beneden, Belgium), Bracconot (Statione Zoologique, France), and Van Soest (Zoological museum, Amsterdam) are experts in Thaliacea. Feneau, (Station Zoologique, France) is an expert on Larvacea. Tokioka (Seto Marine Biological Laboratory, Japan) is interested in all groups of pelagic tunicates.

Areas to be Explored

Survey : Dredging should be undertaken beyond 100m level all over Indian Ocean and its insular waters. This will help to have more knowledge on benthic fauna of Protochordata.

Taxonomic study : Among sessile tunicates, families Polycitridae, Dideminidae, Diazinidae, Cionidae, Corellidae, Octonimidae, Sortillidae and Molgulidae are to be worked out.

Estimation of Taxa

	No. of families			*No. of genera*		
	World	*India*	*ZSI*	*World*	*India*	*ZSI*
Cephalochordata						
Leptochordii	3	3	3	3	3	3
Tunicata						
Ascidiacea	15	7	5	-	-	-
Thaliacea	3	3	3	21	21	19
Larvacea	3	3	2	15	13	5

Total Number of Species Known

Taxa	*World*	*India*	*ZSI*
Sessile tunicata	2000 (approx.)	40	19
Pelagic tunicata	149	62	56
Cephalochordata	24	14	6

Expertise

INDIA

In ZSI

P. Dhandapani - Marine Biological Station, Zoological Survey of India, Madras - [Protochordata except ascidians].

Elsewhere

P. V. Bhavanarayana, Dept. of Zoology, Andhra University, Visakhapatnam - 3. [Salpida].

Jayapaul Azaria, Dept. of Zoology, University of Madras, Madras - 20 [Cephalochordata].

T. Ranganathan, Dept. of Zoology, Hindu College, Tuticorin, Tamil Nadu - [Ascidiacea].

ABROAD

N. J. Berrill, 410, Swathmore Avenue, Swathmore, Pennsylvania, U.S.A. [Tunicata].

J. C. Bracconor, Station Zoologique, Villefranche - sur. Marine, France [Doliolida].

R. Feneaux, Station Zoologique Villefranchesur, Marine, France. [Larvacea].

R. W. M. Van Soest, Institute of Taxonomic Zoologic, University of Amsterdam - [Thaliacea].

H. John, Wickstead, The Marine Biological Association, Citadal Hill, Plymouth, England - [Cephalochordata].

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PISCES

Introduction

The fish fauna of India and adjacent countries exhibits enormous diversity in their morphology, in the habitats they occupy, and in their biology. Fishes, like many other forms of life, are of immense value to mankind. Today they form an important element in the economy of India and many countries while giving incalculable recreational and psychological value to the naturalist, sports enthusiast and home aquarist. Many Government institutions are devoted to the study of their biology and propagation. They are used as general indicators or summators of pollution, partly to the direct benefit of mankind and partly to protect what people consider a valuable and necessary part of their heritage and life. It is desirable to maintain the diversity that the systematist studies.

Fish live in almost every conceivable aquatic habitat; they are found along the coasts of the Indian subcontinent, whether rocky, sandy or muddy, and amongst coral reefs, in deep sluggish rivers or in fast torrential streams, in lakes, ponds and wells, in river estuaries, coastal lagoons and backwaters; or total darkness in caves. The distribution of marine fishes is rather wide, and some genera are common to the Indo-Pacific and the Atlantic regions. It was estimated by Alcock (1899) that 57 per cent of the Indian marine genera were common to the Indian seas and to the Atlantic and Mediterranean. The freshwater fish fauna of the Indian subcontinent has elements in it which is common to the Indo-Malayan and Indo-Chinese subregions (Jayaram, 1974). Barring the cichlid, *Etroplus* in southern India and Sri Lanka, the African element is absent from most parts of peninsular India. The Lampreys and hagfishes (Agnathi), lungfishes ad mud-sirens (Dipneusti) and the stergeons (Actinopterygii) are totally absent in India. Although fishery science in the modern sense is of recent origin in India, the ancient Hindus were not ignorant of the value of fisheries. References to the utility of fish as a source of food exist in Kautilaya's "Arthasastra" (*circa* 300 B.C) (Hora, 1948), while the second pillar edict of Ashoka forbade the use of fish on certain phases of the moon which Hora (1950) has interpreted as being based on principles of fisheries conservation.

Historical Resumé

The study of fish systematics, ichthyology in the limited sense of the word, has had a long and interesting history; its makers have often been dynamic figures. Brief histories of Indian ichthyology may be found in Day (1878), Jordan (1895), Axelrod and Schultz (1905) and Whitehead and Talwar (1976).

Among books published on Indian fishes, Francis Day's (1875-1878) treatise *The Fishes of India* is of greatest importance. Hamilton-Buchanan (1822) described numerous freshwater fishes from the Gangetic system, and a synthesis of this work and all subsequent studies in the ichthyo fauna of the Ganga is given in Talwar (1991). Max Weber and De Beaufort started their series on the fishes of the Indo-Australian archipelago in India, the accounts of Indian fishes, *viz.* "Commercial sea Fishes of India" by Talwar & Kacker (1984) and the most recent book entitled "Inland Fishes of India and adjacent countries" by Talwar & Jhingran (1991) not only constitute new work, but also serve as a *vade-mecum* to the fishery scientist. An outstanding work "Fishes of the Laccadive Archipelago" by Jones & Kumaran (1980) was a noteworthy advance in our knowledge of fish faunal resources of the Laccadive sea. The manual brought out by FAO entitled "FAO Species Identification sheets for Fishery Purposes-Western Indian Ocean" (edited by Fischer & Bianchi, 1984), is simply a wonderful resource for anyone dealing with sea fishes. As large and

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impressive this manual is, it should not be expected to serve as a systematic revision of any family even though there are nomenclatural or systematic changes incorporated in the text. The five documents, which were distributed by the Government of India, deserve special mention. These are the volumes on fishes under the *Fauna of India* series; three volumes by K.S. Misra, and one volume each by Menon and Raj Tilak. Another noteworthy publication is a *Handbook* on freshwater fishes of the Indian region by Jayaram (1981).

Estimation of Taxa

Fishes constitute almost half the total number of vertebrates. Nelson (1984) estimated 21,723 living species of fish in the world compared with 21,450 extant tetrapods (a total of about 43,173 recognized vertebrate species have been described). Cohen (1970) had earlier estimated about 20,000 species of fishes of which approximately 19,400 are teleosts, nearly 59% marine and 41% freshwater. Day (1889) listed 1418 fish species under 342 genera, from the faunal limits of India. Subsequently, about 275 species were added which were dredged by the R.I.M.S. *Investigator* from the deep waters (Alcock, 1899; Mc Ardle, 1901; Eschmeyer *et al.*, 1973; Fricke, 1983). Subsequent additions of the Indian total reflects the dominance of such workers as Hora, Koumans, Trewavas, Misra, Jones, Whitehead, Menon, Silas, Jayaram, Tilak, Yazdani, Rama Rao, Husain, Talwar, etc - all Ichthyologists primarily from the Zoological Survey of India. Tiwari (1985) estimated the number as about 1650 fish species from the faunal limits of India. The present estimate is, however, 2546 species belonging to 969 genera and 254 families. The estimate of the number of fish species in the 39 orders, is tabulated (Table 1).

Systematic fish collections in India have been adequately supported at the national level. These suitably preserved specimens of animals stored in the Zoological Survey of India and several universities constitute an invaluable, and for many species and many regions, an irreplaceable, resource that requires continuing care. The use of and need for the resource is broad and a varied clientele as systematists, evolutionists, zoogeographers, anatomists, applied and academic ecologists, teachers, students, hobbyists and the general public, public health officials and numerous other Government agencies at all levels, draw upon the bank of information included in and associated with the collections. The science of ichthyology is still much concerned with old collections of fishes and the type-specimens that they contain. The Zoological Survey of India presently houses about 675 fish types and representatives of about 80% of the ichthyofauna known from the Indian region.

Ichthyofaunal Studies : An Analysis

It is an axion of ecology that tropical regions exhibit greater species diversity than do temperate ones (Smith, 1974). South America has the greatest diversity of freshwater fish species (Gery, 1969). Africa and Asia follow and they, too, have outstandingly diverse faunas (Darlington, 1975). The same reasoning can be applied to marine tropical areas. The arrangement of the families is phylogenetic following Nelson (1984), but with a few deviations based on recent works.

Class CHONDRICHTHYES

Order CHIMAERIFORMES

Family CHIMAERIDAE

Two genera and about 20 species; only *Chimaera monostrosa* Linnaeus recorded in Indian waters (Misra, 1969).

Family RHINOCHIMAERIDAE

Three genera with ten species; all three genera reported from Indian Seas, *viz. Harriotta* (one species), *Rhinochimaera* (one species) and *Neoharriotta* (one species) (Misra, 1969; Silas *et al.*, 1969).

Order HEXANCHIFORMES

Family HEXANCHIDAE

Cow sharks have a worldwide distribution in boreal and from cold temperate to tropical seas. Three genera with four species (Compagno, 1984); one species only from the Indian region. Compagno & Talwar (1985) reported a member of this family, *viz. Heptranchias perlo* (Ronnaterre) for the first time from Indian waters, and further showed that the report (Misra, 1969) of *Notorynchus cepedianus* (Peron) from Indian waters stand corrected.

Order SQUALIFORMES

Family ECHINORHINIDAE

One genus, *Echinorhinus*, with two species; only *E. brucus* (Bonnaterre) reported in India (Silas & Sevaraj, 1972) off the Kerala coast.

Family SQUALIDAE

Dogfish sharks occurring in warm-temperate and tropical areas are mostly confined to deeper water (50 m or more). Seventeen genera with 67 species (Compagno, 1984); four genera with four species in the Indian region. *Centroscymnus crepidater* (Bocage & Capello) is listed from Indian waters on the basis that *Centrophorus rossi* Alcock, 1898, is a tentative synonym. Silas & Prasad (1969) reported *Squalus fernandinus* Molina from the Arabian Sea, a misidentification of *S. mitsukurii* Jordan & Snyder. Silas *et al.* (1969), followed by Nair & Mohan (1971, 1972), recorded *Centrophorus armatus* (Gilchrist) from the Indian region which appears to be identical with *C. uyato* (Rafinesque). *Centroscyllium ornatum* (Alcock) is restricted to the Bay of Bengal.

Order ORECTOLOBIFORMES

Family RHINIODONTIDAE

Compagno (1984) reviewed the family comprising a monotypic genus. *Rhiniodon typus* Smith is the world's largest fish with lengths upto 15.2 m. Apparently of relatively limited interest to fisheries. Small harpoon fisheries exist in India and Pakistan.

Family HEMISCYLLIDAE

Two genera with eleven species (Compagno, 1984); one genus, *Chiloscyllium*, with four species in Indian waters, confined to inshore waters. These fishes are regularly taken in small scale artisanal fisheries by bottom trawlers.

Family STEGOSTOMATIDAE

This family comprises a single monotypic genus in the Indian region. The zebra shark, *Stegostoma fasciatum* (Hermann) is regularly taken in inshore fisheries in India. The systematics of this species has been discussed by Compagno (1984).

Family GINGLYMOSTOMATIDAE

Two genera with three species (Compagno, 1984); the monotypic genus *Nebrius* only in the Indian region. *N. ferrugineus* (Lesson) is a sluggish, nocturnal shallow-water bottom shark and is caught with gill-nets and line gear.

Order LAMNIFORMES

The mackerel sharks comprise of seven families; four in the Indian region.

Family ODONTASPIDIDAE

Two genera with four species; one genus, *Eugomphodus*, with two species in Indian waters (Compagno, 1984). While *E. tricuspidatus* (Day) is fished in India and Pakistan, the occurrence of *E. taurus* (Rafinesque) in India needs confirmation though its report from Pakistan is definite.

Family PSEUDOCARCHARIIDAE

The single living species, *viz. Pseudocarcharias kamoharai* (Matsubara, 1936) is doubtfully listed from the Bay of Bengal by Compagno (1984).

Family ALOPIIDAE

A single genus with three species recognised; two species in the Indian region. *Alopias pelagicus* Nakamura occurs in the Arabian Sea off India and Pakistan, and *A. vulpinus* (Bonnatérre) in Pakistan, India and Sri Lanka (Compagno, 1984). Both these are deepwater sharks.

Family LAMNIDAE

Three genera with five species (Compagno, 1984); only *Isurus oxyrinchus* Rafinesque has been reported in Indian waters. This genus has been revised by Garrick (1967).

Order CARCHARHINIFORMES

Compagno (1988) published a most comprehensive and informative work entitled 'Sharks of the order Carcharhiniformes, on the anatomy and systematics of chondrichthyan fishes' This is the largest group of living sharks, with inshore, oceanic and deep-water benthic species in all temperate to tropical seas. Eight families; six in the Indian region.

Family SCYLIORHINIDAE

Mostly small harmless sharks not exceeding a length of 100 cm; predominantly bottom or near bottom dwelling fishes. The most recent major revision is by Springer (1979); Compagno (1984) reviewed these fishes and recognised 15 genera and 89 species of which four genera with six species inhabit the Indian region. The genus *Apristurus* is represented in the Indian region by *A. investigatoris* (Alcock), known only from its type (holotype only) from the Andaman Sea. Specimens of *Atelomycterus marmoratus* (Bennett) from India are badly needed for study. The genus *Cephaloscyllium* is represented by *C. silasi* (Talwar, 1974); Compagno & Talwar (1984) showed that Rama Rao's (1975) report of *Scyliorhinus natalensis* (Regan) was a misidentification being identical with *Cephaloscyllium silasi*. Compagno (1984) discussed the identity of the poorly known shark, *Halaelurus alcocki* German, 1913.

Family PROSCYLLIDAE

Four genera with six species; one genus with a single species in the Indian region. *Eridacnis radcliffei* Smith known from the Gulf of Mannar, Bay of Bengal and the Andaman Sea, in the Indian region. Nair & Mohan (1973) relegated *Proscyllium alcocki* Misra, 1950, described from the Andamans, to the synonymy of *Eridacnis radcliffei* Smith, 1913.

Family TRIAKIDEA

Nine genera with 34 species; two genera with two species in the Indian region. The genus *Iago* was reviewed by Compagno (1984) who in addition to *I. omanensis* (Norman), noted a low-finned *Iago* from southern India that is sympatric with *I. omanensis* and may represent a new species. The other genus, *Mustelus* was also reviewed by Compagno (1984) who noted the occurrence of *M. mosis* Hemprich & Ehrenberg in India.

Family HEMIGALEIDAE

Four genera with five species; three genera with three species in the Indian Seas and these have been reviewed by Compagno (1984). The Hemigaleidae is a small family of common coastal tropical sharks of continental and insular shelf waters down to 100 m but usually in coastal waters. Members of this family are common catches in artisanal and small commercial inshore and near offshore fisheries where they occur. *Hemipristis pingali* Setna & Sarangdhar, 1946, described from Bombay, has been relegated to the synonymy of *H. elongatus* (Klunzinger, 1871) by Compagno (1984).

Family CARCHARHINIDAE

This is one of the largest and most important families of sharks, with many common and wide-ranging species found in all warm and temperate seas. Twelve genera with 46 species; ten genera with 26 species in the Indian region. Garrick (1982) revised the genus *Carcharhinus*. The genus *Glyphis* was revised by Compagno (1984) who discussed the specific identity of the Ganges shark, *G. gangeticus* (Muller & Henle), the famous, notorious and elusive shark of Indian waters. The genus *Loxodon* was revised by Springer (1964) who relegated *Scoliodon ceylonensis* Setna & Sarangdhar, 1964, to the synonymy of *Loxodon macrorhinus* Muller & Henle, 1839. The classification and species of *Negaprion* are discussed in detail by Compagno (1979). The genera *Rhizoprionodon* and *Scoliodon* were revised by Springer (1964).

Family SPHYRNIDAE

The hammerheads are a small but common family of wide-ranging warm-temperate and tropical sharks. Two genera with nine species; both genera with four species in the Indian region. This family has been recently reviewed by Compagno (1984). Hammerhead sharks are important for fisheries and are used as food and also for the preparation of various subproducts, especially Vitamin A from the liver.

Order PRISTIFORMES

This order comprises a single family of circumtropical batoids, some entering freshwater.

Family PRISTIDAE

Rays of very large and of shark-like appearance, adults of some species attain over 6 m. Two genera and 6 or 7 species; the monotypic genus *Anoxypristis* and three species of *Pristis* occur in the Indian region. Some of these species are fairly abundant in the Indian region; the flesh is much esteemed and the liver yields considerable oil.

Order TORPEDINIFORMES

Family TORPEDINIDAE

Electric rays are small to moderately large batoid fishes. One genus, *Torpedo*, with about fourteen species; four species in the Indian region, reviewed by Talwar (1981). Talwar (*op. cit.*) reported *T. fairchildi* Hutton, *T. macneilli* (Whitley) and *T. fuscomaculata* Peters for the first time from Indian waters.

Family NARKIDAE

Mostly deep-water rays encountered in trawl catches, some capable of delivering powerful shocks. Five genera with about ten species; three genera in Indian waters, *viz.* monotypic *Bengalichthys*, *Narke* (one species) and *Heteronarce* (reviewed by Talwar, 1981; three species). Garrick (1951) considered *Bengalichthys* a subgenus of *Narke* Kaup. Talwar (1981) discovered *Heteronarce prabhui* off the Kerala coast and, further, extended the range of distribution of *H. mollis* (Lloyd) to India.

Family NARCINIDAE

Four genera with about 15 species; two genera in Indian waters, *viz. Benthobatis* (one species and *Narcine* (three species) (Misra, 1969).

Order RAJIFORMES

Family RAJIDAE

Nine genera with more than 200 species; three genera, *viz. Breviraja* (one species), *Cruriraja* (one species) and *Raja* (three species) in Indian Seas. The Indian Ocean species were revised by Stehmann (1976).

Family RHINOBATIDAE

The guitarfishes are harmless batoids. Eight or nine genera, with about 52 species; four genera with ten species in the Indian region. Nair & Mohan (1973) discovered *Rhinobatos variegatus* from the deep waters of the Gulf of Mannar. The fishes of the genus *Rhinobatos* have been reviewed by Talwar (1984).

Order MYLIOBATIFORMES

Family MYLIOBATIDAE

Moderate-sized to very large batoid fishes. Worldwide in tropical and subtropical waters, inshore and well offshore. Five genera with 27 species; three genera in the Indian region, with five species. Several of these contribute to fisheries and have been reviewed by Talwar (1984).

Family MOBULIDAE

The mantas are moderate-sized to gigantic batoid fishes, maximum width at least 6.7 m. Worldwide in tropical and sub-tropical waters, close inshore and well out to sea. Two genera with ten species; two genera with three species in Indian waters (Talwar, 1984). *Manta birostris* (Donndorff) is one of the largest fishes and grows to a width of more than 7 m. and in weight in excess of 1400 kg.

Family DASYATIDAE

Small to large batoid fishes, found in all tropical and subtropical oceans. Many species are dangerous, because of their large size, and large, serrated, venomous stings. Nine or ten genera and about 89 species (Smith & Heemstra, 1986); seven genera with 26 species in Indian waters. The monotypic genus *Hypolophus* was revised by Compagno & Roberts (1982). Nair & Soundarajan (1973) reported the occurrence of the deep-water stingray, *Urotrygon daviesi* Wallace for the first time from Indian Seas.

Class OSTEICHTHYES

Order OSTEOGLOSSIFORMES

The fishes of this order are predominantly tropical freshwater fishes of extraordinary diverse body form and size. Six families of which only one occurs in the Indian region.

Family NOTOPTERIDAE

Three genera in tropical Africa and south-east Asia, one in the Indian region. The genus *Notopterus* with four species, inhabits the freshwaters of India and southeast Asia; two species in the Indian region. *Notopterus osmani* Rahimullah & Das, 1936, described from the Deccan was considered (Misra, 1976) a junior synonym of *N. notopterus* (Pallas). This species thrives well in lentic waters and is common in tanks throughout the greater parts of India. Swamps in India yield considerable quantities of *N. chitala* (Hamilton-Buchanan), but the catches are fast declining. The flesh of both these species is of good flavour, but full of bones.

Order ELOPIFORMES

Three families are recognised, all known from the Indian region. although primarily marine,these fishes are known from brackish and fresh waters. Forey (1973) provides a detailed account of the fossil and extant forms, and Greenwood (1977) discusses their anatomy and classification.

Family ELOPIDAE

One genus, *Elops*, with six species was recognised by Whitehead (1962); only *E. machnata* (Forsskal) is known from the Indian region. This fish is occasionally caught along the east coast of India, especially at Madras. The flesh is rather insipid and full of bones. The ladyfish has for centuries been important in pond culture in Hawaii where the fry is trapped on the incoming tide, but it is only of incidental importance in south-east Asia. Nybelin (1971) has studied the caudal skeleton in *Elops*.

Family MEGALOPIDAE

This family comprises a single genus, *Megalops*, with two species, *viz. M. cyprinoids* (Broussonet) of the Indo-west Pacific and *M. cyprinoides* (Broussonet) of the Indo-west Pacific and *M. atlanticus* (L.) of the western Atlantic. The Indo-Pacific tarpon is a fast growing carnivore, but the flesh is poor and bony; attains a maximum length of a metre. This fish is fairly common in the fresh waters and estuaries along the coast of India, and contributes a minor fishery in the coastal waters of Andhra Pradesh and Kerala. In the Godavari and Krishna rivers in peninsular India, it migrates upto 100 km upstream, and in the Cauvery river upto the Mettur Dam, a distance of 400 km from the sea.

Family ALBULIDAE

The bonefishes are elongate, fusiform fishes resembling the Clupeidae, but possessing a lateral line and lacking scutes along the belly. The infraorbital lateral line canal extends onto the premaxilla, which is rare among living teleosteans (Nelson, 1984). Two genera are recognised in this family of which one (*Albula*) occurs in the Indian region. *Albula vulpes* (Linnaeus) is taken commercially in Indian coastal waters. The flesh is palatable, but with numerous fine bones. Until recently *A. vulpes* was considered to be a single wide-ranging tropical species; Shaklee and Tamaru (1981) using protein analysis, noted the existence of two additional species which appear to be genetically more distinct than many genera of fishes.

Order NOTACANTHIFORMES

Members of this deep-sea order have been taken between 125 and 4900 m, but most seem to occur in depths of 450-2500 m.

Family HALOSAURIDAE

Halosaurs are benthopelagic inhabitants of the continental slope, rise and abyssal plain beneath warm seas. Three genera with 16 species (Smith & Heemstra, 1986); two genera occur in Indian waters, *viz. Aldrovandia* (one species) and *Halosaurus* (four species) (Alcock, 1899; Sulak, 1977). Mc Dowell (1973) synonymised *Halosaurus nigerrimus* Alcock, 1898, from the Arabian Sea, with *Aldrovandia phalacra* (Vaillant, 1888).

Family NOTACANTHIDAE

Spiny eels hover just above the bottom at depths of 125-3500 m. Two genera with nine species (Nelson, 1984); only *Notacanthus indicus* Lloyd, 1909, recorded in the Indian region.

Order ANGUILLIFORMES

With the exception of one family of freshwater eels, all members of this order are marine in habitat. This large and diverse group of fishes is divided into 16 families (Smith & Heemstra, 1986) of which eleven occur in the Indian region. The extended pelagic life as a leptocephalus favours wide dispersal of species and many of our eels are known throughout the Indo-Pacific. For this reason, continuing additions to our eel fauna are to be expected as their special habitat is explored and collected more fully by scientists, especially offshore in deep water.

Family ANGUILLIDAE

One genus, *Anguilla*, with 19 species and subspecies worldwide; one genus with two species in the Indian region. Comprehensive taxonomic review by Ege (1939) and Tesch (1979) has summarised the biology, fishery and culture of freshwater eels. *Anguilla bengalensis bengalensis* (Gray) is of considerable fishery value in the inland waters of the east coast of India and the Andaman Islands. Elver resources of this species are plentiful in certain estuarine locations in India for both *A. bengalensis* and *A. bicolor* Mc Clelland, and there is a good export market for both live elvers and eels.

Family MORINGUIDAE

Tropical seas only; of no commercial significance. Two genera (Smith & Castle, 1972); one in the Indian region. The genus *Moringua* with about ten species, have been reviewed by Castle (1968); three species have been listed from the estuarine and freshwaters of the Indian region. *Aphthalmichthys gangeticus* Fowler, 1912, is probably identical with *Moringua arundinacea* (Mc Clelland) (Talwar & Jhingran, 1991). Menon (1974), followed by Sen (1975), erroneously considered *Moringua hodgarti* Chaudhuri, 1913, a synbranchid.

Family MURAENIDAE

In all oceans, some entering estuaries. About 14 genera and 200 species worldwide; eight genera and 35 species in the Indian region, several of which need further study and comparison with extralimital specimens. The genus *Anarchias* represented by two species, and the genus *Enchelynassa* Kaup represented by its type-species, *E. canina* (Quoy & Gaimard), have been reported only from the Minicoy Islands in the Indian region (Jones & Kumaran, 1980). *Echidna nigra* (Day) has not been listed since its original discovery from the Andaman Sea.

Family NEMICHTHYIDAE

Snipe eels are mesopelagic fishes, captured from the surface down to 2000 m or more; no commercial significance. Three genera and eight species worldwide; two genera and two species in the Indian region. Comprehensively reviewed by Nielsen and Smith (1978).

Family SYNAPHOBRANCHIDAE

All oceans; of no commercial significance. Mostly on bottom in 100-2000 m. Twelve genera, 18 species; two genera and three species in the Indian region. Reviewed by Robins & Robins (1976).

Family OPHICHTHIDAE

Typically small (less than 30 cm), worm-like sand-and mud-burrowing forms; no commercial significance. Mc Cosker (1977), followed by Mc Cosker and Castle (1986), recognise two subfamilies with a total of 59 genera and about 220 species worldwide; thirteen genera with 24 species in the Indian region (Talwar, 1984). *Pisodonophis assemensis* Sen, 1985, was relegated to the synonymy of *P. boro* (Hamilton-Buchanan) by Talwar & Jhingran (1991).

Family NETTASTOMATIDAE

This family of tropical and warm temperate waters is poorly known; eventually, it may be shown to be best combined with Congridae (Smith, Bohlke & Castle, 1981). All oceans, but of no commercial significance. Five genera worldwide with about 25 species; two genera and two species in the Indian region. Adults on or near the bottom in 500-2000m; larvae in open ocean.

Family COLOCONGRIDAE

One genus, *Coloconger*, with four species occurring in the Atlantic, Indian and Pacific Oceans; only one, *Coloconger raniceps* Alcock from the Andaman Sea is known from the Indian region.

Family MURAENESOCIDAE

All oceans, abundant enough in India and south-east Asia to be commercially significant. Seven genera worldwide, with about 14 species; five genera with seven species in Indian region. The genera *Congresox* and *Muraenesox* have been revised by Castle & Williamson (1975). Talwar (1979) rediscovered the rare deep-water eel, *Sauramuraenesox vorax* Alcock, 1889, from off the Madras coast, and discussed its specific identity. The systematics of the monotypic genus *Gavialiceps* has been discussed by Norman (1939) and Castle (1977).

Family CONGRIDAE

Adults benthic from shore to deep water; larvae wide-spread and abundant in open ocean. All oceans, but no where abundant enough to be commercially significant. About 34 genera worldwide, with 95 species; thirteen genera and 18 species from Indian waters. The discovery of *Heteroconger hassi nicobarensis*, *H. obscura* and *Gorgasia maculatus* from the Nicobar Islands by Klausewitz & Eibl-Eibesfeldt (1959) were noteworthy finds. Talwar & Mukherjee (1977) discovered *Ariosoma gnanadossi* from off the Madras coast.

Family SERRIVOMERIDAE

These bathypelagic fishes are uniformly black, over-laid with silver. Three genera with about ten species worldwide; *Serrivomer microps* (Alcock) from the Andaman Sea, is only known from the Indian region.

Order CLUPEIFORMES

Primitive teleosts with a distinctive type of connection between the swimbladder and the ears which is unique among fishes (Greenwood *et al.*, 1966). Five families are currently recognised (Whitehead, 1985); four in the Indian region, *viz.* Clupeidae, Pristigasteridae, Chirocentridae and Engraulididae. These four families are united in the suborder Clupeoidei and are popularly referred to as clupeoids. Pelagic, mainly inshore fishes, often forming large and densely packed shoals which are heavily preyed upon by fishes, birds and man. The clupeoid fishes (i.e. including the anchovies) are the most important single group exploited by world fisheries and in some areas they account for a third or even a half of the total catch.

Family CLUPEIDAE

Whitehead (1985) recognised five subfamilies and reviewed them; some 180 clupeid fishes of the world are described and placed in 56 genera. Of these, 33 species belonging to 14 genera and five subfamilies, have been reported from Indian waters.

Subfamily Alosinae

Gudusia (revised by Whitehead, 1965; two species); and *Hilsa* (with two subgenera, revised by Whitehead, 1965; three species). *Gudusia godanahiai* Srivastava, 1968, described from Uttar Pradesh, has been relegated to the synonymy of *G. chapra* (Hamilton-Buchanan) by Talwar & Whitehead (1971).

Subfamily Clupeinae

Escualosa (one species), *Herklotsichthys* (revised by Wongratana, 1980; one species); *Amblygaster* (three species); and *Sardinella* (reviewed by Whitehead, 1985; eight species). Several species of *Sardinella* make very significant contribution to artisanal and fully mechanised fisheries in the Indian region. *Sardinella (Amblygaster) jonesi* Lazarus, 1983, described from Kerala, appears to be identical with *Amblygaster sirm* (Whitehead *et al.*, 1988). Menon & Talwar (1974) recorded *A. leiogaster* (Valenciennes) from India for the first time.

Subfamily Dussumieriinae

Dussumieria (reviewed by Whitehead, 1985; two species) and *Spratelloides* (two species).

Subfamily Pellonulinae

Corica (one species), monotypic *Dayella*, and monotypic *Ehirava*. Talwar & Jhingran (1991) treated *Corica biharensis* Kamal & Ahsan, 1979, as a junior synonym of *Corica soborna* Hamilton-Buchanan.

Subfamily Dorosomatinae

Anodontostoma (reviewed by Whitehead, 1985; three species); *Gonialosa* (three species, revised by Wongratana, 1983) and *Nematalosa* (revised by Nelson & Rotham, 1973; two species). The Dorosomatinae are either marine, pelagic and apparently anadromous, or estuarine or purely fluviatile.

Family PRISTIGASTERIDAE

These fishes are marine coastal, but some species enter estuaries while a few are restricted to freshwater. Until recently, the pristigasterines were considered a subfamily of the Clupeidae. Nelson (1967) found unique features in their gill arches; he raised them to the rank of super-family. Whitehead (1985) recognised the family and reviewed them; nine genera (three worldwide, five New World, and one Indo-Pacific) and 33 species (16 New World, one West Africa and 16 Indo-Pacific). Of these, four genera and 13 species have been recorded from Indian waters, *viz. Ilisha* (reviewed by Whitehead, 1985; nine species), *Opisthopterus* (one species), *Pellona* (reviewed by Wongratana, 1983; two species) and the monotypic genus *Raconda*. Though no special fisheries exist for particular species, pristigasterids are common in Indian fish markets and make a useful contribution to clupeoid catches.

Family CHIROCENTRIDAE

Chirocentrids are marine coastal fishes widely distributed in the warmer parts of the Indo-Pacific region. Wolf-herrings are voracious carnivores, unlike all other clupeoids. One genus with two species recognised, both in the Indian region. Bardack (1965) gives a detailed description of the genus *Chirocentrus* Cuvier; Whitehead (1985) has recently reviewed them. The wolf-herrings contribute to an important fishery along the coast of India but 76% of the total catch comes from the east coast; Tamil Nadu occupies the foremost place in the fishery. Among the largest of the clupeoids, they reach 100 cm standard length. Good eating but bony; large specimens are dangerous.

Family ENGRAULIDIDAE

Anchovies are typically marine coastal and schooling fishes, occurring in all seas, but some species enter brackish water to feed or spawn. The family name Engraulidae has been used in almost all previous literature but is an incorrect derivation from *Engraulis* (Whitehead, Nelson & Wongratana, 1988); the correct (but less euphonic) derivation is Engraulididae (as explained by Steykal, 1980). Some 139 anchovy species are presently recognised, placed in 16 genera and these have been recently reviewed by Whitehead, Nelson & Wongratana (1988); five genera with 35 species are reported from Indian waters, *viz. Coilia* (five species), *Encrasicholina* (three species), *Stolephorus* (seven species), *Setipinna* (five species) and *Thryssa* (15 species). Whitehead (1973) considered *Coilia korua* Dutt & Rao, 1972, conspecific with *C. reynaldi* Valenciennes; and *Setipinna godavari* Babu Rao, 1962, identical with *S. tenuifilis* Valenciennes. The anchovies are small translucent silvery fishes, occurring often in immense shoals in coastal waters. Valuable marine fish as a source of food and fish meal in India; also suitable for salting and sundrying as well as canning. The average annual catch of anchovies in India is about 48,000 tonnes of which 90% is from the west coast of India.

Order GONORHYNCHIFORMES

This order comprises a small group of seven genera, totally some 30 species of diverse morphology and habitat (Howes, 1985). Several features suggest some affinity between this order and the clupeiformes (Nelson, 1984). Four families, one in the Indian region.

Family CHANIDAE

This family comprises a monotypic genus. *Chanos gardineri* Regan, 1903, described from the Maldives, has been shown by Palmer (1962) to be conspecific with *Chanos chanos* (Forsskal). The milkfish is of considerable importance as a foodfish in south-east Asia. Although an inhabitant of the sea in its adult stages, its fry, fingerlings and early juveniles can be obtained mostly from the brackish-water regions. The adults attain a length of 1.8 m and its place in the estuarine fishery is important being one of the most useful species for fish culture. In India this species is very popular among fish culturists due to its immense adaptive powers and fast-growing qualities.

Order CYPRINIFORMES

This group consists solely of freshwater fish and is widespread in tropical and temperate waters of Europe, Africa, Asia and North America. This is the largest order of the fresh-water fishes; six families, 256 genera and 2422 species (Nelson, 1984). Several members of this order are important foodfishes and also popular aquarium fishes, especially the minnows and loaches. Seven families; five in the Indian region.

Family CYPRINIDAE

A very large and most dominant group of primary freshwater fishes in most areas within its distribution and is of considerable economic significance in the Indian region. This is the largest family of fishes known, comprising about 194 genera and 2074 species (Nelson, 1984). Recent studies on the osteology of this family include Howes (1978, 1980, 1981, 1982, 1983 and 1984). This very speciose family has been divided into various subfamilies and the classification followed here is after Banarescu (1968, 1972) and Gosline (1978). Talwar & Jhingran (1991) have given a most comprehensive synthesis of the knowledge of the cyprinoids of India and adjacent countries, and have also presented keys to their specific identity coupled with fishery information.

Subfamily Cyprininae

The subfamily contains the great bulk of the cyprinoid fishes of the Indian region. Several hundred species of barbs are known from Europe, Africa and Asia, but most of the little creatures we know as good aquarium fishes come from India and Malay regions. Numerous genera recognised, but only 24 genera with 145 species in the Indian region (Talwar & Jhingran, 1991); the fishes of the genera *Carassius, Ctenopharyngodon, Cyprinus* and *Tinca* do not occur naturally in India but were introduced at various times for cultural purposes. Noteworthy studies on this group of fishes include Karaman (1969) on *Capoeta*; Natarajan *et al.* (1978) on *Catla*; Rainboth (1985, 1986a, 1986b) on *Neolissochilus*, *Chagunius* and *Gonoproktopterus*, respectively; Banarescu (1983) on *Cirrhinus*; Howes (1981) on *Ctenopharyngodon*; Kirpichnikov (1967) on *Cyprinus*; Smith (1945) on *Cyclocheilichthys*; Howes (1982) on *Cyprinion* (= *Semiplotus*); Taki

& Kawamoto (1977) and Kottelat (1978) on *Hampala*; Kottelat (1987) on *Labiobarbus*; Smith (1945) on *Mystacoleucus*; Hora (1937) and Tilak & Sati (1984) on *Oreichthys*; Silas (1952) on *Osteobrama*; Hora (1942) on *Osteochilus*; Yazdani & Rao (1975) and Taki *et al.* (1978) on *Puntius*; Silas (1952) on *Rohtee*; and Hora (1942) on *Schismatorhynchos*.

In India, *Catla catla* (Hamilton-Buchanan) was originally confined to the plains of north of Kristna, but during the last three decades it has been introduced to practically all river systems and many of the tanks and reservoirs where it now supports a very important fishery. Natarajan *et al.* (1978) have observed strong indications of existence of three infra-specific populations of *C. catla* from the Rihand reservoir (Uttar Pradesh), each of which showing specific 'roles' corresponding to 'niches' in the ecosystem; these ecological populations are also distinguished by distinct morpho-biological features. Dutt & Murthy (1976) have shown that *Cirrhinus chaudhryi* Srivastava, 1968, described from Gorakhpur (U.P.) is identical with *Cirrhinus mrigala* (Hamilton-Buchanan). Talwar & Jhingran (1991) have relegated *Cirrhinus horai* Lakshmanan, 1966, described from the Godavari river, to the synonymy of *Cirrhinus macrops* Steindachner. The rare Burmese kingfish, *Cyprinion modestum* (Day) has been reported (as *Semiplotus modestus*) from India by Barman (1988). Talwar & Jhingran (1991) relegated *Puntius sarana sarana* (Hamilton-Buchanan, 1822) as they considered the former as the juveniles of the latter species. Further, they treated *Puntius jayarami* Singh & Singh, 1988, to be identical with *Puntius sarana orphoides* (Valenciennes, 1842); and both *Puntius muzaffarpurensis* Srivastava, Varma & Sharma, 1976, and *Puntius coorgensis* Jayaram, 1982, to be conspecific with *Puntius vittatus* Day, 1865. The fishes of the genus *Tor* constitute the most important (along with *Neolissochilus*) of game fishes in India and these have been partly dealt with by Tilak & Sharma (1982).

Subfamily Cultrinae

The members of this subfamily are distributed in south-east Asia and China, and reappraissal and taxonomic relationships of the various taxa is given in Howes (1979) who pointed out that of all the cyprinid subfamilial assemblages recognised at present there is probably none so ill-defined as Cultrinae. The members of this subfamily are small fishes with lots of intermuscular bones and hence not preferred as food fishes. Twenty-one genera presently recognised; four genera with 19 species in the Indian region (Talwar & Jhingran, 1991).

Banarescu (1969) reviewed the genus *Chela*, and Howes (1979) has given an osteological account and relationships of the genus. Tilak & Jain (1987) have shown that *Danio menoni* Barman, 1985, is a junior synonym of *Chela laubuca* (Hamilton-Buchanan, 1822). Banarescu (1968) revised the genus *Salmostoma*, but Howes (1979) was of the opinion that this interesting genus must be critically revised on an osteological basis before any assumptions can be made concerning intrageneric relationships. Reddiah (1980) described a new species of *Salmostoma*, *viz.* S. *kardahiensis* from Jabalpur (M.P.).

Subfamily Leuciscinae

The consensus of ichthyological opinion is that the genus Hypophthalmichthys belongs to the Leuciscinae, but Howes (1981) thesis was that it represents a distinct monophyletic lineage representative of a basic division within the Cyprinidae. The genus has been reviewed by Howes (1981) who recognised three species; two species, *viz. H. molitrix* (Valenciennes) and *H. nobilis* (Richardson) have been introduced in Indian inland waters for cultural purposes.

Subfamily Rasborinae

This subfamily is rather numerously represented by both genera and species in the freshwaters of India and adjacent countries, and individuals of several species may be abundant. In most of the genera the fish are too small and bony to have a direct economic value to man. They are, however, sold as aquarium fishes being vivdly coloured. Twelve genera with 57 species have been recognised in the Indian region (Talwar & Jhingran, 1991).

Babu & Nair (1978) discovered *Amblypharyngodon chakaiensis* from Kerala. Talwar & Jhingran (1991) relegated *A. gadigarhi* Malhotra & Singh Dutta, 1975, described from Jammu, to the synonym of *A. mola* (Hamilton-Buchanan, 1822). The relationships of the genus *Aspidoparia* has been discussed by Howes (1979) based on osteological characters. Although several authors recently paid attention to the systematic position of the genus *Barilius* (last and best treatment is of Howes, 1980), their systematics at the species level is still poorly understood. Several species of *Barilius* described in recent years, *viz. B. jayarami* Barman, 1985; *B. howesi* Barman, 1986; *B. nelsoni* Barman, 1989; and *Barilius menoni* Sen 1976; *B. corbetti* Tilak and Husain, 1980; and *Barilius jalkapoorei* Shrestha, 1982, from the Indian region, have all been shown (Talwar & Jhingran, 1991) to be conspecific with pertinent well-defined species. Howes (1983) resurrected the genus *Bengala* Gray, 1833, for the reception of *Cyprinus elanga* Hamilton-Buchanan, 1822. A good osteological account of this species is given in Howes (1980). The fishes of the genus *Brachydanio* have been reviewed by Myers (1924); *B. frankei* Meinken, 1963, erroneously stated as from India by Julian (1974), is, however, from an unknown locality (Frank & Franke, 1963). *Danio (Brachydanio) horai* Barman, 1983, described from the Namdapha river, is a synonym of *Brachydanio acuticephala* (Hora, 1921) (Tilak & Jain, 1988); *Danio analipunctatus* Boulenger, 1911, described from Burma, is conspecific with *Brachydanio nigrofasciatus* (Day, 1869) (Myers, 1953); and *Danio (Brachydanio) jayarami* Barman, 1984, described from Burma, is identical with *Brachydanio shanensis* (Hora, 1928) (Talwar& Jhingran, 1991). Hora & Mukerji (1934) presented a synopsis of the the Oriental genus *Danio*. These fishes are of no practical value but their chief value lies in the fact that they form food for the predatory fishes. Several of them are very beautifully coloured and hence are important as aquarium fishes, both inland and overseas. *Danio browni* Regan, 1907, from Burma, and *Danio deyi* Sen & Dey, 1985, from Meghalaya, are both conspecific with *Danio aequipinnatus* (Mc Clelland, 1839) (Talwar & Jhingran, 1991); *Danio meghalayensis* Sen & Dey 1985, from the the Khasi hills, is identical with *Danio dangila* (Hamilton-Buchanan, 1822); *Danio manipurensis* Barman, 1987, from Manipur, is a junior synonym of *Danio naganensis* Chaudhuri, 1912; and *Danio assamensis* Barman, 1985, described from Assam , a junior synonym of *Danio regina* Fowler, 1934 (Talwar & Jhingran, 1991). Hora & Mukerji (1934) revised the genus *Esomus*. These fishes are of larvicidal value and also used as aquarium pets. *Esomus manipurensis* described recently from Manipur by Tilak & Jain (1990) is conspecific with *E. danricus* (Hamilton-Buchanan, 1822). A good osteological treatment of the genus *Parlucioosoma* is given by Howes (1980) Howes (1980) resurrected the genus *Raiamas* from the synonymy of *Barilius*, and also reviewed it. *Barilius corbetti* Tilak & Husain, 1980, described from the corbett National Park (U.P.), is a juvenile of *Raiameas bola* (Hamilton-Buchanan); and *Bariliuus jalkapoorei* Shrestha, 1982, from Nepal, is identical with *Raimas guttatus* (Day, 1869) (Talwar & Jhingran, 1991).

Subfamily Schizothoracinae

This is a specialised group of fishes, dominant of the torrential mountain streams of the Himalaya and Central Asia. In India, they are distributed along the Himalayas, an exception is the singular schizothoracine genus of the Periyar river and lake in peninsula India. Further, the occurence of a schizothoracine fish in a subterranean cave near Udaipur in Rajasthen (Tehsin, Durve & Kulshreshtra, 1988) is indeed puzzling (Talwar & Jhingran, 1991). Eight genera with 20 species have been reported from the Indian region and these have been revised by Tilak (1987) and recently reviewed by Talwar & Jhingran (1991). *Ptychobarbus rattanensis* Malhotra & Jyoti, 1975, described from Kashimir, has been shown (Talwar & Jhingran, 1991) to be a junior synonym of *Ptychobarbus conirostris* Steindachner. The discovery of the genus *Gynocypris* in Ladakh of the Indian rigion by Talwar (1978), was indeed a noteworthy find. Tilak (1987) redescribed *G. biswasi* Talwar and gave more distinguishing characters to its specific identity.

Subfamily Garrinae

Five genera recognised; two in Indian region. The genus *Crossocheilus* is Oriental but extends into Afghanistan and Iran, and has been recently revised by Banarescu (1986); Kottelat (1987) discussed the generic name and type-species. The genus *Garra* has been revised by Menon (1964); in some species the mental adhesive disc is weakly developed, vestigial, or perhaps even absent; this, coupled with ontogenetic changes associated with the mental disc (see Hora, 1921) and the highly variable timing of its appearance, has contributed to considerable systematic confusion at the genus as well as species level. *Garra satyendranathi* Ganguly & Dutta, 1973, described from Bihar; *Garra tirapensis* Datta & Barman, 1984, described fron Arunachal Pradesh; and *Garra menoni* Rema Devi and Indra, 1984, described from the Silent Valley (Kerala), are all clearly conspecific with pertinent well-defined species (Talwar & Jhingran, 1991).

Family PARASILORHYNCHIDAE

This family was proposed by Rao & Yazdani (1978) and comprise small hillstream fishes inhabiting the Western Ghats, Satpura mountains and the Bailadila range in Madhya Pradesh. Rao & Yazdani (1978) reviewed the single genus, *Parapsilorhynchus*, which comprises three species.

Family PSILORHYNCHIDAE

This family comprises a single genus (*Psilorhynchus*) of small hillstream fishes and is known to occur primarily in the Gangetic drainage of south-east Asia. The genus has recently been revised by Rainboth (1983) who described a new species, *P. gracilis* from Bangladesh. As presently understood the genus *Psilorhynchus* comprises of five species, all in the Indian region. Wu et al. (1981) combine this group of fishes with Cyprinidae, but Nelson (1984) recognises the family as distinct.

Family BALITORIDAE

The members of this family are small freshwater fishes which occupy torrential and swift streams from low to high altitudes (Kottelat, 1989) and were till recently treated under the family-group name Homalopteridae.

Subfamily Balitorinae

The balitorids are small fishes extensively distributed in the hills of south-east Asia; some 28 genera containing about 120 species (Kottelat, 1988). In India, they are found in the hills of Meghalaya and along the eastern Himalaya as far as the Tista and Kosi drainages on the one hand, and the Western Ghats of peninsular India on the other; four genera and ten species in the Indian region (Menon, 1987). Kottelat (1988) revised the genus *Balitora*; and Menon (1987) the genera *Bhavania, Homaloptera* and *Travancoria*.

Subfamily Nemacheilinae

This subfamily comprises the loaches which are mainly found in the montane and submotane regions, but rarely in the plains. These fishes are usually referred to as the subfamily Noemacheilinae (the correct spelling actually is Nemacheilinae *vide* Kottelat, 1987). Four genera; three in the Indian region. The genus *Aborichthys* has been revised by Menon (1987) but an important ommission was *Aborichthys tikaderi* Barman, 1984; and the genus *Triplophysa* has also been revised by Menon (1987). The genus *Nemacheilus* (unwarranted spelling variant *Noemacheilus* by Menon, 1987; *vide* Kottelat, 1987; Roberts, 1989) has been revised by Menon (1987); about 200 species, 63 in the Indian region. Menon (1987) gave an unjustified replacement name for *Nemacheilus elongatus* (Sen & Nalbant, 1981). *Noemacheilus assamensis* Menon, 1987, described from Assam, is undoubtedly identical with *Nemacheilus labeosus* (Kottelat, 1982) from the Salween drainage (Talwar & Jhingran, 1991).

Family COBITIDAE

The loaches are distributed in Eurasia and northern Africa, but the greatest diversity is in southern Asia. They are bottom dwellers, mostly of small size and are mainly found in streams, rivers and lakes of hilly areas. A number of loaches are popular with aquarists. The two subfamilies currently recognised are present in the Indian region.

Subfamily Cobitinae

Thirteen genera with about 40 species; seven genera with 14 species in the Indian region (Talwar & Jhingran, 1991). Whitley (1931) proposed a new generic name, *Enobarbichthys*, for *Platacanthus maculatus* Day, 1870, a species presently known only on its holotype; Silas (1960) redescribed this specimen. Tilak & Husain (1981) reviewed the genus *Lepidocephalus*; they relegated *L. menoni* Pillai & Yazdani, 1976, to the synonymy of *L. annandalei* (Chaudhuri). Talwar & Jhingran (1991) considered *L. dibruensis* Sen, 1979, conspecific with *L. guntea* (Hamilton-Buchanan). Banarescu & Nalbant (1968) discovered *Neoeucirrhichthys maydelli* from Assam. Kottelat (1987) revived the generic status of *Pangio* Blyth for fishes earlier placed in *Acanthophthalmus*.

Subfamily Botiinae

Two genera with about 20 species; only *Botia* with ten species in the Indian region (Talwar & Jhingran, 1991). Banarescu & Nalbant (1968) followed by Taki (1972), reviewed the genus *Botia*. These fishes are in principle inhabitants of running waters, mostly in upland areas. Rao & Yazdani (1977) reported *Botia dayi* Hora from the Western Ghats, a misidentification for *B. striata* Rao (Sane & Chhapgar, 1986).

Order SILURIFORMES

The classification of catfishes is not settled and disagreement exists on the interrelationships of the families. Works on their zoogeography and systematics include Chardon (1967, 1968), Gosline (1975) and Lundberg & Baskin (1969). Thirty-one families with about 400 genera and approximately 2211 species (Nelson, 1984); 13 families with 51 genera and 164 species reported from the Indian region (Talwar & Jhingran, 1991). Two families (Ariidae and Plotosidae) consist largely of marine species, but have representatives that are frequently found in brackish and fresh waters. Other catfish families are freshwater although some have species which can invade brackish water. The Indian catfishes have been reviewed by Misra (1976), Jayaram (1981), Talwar (1984) and Talwar & Jhingran (1991).

Family BAGRIDAE

Twenty-seven genera with roughly 205 species (Nelson, 1984); six genera, *viz. Aorichthys* (revised by Jayaram, 1972; two species), *Batasio* (revised by Hora & Law, 1941; three species), monotypic *Horabagrus*, *Mystus* (reviewed by Jayaram, 1966; 19 species), monotypic *Rama* (= *Chandramara*) and *Rita* (revised by Jayaram, 1966; four species) occur in India. These fishes are mainly freshwater but at least one species (*Mystus gulio*) is partly marine. Some species are kept as aquarium fishes while others are very large and important as food fishes. *Aorichthys aor* (Hamilton-Buchanan) and *A. seenghala* (Sykes) are important giant catfishes of India and extensively caught in the larger rivers. They attain a length of about 1.5 m; they fight well and provide a good sport. Ganguly & Datta (1975) described *Mystus mukherjii* from Bihar, but this is conspecific with *Mystus cavasius* (Hamilton-Buchanan) (vide Talwar & Jhingran, 1991). Ramakrishniah (1988) discovered *Mystus krishnensis* from the Krishna river. Tilak (1988) discussed the specific identity of *Chandramara chandramara* and extended its distributional range to Uttar Pradesh.

Family SILURIDAE

This is one of the most distinctive and well-defined families of catfishes and are chiefly Asiatic in distribution. Nine or ten genera with roughly 45 species; five genera in Indian region, *viz. Kryptopterus* (one species recently discovered by Datta *et al.*, 1987), *Ompok* (reviewed by Talwar & Jhingran, 1991; four species), *Pinniwallago* (one species), *Silurus* (revised by Kobayakawa, 1989; four species) and *Wallago* (revised by Roberts, 1982; one species). *Wallago attu* is one of the largest local catfishes and thrives well in rivers and tanks also. It is a good sport fish and grows to about 2 m and weighs more than 45 kg.

Family SCHILBEIDAE

About 16 genera equally divided between Africa and Asia, most of the Asian genera restricted to the Indian subcontinent; seven in the Indian region, *viz. Ailia* (reviewed by Hora, 1941; two species), *Clupisoma* (reviewed by Talwar & Jhingran, 1991; five species), *Eutropiichthys* (reviewed by Hora, 1937; three species), monotypic *Neotropius*, *Pseudeotropius* (reviewed by Hora,1941; two species), monotypic *Proeutropiichthys* (reviewed by Talwar & Jhingran, 1991) and *Silonia* (reviewed by Hora, 1938; two species). Tilak (1964) considered the genera *Neotropius* and *Pseudeutropius* as bagrids based on osteological characters. In India these catfishes constitute a striking and well-marked group. Some of them are among the largest freshwater fishes of Asia. Little study has been devoted to these economically valuable fishes which are known to undertake spawning migrations up some rivers.

Family PANGASIIDAE

This family ranges from the Indian subcontinent (including the Indus basin but not Sri Lanka), through mainland south-east Asia, Sumatra and Borneo. Five or six genera; only one genus with a single species in the Indian region. *Pangasius pangasius* (Hamilton-Buchanan) grows upto 1.5 m and inhabits the lower portions of large rivers and estuaries in India, and provide a good sport to anglers.

Family AMBLYCIPITIDAE

These small fishes inhabit swift streams of southern Asia. Two genera recognised, with five species; the monotypic genus, *Amblyceps* is restricted to the foot-hills of Himalaya in India (Talwar & Jhingran, 1991).

Family AKYSIDAE

Akysids are small to minute, cryptically coloured, secretive catfishes of the freshwaters of southern Asia. Three genera; one in the Indian region which is restricted to Burma. Hora (1936) revised the genus *Akysis*; six species recognised, two in the Indian region. They are diminutive inhabitants of mountain streams and lakes.

Family SISORIDAE

Sisoridae is an exclusively Asian family of bottom dwelling catfishes and has its greatest diversity in the Indian subcontinent. About 20 genera with at least 68 species (Nelson,1984); 18 genera in the Indian region with 65 species. Roberts (1983) revised the genus *Bagarius*; *B. yarrellii* Sykes is the giant species of *Bagarius* and the largest Asian catfish, the true *B. bagarius* is relatively small Tilak (1988) gave the salient diagnostic characters of the monotypic genus *Conta*; and Kottelat (1983) reviewed the the genus *Erethistes*. Li (1986) presented a synopsis of the various species of *Glyptothorax* and proposed two new subgenera. Tilak (1978) reviewed the genus *Hara*; Talwar and Jhingran (1991) relegated *Hara saharasai* Datta Munshi & Srivastava, 1988, described from Bihar, to the synonymy of *Hara hara* (Hamilton, 1822).

Family CLARIIDAE

This distinctive air-breathing Afro-Asian catfish family comprises some 14 or 15 genera with about 100 species (Nelson, 1984; Roberts, 1989); two genera with five species in the Indian region. Teugels & Roberts (1987) designated the type-species of the genus *Clarias*. Of the four species of *Clarias* known from the Indian region, *C. dayi* Hora is a rare species being known only by a single specimen (Talwar & Jhingran, 1991) The monotypic genus, *Horaglanis* represented by the blind catfish, *H. krishnai* Menon, is fairly common in the wells of Kottayam district of Kerala, but is of little interest to fisheries.

Family HETEROPNEUSTIDAE

This family is represented by a single genus with two species, both in the Indian region (Hora, 1936) These fishes live in stagnant pools and ditches deficient in oxygen. *Heteropneustes fossilis* (Bloch) is a fish of high economic importance and is in great demand because of its medicinal value. Datta Munshi and Srivastava (1988) have reported *Heteropneustes microps* (Gunther) in Bihar and Uttar Pradesh.

Family CHACIDAE

This small family contains a single genus, *Chaca*, restricted to the Indian subcontinent and Malay Peninsula. Roberts (1982) followed by Brown & Ferraris (1988), revised this genus. Of the three species recognised, two occur in the Indian region. *Chaca chaca* (Hamilton-Buchanan) is fairly common in the catches of the Ganga-Brahmaputra drainages, but is not eaten perhaps due to its ugly appearance. *Chaca burmensis* was discovered from Burma by Brown & Ferraris in 1988.

Family OLYRIDAE

This family comprises specialised hillstream fishes of a single genus, *Olyra*, only. Roberts (1989) considers these fishes as apparently bagrids. Hora ((1936) revised the genus *Olyra*, with four species. Menon (1974) considers the genus as monotypic. The genus which is restricted to eastern Himalaya and western Thailand, is badly in need of revision.

Family ARIIDAE

The "sea catfishes" or Ariidae, include a number of species endemic to fresh water. About 20 genera with about 120 species; six genera with 23 species in the Indian region. Jayaram (1982) reviewed the Indian species of the genus *Arius*. Wheeler & Baddokwaya (1981) give reasons for not recognising *Tachysurus* as the senior synonym of the species and commercially important *Arius*. Kailola (1986) discussed the systematics of *Arius thalassinus* (Ruppell) and *A. bilineatus* (Valenciennes). The genera *Batrachocephalus*, *Hemipimelodus*, *Osteogeneiosus* and *Ketengus* have also been reviewed by Jayaram (1982).

Family PLOTOSIDAE

Found in tropical and subtropical waters of the Indo-west Pacific; freshwater species limited to Australia and New Guinea. About eight genera with about 30 species (Nelson, 1984); one genus with three species in the Indian region. The genus *Plotosus* has been reviewed by Goman & Taylor (1982). *Plotosus canius* Hamilton-Buchanan contributes a moderate fishery in the Hooghly estuary (West Bengal) and also in other brackishwater lakes along the east coast of India. *Plotosus lineatus* (Thunberg) contributes to artisanal fisheries in the Hooghly estuary and Chilka lake.

Order SALMONIFORMES

Family ARGENTINIDAE

Five genera and at least 50 species; only *Nansenia groenlandicus* (Richardson) in the Indian region (Misra, 1976). Nelson (1984) places this genus in the family Bathylagidae.

Family ALEPOCEPHALIDAE

The Alepocephalidae are moderate to large deep-sea salmoniform fishes, most commonly encountered below 1,000 m. In terms of biomass and species diversity, the family is one of most important in the deep sea. The group is poorly known, but regional reviews have been prepared for the Indian Ocean (Sazonov & Ivanov, 1980). The genus *Alepocephalus* needs revision; at least 15 species, four in the Indian region. The genus *Aulastomomorpha* is represented in the Indian region by *A. phosphorops* Alcock, the other species is restricted to the Gulf of Oman. The genus *Bathytroctes* has been reviewed by Markle & Quero (1984); four species known, two in the Indian region, *viz. B. squamosus* (Alcock) and *B. rostratus* Gunther. The genus *Einara* is known by two species, but only *E. eduntula* (Alcock) in Indian Seas. Of the seven recognised species of *Conocara*, only *C. microlepis* (Lloyd) inhabits Indian waters. The genus *Leptoderma* is poorly known and is in need of revision; about five species of which *Leptoderma affinis* Alcock is reported off the Krishna delta. The unique holotype of this species was located in the ZSI by Talwar (1977), but is unfortunately mutilated. The genus *Nercetes* is known by three to five species; two in the Indian region. The genus *Rouleina* is known by about five species, two in the Indian region, *viz. R. guentheri* (Alcock) and *R. squamilatera* (Alcock).

Family PLATYTROCTIDAE

Platytroctids are a fascinating scene in the evolutionary play; this interesting deep-sea fish family has been reviewed by Matsui & Rosenblatt (1977). Twelve genera with 31 species; two genera with two species in Indian seas, *viz. Platytroctogen mirus* Lolyd and *Platytroctes apus* Gunther.

Family GALAXIIDAE

This family comprises cold-water fishes which form the dominant element in the freshwater fish fauna of the Southern Hemisphere. The status of *Galaxias indicus* Day, 1888, from the coasts of Bengal and Madras, has remained a mystery since the types are lost and there has been no subsequent record of the species from the Indian region. Mc Dowall (1973) evaluated the status of *G. indicus* and considered it a *nomen dubium.*

Family SALMONIDAE

The members of this family are primarily denizens of the Arctic and northern Seas. Man-made introductions and transplantations have spread several species of salmons and trouts to reas far beyond their natural distributional range where they are said to be fairly established. Species of *Salvelinus*, *Salmo* and *Onchorhynchus* have been introduced into Indian waters and these have been reviewed by Jhingran & Sehgal (1985) and recently by Talwar & Jhingran (1991).

Order STOMIIFORMES

Mesoplagioc and bathypelagic fishes distributed in all oceans, with nine families, about 50 genera and 300 species (Smith & Heemstra, 1986) Family classification last revised by Weitzman (1974).

Family GONOSTOMATIDAE

Elongate bioluminescent fishes of oceanic, mesopelagic and bathypelagic habitats found throughout the world's oceans. Six genera with about 27 species known; four genera with nine species in the Indian region (Misra, 1976). Grey (1960, 1964) reviewed species of all genera except *Cyclothone*; Mukhacheva reviewed *Gonostoma* in 1972, *Cyclothone* in 1964 and 1974, and *Diplophos* in 1978. The genus *Cyclothone* (with 12 species) occurs in virtually all seas and has, perhaps, the greatest abundance of individuals of any fish genus in the world. The monotypic genus *Triplophos* represented by its type-species, *T. hemingi* (Mc Ardle), was discovered originally from the Bay of Bengal.

Family STERNOPTYCHIDAE

Bioluminescent fishes, primarily of mesopelagic but some bathypelagic habitat, found in all major oceans. Ten genera with a total of about 45 species, revised by Baird (1971); four genera in Indian seas, *viz. Argyroplecus* (four species), *Polyipnus* (one species), *Sternoptyx* (one species) and *Valenciennellus* (one species).

Family PHOTICHTHYIDAE

Bioluminescent fishes of mesopelagic and bathypelagic habit, found in all oceans. Seven genera with about 21 species; three genera (*Photichthys, Polymetme* and *Vinciguerria*) with four species in the Indian region. They are of no commercial importance.

Family CHAULIODONTIDAE

The viperfishes occur in mid-depths of open oceans around the world. One genus with eight species, recently revised by Parin & Novikova (1974). *Chauliodus pammelas* Alcock occurs in the Laccadive Sea and *C. sloani* Schneider in the Bay of Bengal, of the Indian region.

Family STOMIIDAE

Two genera with a total of eleven species; recently revised by Shcherbachev & Novikova (1976) and Gibbs (1969; *Stomias* only). The genus *Stomias* (with two species) only occurs in the Indian region, *viz. S. affinis* Gunther and *S. nebulosus* Alcock.

Family ASTRONESTHIDAE

Five genera with a total of about 35 species; revised by Regan & Trewavas (1929) and Gibbs (1964). One genus, *Astronesthes*, with three species in the Indian region (Misra, 1976; Silas, 1969). Silas (1976) listed *Astronesthes lucifer* Gilbert from Indian Seas for the first time.

Family MELNOSTOMIIDAE

Fifteen genera with a total of about 200 species; revised by Regan & Trewavas (1929). Of these only, *Melanostomias melanops* Brauer reported from Indian waters.

Family MALACOSTEIDAE

Black to dark brown, mesopelagic or bathypelagic fishes occurring in all oceans. Three genera with about 17 species (Morrow, 1964; Smith & Heemstra, 1986); two genera, *viz. Photostomias* (one species) and *Malacosteus* (one species) in the Indian region (Misra, 1976).

Family IDIACANTHIDAE

One genus, *Idiacanthus* with about four species (Gibbs, 1964); *I. fasciola* Peters only has been reported from Indian waters.

Order AULOPIFORMES

The Aulopiformes comprise about 15 families of predatory marine fishes, most of which have become adapted to a deep sea habitat.

Family CHLOROPHTHALMIDAE

Greeneyes are circumglobal at temperate and tropical latitudes. They are benthic fishes, dwelling on the outer continental shelf, slope, rise and abyssal plain. Seven genera with 38 species (Sulak, 1977); four genera with eight species in Indian waters, *viz. Bathypeterois* (three species), *Bathytyphlops* (one species), *Ipnops* (one species), *Parasudis* (one species) and *Chlorophthalmus* (two species). Talwar (1973) relegated *C. bicornis* Norman, 1939 to the synonymy of *C. corniger* Alcock, 1894. The holotype of *Bathypterois atriocolor* Alock, 1897 was rediscovered in the collections of the Zoological Survey of India by Talwar (1977).

Family SCOPELARCHIDAE

Scopelarchids are oceanic and mesopelagic or bathypelagic in habitat. They have no commercial value. Four genera with a total of 17 species, recently revised by Johnson (1984); *Scopelarchus guentheri* Alock is the only representative of the family in the Indian region (Misra, 1976).

Family SYNODONTIDAE

Four genera with 50 species; three genera with 18 species in the Indian region. Indo-west pacific *Synodus* revised by Cressey (1981). Dutt and Sagor (1981) reported several new records of *Saurida* sp. from Indian waters. Bottom-dwelling fishes; their flesh is of good quality and flavour, though bony.

Family HARPADONTIDAE

A single genus, *Harpadon*, with three species, all in the Indian region (Talwar 1984). *Harpadon nehereus* (Hamilton-Buchanan) constitutes a fishery of great commercial importance in India.

Family PARALEPIDIDAE

They are meso-to bathypelagic and may occur in very large numbers from near the surface to mid-depths (over 800m); some species are common over the continental shelf. Twelve genera with about 50 species; four genera with six species in the Indian region, *viz. Lestidium* (three species *vide* Talwar, 1973); *Stemonosudis* (one species) and *Paralepis* (one species) (Misra, 1976); and *Sudis* (one species, Silas, 1969). Barracudinas are taken as bycatch in offshore trawl fisheries (pelagic trawls).

Family EVERMANNELLIDAE

Evermannellids are oceanic and mesopelagic in habitat. Three genera and seven species, recently revised by Johnson (1982); only *Coccorella atrata* (Alcock) in the Indian region. Probably *Evermannella indica* (Brauer, 1906) also occurs in Indian waters.

Family ALEPISAURIDAE

Large pelagic fishes, attaining a length of 2 m. Lancetfishes occur in the lower epipelagic realm of the open ocean and often caught on tuna longlines. Like many of their relatives, Lancetfish are synchronous hermaphrodites with male and female parts of the gonad active at the same time (Smith & Atz, 1973). one genus, *Alepisaurus*, with two species, both recorded from Indian waters (Silas, 1965).

Order MYCTOPHIFORMES

Family NEOSCOPELIDAE

Benthopelagic over continental and island slope regions or oceanic, bathypelagic in tropical and subtropical waters of all three oceans. Three genera with six species (Nafpaktitis, 1977); two genera with two species in the Indian region (Misra, 1976). *Neoscopelus macrolepidotus* Johnson is reported from the Andaman Sea and south-west coast of India (Samuel, 1966), but *Scopelengys tristis* Alcock recorded only from the Laccadive Sea in the Indian region. (Jones & Kumaran, 1980).

Family MYCTOPHIDAE

The lanternfishes are high-oceanic mesopelagic-bathypelagic or pseudoceanic pelagic/epibenthic from Arctic to Antarctic waters. Thirty genera (Paxton, 1979), with about 235 species; thirteen genera in Indian waters (Kotthaus, 1972; Misra, 1976; Fischer & Bianchi, 1984), *viz. Benthosema* (three species), *Bolinichthys* (two species), *Centrobranchus* (one species), *Centroscopelus* (one species), *Diaphus* (Indian Ocean species revised by Nafpaktitis, 1978; 14 species), *Diogenichthys* (two species), *Gonichthys* (one species), *Hygophum* (two species), *Lampanyctus* (three species), *Lepidophanes* (one species), *Myctophum* (six species), *Notolychnus* (one species) and *Symbolophorus* (two species). There has not been a family revision at the species level since Fraser-Brunner's (1949) study.

Order GADIFORMES

Gadiforms are primarily marine benthopelagic or bathypelagic fishes of worldwide distribution. Eight families; three in the Indian region.

Family MORIDAE

About 15 genera and 55-60 species (Smith and Heemstra, 1986); only *Physiculus* with two species in Indian waters. Fishes of the continental slope and abyssal depths.

Family BREGMACEROTIDAE

A worldwide revision by D' Ancona & Cavinto (1965); Houde (1984) discusses larval development. One genus, *Bregmaceros*, with about seven valid species; only *B. macclellandi* Thompson in Indian waters. This interesting 13 cm codlike fish is caught along the west coast of India supporting a seasonal fishery around Bombay (Talwar, 1984).

Family MACROURIDAE

More than 250 species (in about 30 genera) in all oceans from 100 m to more than 5000 m. Almost all benthopelagic, but a few bathypelagic. Family most recently revised by Marshall & Iwamto (1973) and Okamura (1970). The family is represented by ten genera in the Indian region, *viz. Bathygadus* (one species), *Coelorinchus* (three species), *Coryphaenoides* (four species), *Gadomus* (one species), *Hymenocephalus* (one species), *Macrourus* (one species), *Malacocephalus* (one species), *Nezumia* (four species), *Sphagemacrurus* (one species) and *Ventrifossa* (one species).

Order OPHIDIIFORMES

Ophidiiforms are primarily marine and occupy a variety of habitats, from the intertidal region to the greatest depths of the sea. Cohen & Nielsen (1978) recognise 87 genera divided into four families, and about 294 species in the world; four families in the Indian region.

Family OPHIDIIDAE

About 39 genera with 135 species; the genera reviewed by Cohen & Nielsen (1978). The fishes of 14 genera have been reported from Indian waters, *viz. Bassozetus* (one species), *Brotula* (one species), *Dicrolene* (three species), *Glyptophidium* (recently revised by Nielsen & Machida, 1988; two species), *Holomycteronus* (one species), *Hypopleuron* (one species), *Lamprogrammus* (two species), *Monomitopus* (two species), *Neobythites* (one species), *Porogadus* (two species), *Pycnocraspedum* (one species) *Sirembo* (one species) and the monotypic genus *Tauredophidium*. Further, the monotypic genus *Spottobrutula* represented by its type-species, *S. mahodadi*, was discovered by Cohen & Nielsen (1978) from the Andaman Sea.

Family CARAPIDAE

A review of the genera is provided by Cohen & Nielsen (1978) and a limited revision of the family by Arnold (1956). Trout (1981) has recently reviewed the systematics, ecology and behaviour of carapine fishes. At least six genera containing about 30 species; three genera with five species in the Indian region (Mahadevan, 1962; Jones & Kumaran, 1980), *viz. Carapus* (three species), *Encheliophis* (one species) and *Onuxodon* (one species). Pearlfishes are morphologically conservative and hence difficult to identify. The family needs revision.

Family BYTHITIDAE

About 23 genera with at least 200 species, half of which are undescribed (Smith & Heemstra, 1986); seven genera reported from the Indian region, placed in eight species. Silas (1969) listed the genus *Catactyx* off the south-west coast of India; Menon & Rama-Rao (1972) reported *Dinematichthys iluocoeteoides* Bleeker for the first time in the Indian region; and Cohen & Nielsen (1972) revised the genus *Saccogaster*.

Family APHYONIDAE

Deep-sea fishes, reviewed by Nielsen (1969) and Cohen & Nielsen (1978). The aphyonid genera are notable for a number of neotenic characters and convergence has been suggested. Five genera with about 20 species; only *Barathronus diaphanus* Brauer, 1906, has been reported from Indian waters.

Order BATRACHOIDIFORMES

A single family with about 18 genera and 60 species. Batrachoidids are thought to be closely related to the Lophiiformes and Gobiesociformes (Rosen and Petterson, 1969).

Family BATRACHOIDIDAE

The toadfishes are primarily coastal benthic in temperate and tropical seas, a few species entering brackish waters. Nineteen genera with about 64 species; two genera, *viz. Austrobatrachus* (one species) and *Batrichthys* (one species) in Indian waters (Hutchin, 1981; Talwar & Jhingran, 1991). The toadfishes are of no commercial interest.

Order LOPHIIFORMES

Anglerfishes are inshore benthic on muddy to rocky bottom, coral and rocky reefs, to meso and bathypelagic. Sixteen families with about 59 genera and 250 species; six families in the Indian region.

Family LOPHIIDAE

Four genera with a total of 25 species (Caruso, 1981); three genera with six species in the Indian region. the monotypic genus *Lophiomus* and *Lophiodes* (four species) are deep-water species. *Lophius vomerinus* Valenciennes has been reported in the Bay of Bengal off Burma. This group of fishes has been revised by Caruso (1983) and their intergeneric relationships discussed by Caruso (1985).

Family ANTENNARIIDAE

Anglers (also called 'frogfishes' or 'toadfishes') are of no economic importance except in the aquarium trade. Thirteen genera with a total of 40 species; three genera and eight species in the Indian region. Generic revision by Pietsch (1984), and an account of the systematics, zoogeography and behavioural ecology by Pietsch & Grobecker (1987). Schultz (1975) revised the Indo-Pacific species of the genus *Antennarius* and described a new species from Vizagapatanam (Andhra Pradesh). The genus *Antennatus* represented by *A. tuberosus* (Cuvier), is restricted to Sri Lanka in the Indian region.

Family CHAUNACIDAE

Species inhabit continental slopes in all oceans. A single genus, *Chaunax*, with about twelve species (Smith and Heemstra, 1986), although le Danois' world revision (1979) recognises only nine species; two species in the Indian region.

Family OGCOCEPHALIDAE

Mainly benthic fishes that walk on the bottom with their pectoral and pelvic fins; most species occur in rather deep water. Bradbury (1967) reviewed the genera of the world. Nine genera and about 60 species; five genera in the Indian region, *viz. Dibranchus* (two species), *Halieutaea* (four species), *Halicmetus* (one species) *Halieutopsis* (two species) and *Malthopsis* (four species).

Family ONEIRODIDAE

Nearly cosmopolitan in all oceans of the world. Fifteen genera and about 55 species. The genus *Oneirodes* revised by Pietsch (1974), is represented by *O. flagellifer* (Regan & Trewavas), and the genus *Lophodolus* represented by *L. indicus* Lloyd, in Indian waters.

Family DICERATIIDAE

Two genera each with two species, revised by Uwate (1979); only *Diceratias bispinosus* (Gunther) in the Indian region. *Paroneirodes glomerosus* Alcock, 1890, was relegated by Uwate (1979) to the synonymy of *Diceratias bispinosus* (Gunther).

Order CYPRINODONTIFORMES

Family EXOCOETIDAE

Flying fishes are typical members of the epipelagic fish community that inhabits surface waters of the open ocean. Seven genera with a total of about 60 species; five genera with twelve species in the Indian region (Talwar, 1984) Generic classification revised by Parin (1961); the Indian species reviewed by Talwar (1984). The taxonomy of the Indo-Pacific species is in need of revision.

Family HEMIRAMPHIDAE

Most halfbeaks are marine and epipelagic, but some inhabit freshwaters. Twelve genera and about 80 species; seven genera with 21 species in the Indian region (Talwar, 1984; Talwar & Jhingran, 1991). Mohr (1926, 1936) has revised the genera *Zenarchopterus* and *Dermogenys*; and Parin, Collette & Shcherbachev (1980) the genera *Hemiramphus*, *Hyporhamphus* and *Rhynchorhamphus*. Collette (1982) rediscovered the rare halfbeak, *Hyporhamphus xanthopterus* Valenciennes, 1846, a species endemic to Vembanad lake, Kerala.

Family BELONIDAE

Epipelagic, most species marine (mostly neretic). There have been extensive changes since the family was reviewed by Mees (1962, 1964). Indo-Pacific species were reviewed by Parin (1967). Ten genera with a total of 32 species; five genera with ten species in the Indian region (Talwar, 1984). Minor commercial importance; flesh excellent in flavour although some people have misgivings about eating it owing to their green bones.

Family ORYZIIDAE

One genus, *Oryzias*, with seven species (Rosen, 1964), confined to the fresh and brackish waters of India and Japan to the Indo-Australian archipelago. Rosen and Parenti (1981) treated these fishes in the Adrianichthyidae. These small fishes are useful mosquito larvivorous. Only *Oryzias melastigma* (Mc Clelland) in the Indian region.

Family HORAICHTHYIDAE

One species, *Horaichthys setnai* Kulkarni found in 1937, occurs along coastal India from near the Gulf of Kutch to Trivandrum (Hubbs, 1941; Silas, 1959). This is one of the smallest known fish in India.

Family APLOCHEILIDAE

About 15 genera with 210 species; only one genus, *Aplocheilus* occurs naturally in the Indian region; fishes of the genera *Cynolebias*, *Nothobranchius*, *Epiplatys* and *Aphyosemion* were brought to India from tropical west Africa for private aquaria, etc. The genus *Aplocheilus* with five species, have been revised by Parenti (1981); four species in the Indian region (Talwar and Jhingran, 1991).

Family CYPRINODONTIDAE

Small, usually creek-dwelling fishes which are related to the Gambusinos. Twenty-nine genera and about 268 species (Nelson, 1984); one genus in the Indian region in fresh and brackish water. The genus *Aphanius* was revised by Parenti (1981); only one species, *A. dispar* (Ruppell) in India which is beautifully coloured and is fairly suitable for aquaria purposes.

Family POECILIIDAE

This family is a large one and has been reviewed by Rosen & Bailey(1936). They are naturally restricted to the New World fishes. Two members of the family, *viz. Gambusia* and *Poecilia*, were at different times introduced into India for antimalarial work. Today *G. affinis* (Baird & Girard) has the widest distribution of any freshwater fish in the world, largely as a result of mosquito control programmes.

Order ATHERINIFORMES

Family ATHERINIDAE

Small silvery fishes, occurring in temperate and tropical waters of all oceans, usually in large schools. Of no great commercial value, but important as bait and forage fish for commercial species. About 29 genera with over 120 species around the world; three genera with six species in the Indian region (Talwar, 1984). *Atherinomorus endrachtensis* (Quoy & Gaimard) occurs in the Andaman Sea (Herre, 1941), but was overlooked by Talwar (1984).

Family NOTOCHEIRIDAE

Two genera with six species (Rosen, 1964); one species, *Iso natalensis* Regan in the Indian region. *Iso flosindicus* Herre, 1944, is considered identical with *I. natalensis* Regan (Smith & Heemstra, 1986).

Order LAMPRIFORMES

The great diversity of body shape and fin development of the lampriformes makes it difficult to diagnose this order.

Family VELIFERIDAE

Rare fishes of the Indo-Pacific region, reviewed by Walters (1960); taken in depths of 40-110 m. Two genera with two species; only *Velifer hypselopterus* Bleeker has been reported (as *V. africanus*) from Indian waters by Dutt (1963).

Family LOPHOTIDAE

Two monotypic genera, reviewed by Walters & Fitch (1960). *Eumecichthys fiski* (Gunther) only has been reported in India (Dutt, 1976). This is a rare fish but widely distributed in the Indo-west Pacific.

Family REGALECIDAE

Rare fishes of open ocean habitat. Two monotypic genera; only *Regalecus glesna* Ascanius in Indian waters (Day, 1889).

Family ATELEOPODIDAE

A bathypelagic family comprising four genera with about 8 to 12 species. One genus, *Ateleopus* with two species, *viz. A. indicus* Alcock and *A. natalensis* Regan in Indian waters (Samuel, 1963).

Order BERYCIFORMES

Zehren (1979) discusses the comparative osteology and phylogeny of these fishes.

Family MONOCENTRIDAE

An Indo-Pacific family of three or four species belonging to two genera; occur primarily off South Africa, Japan and Australia. One species, *Monocentris japonicus* (Houttuyn) only occurs in the Indian region. The light organ on the lower jaw contains symbiotic luminous bacteria.

Family TRACHICHTHYIDAE

Five genera with about 26 species (Nelson, 1984), most species occur in deep water; two genera and three species in India. *Hoplostethus intermedius* (Hector) and *H. mediterraneus* Cuvier were recorded from the Bay of Bengal by Alcock (1899), and *Gephryoberyx darwini* (Johnson) was reported for the first time from Indian waters by Talwar (1975).

Family BERYCIDAE

Two genera with seven species; both genera with two species listed from Indian deep waters by Silas (1969), *viz. Baryx splendens* Lowe and *Centroberyx spinosus* (Gilchrist) (as *Trachichthoides* prox. *spinosus*).

Family HOLOCENTRIDAE

Eight genera with about 61 species; four genera with 19 species in the Indian region. The genus *Myripristis* comprises 21 species, revised by Greenfield (1974) and supplemented by a review by Randall & Gueze (1981); seven species known from the Indian region. The genus *Ostichthys* was revised by Randall, Shimezu & Yamakawa (1982); of the eight recognised species, two are reported from India. The genus *Sargocentrum* comprises about 26 species (Randall and Heemstra, 1985); seven species in the Indian region. In an osteological study, Li *et al.* (1981) erected the new genus *Dispinus* for *Sargocentrum rubrum. Neoniphon* (syn. *Flammeo*) contains five species, revised by Randall & Heemstra (1985); three species in the Indian region.

Family POLYMIXIIDAE

One genus, with six species, revised by Lachner (1955); *Polymixia japonicus* Gunther has been recently reported (Talwar, 1975) from India; *P. fusca* Kotthaus, 1970, also probably occurs in Indian waters.

Family MELAMPHAIDAE

Small dark brown to blackish deep-sea species. Five genera with a total of 33 species, most recently revised by Ebeling & Weed (1973); *Scopelogadus mizolepis* (Gunther) has been reported (Alcock, 1899) from the Bay of Bengal, and probably *Poromitra oscitans* Ebeling also occurs in Indian waters (Parin and Bozodulina, 1988).

Order ZEIFORMES

Family ZEIDAE

Near bottom fishes, common in trawls 100 to 300 m. Five genera with a total of nine species; two genera with two species in the Indian region. The monotypic genus *Cyottopsis* represented by its type-species, *C. roseus* (Lowe), and *Zenopsis conchifer* (Lowe) has been reported from the Arabian Sea by Talwar (1975). Heemstra (1980) gives a map showing locality records, and also discusses the systematics of these fishes.

Family CAPROIDAE

Two genera with eleven species; only the genus *Antigonia* with two species in Indian waters, recently revised by Parin & Borodulina (1986).

Family GRAMMICOLEPIDIDAE

Three genera with a total of five species (Heemstra, 1980); Silas (1969) lists the genera *Daramattus* and *Xenolepidichthys* from the deep waters of the south-west coast of India. Uncommon and not commercially important.

Order INDOSTOMIFORMES

This order was proposed by Banister (1970) and contains a single family only.

Family INDOSTOMIDAE

Small freshwater fishes restricted to Upper Burma, comprising a single monotypic genus, *Indostomus*. Banister (1970) revised the family based on osteological characters; Kottelat (1983) discussed its natural distribution.

Order PEGASIFORMES

Family PEGASIDAE

The fishes of the family Pegasidae, popularly known as seamoths, are characteristic in their oddly shaped body (broad and depressed, encased in bony plates) and enlarged, winglike pectoral fins. Pietsch (1978) placed them among the syngnathiforms while Nelson (1984) retained them in a separate order, Pegasiformes. Cryptic colouring and a strange shape enable seamoths to live undetected in weeds. Four genera with five species (Smith and Heemstra, 1986), all restricted to the Indo-Pacific; *Pegasus volitans* Linnaeus and *Eurypegasus draconis* (Linnaeus) reported from India (Venkateswarlu, 1976). *Parapelagus natans* of Munro (1955) from Sri Lanka is a synonym of *Pegasus volitans*.

Order SYNGATHIFORMES

The members of this group are noted not only for their bizarre appearance, but also for their strange anatomical and biological characteristics which clearly set them apart from all other living fishes. The order comprises seven families of highly specialised species derived from some primitive acanthopterygian.

Family AULOSTOMIDAE

Trumpetfishes are predators and are usually seen on reefs. One genus, *Aulostomus*, with two or three species (Wheeler, 1955); only *A. chinensis* (L.) though widespread in the Indo-west Pacific, is restricted to the Laccadives and Sri Lanka in the Indian region (Jones & Kumaran, 1980).

Family FISTULARIIDAE

The flutemouths usually inhabit shallow waters of tropical and subtropical seas. The elongate tubular snout is a very efficient device for sucking in small fishes which are the most common food item for these stealthy predators. One genus, *Fistularia*, with four species; recently reviewed by Fritzsche (1976); two species in the Indian region.

Family MACRORHAMPHOSIDAE

Three genera with about 12 species; only *Macrorhamphosus scolopax* (Linnaeus) has been listed (as *M. gracilis*) (*vide Silas*, 1969) from off south-western India where it is taken in good numbers in 80 to 300 m near the edge of the continental shelf off Quilon (Kerala).

Family CENTRISCIDAE

The shrimpfishes have an extremely compressed, razorlike body with a sharp ventral edge. Two genera with 4 or 5 species recognised, of which only one species, *Centriscus scutatus* Linnaeus is reported from the Indian region. These fishes swim in a vertical position, with the snout down.

Family SOLENOSTOMIDAE

A small group of Indo-Pacific fishes with one genus, *Solenostomus*, and perhaps two species of which one (*S. cyanopterus* Bleeker) has been recorded from India. This ghost pipefish is an uncommon shore fish in weedy areas throughout the Indo-Pacific region. Always found in pairs, swimming head down close to each other. Searching for food they approach the selected place turning their eyes is all directions, simultaneously or separately (Fishelson, 1966).

Family SYNGNATHIDAE

This family comprise the pipefishes and seahorses. It includes 52 genera with 205 species (Nelson, 1984; Dawson, 1985); 18 genera with 38 species inhabit the Indian region. Dawson (1985) reviewed the Indo-Pacific pipefishes. Although commonly represented in the decorative motifs of fabrics and artwork, these fishes have little economic value. Bellomy (1969) presents an account of the natural history of seahorses. *Phoxocampus belcheri* (Kaup) was reported from Indian waters for the first time by Jones & Kumaran (1980). Day (1878, 1889) reported *Nerophis dumerilli* Steindachner from Bombay, an extralimital Atlantic genus and yet to be found in the Indo-Pacific. Kulkarni & Ranade (1974) make no mention of this species in the *Fauna of Maharashtra State Gazetteers*, nor does Dawson (1985) in the *Indo-Pacific Pipefishes*. The report of *Micrognathus brevirostris* (Ruppell) by James (1971) is dubious since this species is an endemic Red Sea species.

Order DACTYLOPTERIFORMES

Family DACTYLOPTERIDAE

Two genera and seven species, recently reviewed by Eschmeyer (in press); one genus, *Dactyloptera* with four species in Indian waters. Besides *D. orientalis* (Cuvier) and *D. macracanthus* (Bleeker) which are often taken as bycatch in near shore fisheries; *D. petersoni* (Nystrom) was listed by Silas (1969) (as *Daicocus petersoni*) from the south-west coast of India; and *D. indicus* Achari & Lazarus was recently discovered from the Kerala coast. Silas (1969) also lists *Ebisinus cheirophthalmus* (Bleeker) in Indian waters.

Order SYNBRANCHIFORMES

Family SYNBRANCHIDAE

The swamp-eels, a family of eel-like percomorph fishes, are well represented in India. Few groups of teleostean fishes have had so long and obscure taxonomic history as the swamp eels. Rosen & Greenwood (1976) discussed the phylogeny and systematics of this group of fishes; this major revision and excellent osteological account, formed the basis of future work. Travers (1984) thought synbranchids to be closely related to the Mastacembelidae. Four genera with 15 species; two genera with six species in the Indian region (Talwar and Jhingran, 1991).

Order SCORPAENIIFORMES

This order contains the "mail cheeked" fishes. About 20 families, but classifications differ with regard to family limits; about 1000 species.

Family SCORPAENIDAE

About 60 genera with about 310 species; 23 genera and 48 species in the Indian region. The genera *Ablabys* (two species); *Apistus* (one species); *Dendrochirus* (two species); *Parapterois* (one species); *Pterois*, lovely aquarium fishes but their venomous fin spines can cause very painful wounds (six species); *Pontinus* (one species) reported by Rama-Rao (1973); *Paracentropogon* (two species); *Esobsia* (one species), recently revised by Eschmeyer & Rama-Rao (1977); *Parascorpaena* (three species), revised by Eschmeyer & Rama-Rao (in press); *Gymnapristis* (two species);

monotypic genus *Lioscorpius*, revised by Eschmeyer & Collette (1966); *Richardsonichthys* (one species), recently recorded by Ramanathan et al. (1975); *Taenianotus* (one species), reported from the Laccadive Sea by Jones & Kumaran (1980); *Pteroidichthys* (one species), reported by Rama Rao (1980); *Ocosia* (one species discovered by Poss & Eschmeyer (1976) off Kerala coast); *Scorpaena* (one species); *Scorpaenodes* (six species), revised by Eschmeyer & Rama-Rao (1972); *Synderina* (one species), reported off the Kerala coast by Talwar (1977); *Setarches* (two species), revised by Eschmeyer & Collete (1966) and later reviewed by Rama-Rao (1977); *Sebastapistes* (five species), recently revised by Eschmeyer & Rama Rao (in press); *Scorpaenopsis* (four species), revised by Eschmeyer & Rama-Rao (in press); *Amblypistes* (two species); and *Tetraroge* (one species), have been reported from Indian waters. *Tetraroge niger* (Cuvier) is restricted to the Andamans and Sri Lanka in the Indian region.

Family SYNANCEIIDAE

Nine genera with 29 species; six genera with 14 species in the Indian region. The genera *Inimicus* (three species) and *Choridactylus* (one species), both revised by Eschmeyer, Rama-Rao & Hallacher (1979); genus *Synanecia* (three species) revised by Eschmeyer & Rama-Rao (1973); genus *Minous* (five species), revised by Eschmeryer, Rama-Rao & Hallacher (1979); *Pseudosynaneia* (one species); and genus *Trachinocephalus* (one species), have been reported from the Indian region.

Family CARACANTHIDAE

These small fishes live among branches of corals. One genus and four species; *Caracanthus unipinna* (Gray) and *C. madagascariensis* (Guichenot) recorded in the Indian region (Jones & Kumaran, 1980).

Family APLOACTINIDAE

Velvet fishes occur in the Indo-Pacific region; fifteen genera with 38 species, most of which were characterised by Poss & Eschmeyer (1978); two genera with three species in Indian waters. *Acanthosphex leurynnis* (Jordan & Seale) was reported by Ramaiyan & Rao (1970) for the first time from Indian Seas. The genus *Cocotropus* with two species, *viz. C. echinatus* (Cantor) and *C. steinitzi* Eschmeyer & Dor, are both restricted to the Anadaman Sea in the Indian region (Talwar, in press). All members of this poorly known family are extremely rare.

Family TRIGLIDAE

Ten genera with about 69 species; two genera with probably seven species in Indian waters. The Indian Ocean species of *Lepidotrigla* have been revised by Richards & Saksena (1977); six species in Indian waters. The genus *Pterygotrigla* is represented in India by *P. hemisticta* (Temminck & Schlegel) (Day, 1888, 1889). Samuel (1963) erroneously identified a specimen of *P. hemisticta* from the Kerala coast as *P. picta* (Gunther), a species known from the eastern Pacific Ocean (Richards & Saksena, 1974).

Family PERISTEDIIDAE

Some authors include the peristediids as a subfamily of the Triglidae. About four genera and 20 to 30 species (Smith and Heemstra, 1986); they habit the lower shelf/upper slope regions of all oceans between the 60° latitudes. Three genera are represented in the Indian region : *Satyrichthys* (two species); *Peristedion* (three species), the identity of the rare *P. rivers-andersoni* (Alcock, 1894) was discussed by Talwar (1976); and the genus *Gargariscus* recorded by Talwar & Mukherjee (1978) in Indian waters.

Family PLATYCEPHALIDAE

Benthic fishes frequently found on mud or sand bottoms of continental shelf at depths to about 300 m; most species in 10-100 m; a second group of species is associated with rocky shores or coral reefs. Many species are excellent in eating. Primarily Indo-Pacific; about 12 genera with a total of 60 species; eight genera, *viz. Cociella* (one species), *Grammoplites* (two species), *Platycephalus* (one species), *Inegocia* (one species), *Rogadius* (two species), *Thysanophrys* (two species), *Sargogona* (two species) and *Suggrundus* (one species), have been reported from the Indian region. *Platycephalus bengalensis* Rao, 1966, described from India, was relegated to the synonymy of *Suggrundus rodricensis* (Cuvier) by Knapp (1984).

Family PSYCHROLUTIDAE

Talwar (1977) reviewed the status of some type specimens of fishes from the R.I.M.S. "Investigator" collections and included *Liparoides beauchampi* Lloyd, 1909, in the family Cyclopteridae. The "unique holotype" of this species was destroyed in 1923 (Talwar 1977). According to Stein (1977) this species appears to belong to the Cottidae; it resembles members of the genera like *Cottunculus*, a species now considered under the family Psychrolutidae by Nelson (1984).

Order PERCIFORMES

The Perciformes is the most diversified and largest of all fish orders, comprising about 150 families and some 7800 species (Nelson, 1984). Indeed, it is the largest vertebrate order. About one-third of all fish species are perciforms. Perciformes dominate in vertebrate ocean life.

Suborder PERCOIDEI

Family AMBASSIDAE

This is one of the few families of percoid fishes which exhibit greater diversity in fresh water than in marine habitats. Nine genera with about 41 species; four genera with 17 species in the Indian region and these have been reviewed by Talwar (1984) and Talwar & Jhingran (1991). Fraser - Brunner (1954) had revised these fishes. Not of commercial importance, but useful as bait.

Family CENTROPOMIDAE

Coastal waters, most species being partial to brackish water. Four genera with 18 species, revised by Greenwood (1976); two genera with two species in the Indian region. *Lates calcarifer* (Bloch) is a coastal and estuarine species, and is one of the important food fishes of India. *Psammoperca waigiensis* (Cuvier) contributes a minor fishery in Tamil Nadu.

Family ACROPOMITIDAE

Widely distributed, deep-water fishes. The fishes here assigned to this ill-defined 'family' are placed by some recent authors in the Percichthyidae. Four genera with about 15 species; two genera (with two or three species) in the Indian region, *viz. Acropoma* and *Synagrops*.

Family SERRANIDAE

This family comprises three subfamilies, about 48 genera and some 320 species. Common in tropical and subtropical water of all oceans; several species of commercial importance.

Subfamily ANTHIINAE

Anthiines are an assemblage of small to moderate-sized colourful serranids comprising some 20 genera and at least 100 species; two genera with five species reported from the Indian region : *Anthias* (three species) (Jones and Kumaran, 1980), and *Holanthias* (two species), reviewed by Talwar (1976). The discovery of *Holanthias perumali*off Kerala, by Talwar (1976) was an interesting find.

Subfamily CENTROGENYSINAE

This subfamily is represented by *Centrogenys vaigiensis* (Quoy & Gaimard) from the Nicobars in the Indian region. The genus *Centrogenys* is often placed in its own family but bears a superficial resemblance to the cirrhitids.

Subfamily EPINEPHELINAE

The Epinephelinae (rockcods or groupers) are generally demersal fishes of tropical and subtropical seas. Most of the rockcods appear to be protogynous hermaphrodites, beginning life as females and then later changing sex to spawn as males. About 21 genera with some 170 species; nine genera with about 50 species (Morgans, 1982; Talwar, 1984; Heemstra & Randall, 1984) in Indian waters.

Family DINOPERCIDAE

Two monotypic genera *Dinoperca* and *Centrarchops* were previously included in Serranidae, but Heemstra & Hecht (1986) have established a separate family for these two genera. The monotypic genus *Dinoperca* is apparently common in Pakistan. The genus *Centrarchops* is known only from the northern coast of Angola.

Family GRAMMISTIDAE

Seven genera with 18 species, revised by Randall (1971); four genera with four species in the Indian region (Talwar, 1984).

Family PSEUDOCHROMIDAE

About eight genera and at least 60 species; one genus, *Pseudochromis*, with four species in the Indian region. *Pseudochromis dutoiti* Smith, 1955, is a beautiful and fearless aquarium fish that lays and then actively guards its eggs in empty shells or similar objects.

Family PLESIOPIDAE

Plesiopids frequent coral reefs and rocky areas. Six genera and about 20 species; a single genus, *Plesiops*, with four species in the Indian region.

Family ACANTHOCLINIDAE

Three genera with about five species; *Acanthoplesiops indicus* (Day) only recorded from the Indian region.

Family TERAPONIDAE

Vari (1978), in his excellent revision of this family, recognised 15 genera and 37 species; two genera with four species in the Indian region (Talwar, 1984).

Family KUHLIIDAE

Small fishes of shallow tropical waters, commonly found in freshwater and estuaries. Two genera with seven species; only one genus, *Kuhlia*, with two species in the Indian region. *Kuhlia mugil* (Schneider) is a good aquarium fish.

Family PRIACANTHIDAE

Bigeyes are found near the bottom in rocky areas or reefs of tropical and temperate regions in depths of 1 to 400 m. Three genera with about 12 species; all three genera with five species in the Indian region (Talwar, 1984). Talwar (1975) reported *Cookeolus boops* (Schneider) for the first time from Indian waters and discussed its systematics.

Family APOGONIDAE

About 26 genera with about 192 species; nine genera with about 45 species in Indian waters (Day, 1889; Munro, 1955; Jones & Kumaran, 1980). These are small, carnivorous fishes, mostly of shallow water; not of commercial importance in the Indian region.

Family SILLAGINIDAE

Shallow-water fishes of the tropical Indo-west Pacific; often found in or near estuaries. Three genera and about 25 species; two genera in the Indian region, revised by Mc Kay (1985), *viz. Sillago* (nine species) and monotypic genus *Sillaginopsis*. These are good food-fish.

Family MALACANTHIDAE

Five genera with 34 species, revised by Dooley (1978) and Randall (1981); two genera with three species in the Indian region (Munro, 1955; Talbot, 1971; Ranganathan, 1972).

Family LACTARIIDAE

One monotypic genus. *Lactarius lactarius* (Schneider) is a highly valued food-fish and contributes to fishery in the coastal waters of India.

Family POMATOMIDAE

One genus, *Pomatomus*, with a single species in all oceans. *Pomatomus saltatrix* (Linnaeus) is described as being extremely bloodthirsty, killing more fish than it can consume (Nelson, 1984).

Family RACHYCENTRIDAE

This family contains a single monotypic genus, *Rachycentron. R. canadum* (Linnaeus) is often caught offshore over the continental shelf and frequently seen swimming with remoras of similar appearance; a fine sporting fish, fights gamely and jumps repeatedly. The flesh is good in eating.

Family ECHENEIDIDAE

Four genera with a total of eight species; all four genera with five species in Indian waters (Jones & Kumaran, 1980).

Family CARANGIDAE

About 25 genera, with a total of 140 species, 19 genera with 53 species in Indian waters (Talwar, 1984). This family contains some very important food fishes and plays a significant part in the commercial fisheries of the Indian region. The generic limits and infrafamilial relationships of carangids are not well established. Talwar (1984) has reviewed the species occurring in Indian waters.

Family CORYPHAENIDAE

Only one genus with two large colourful species, revised by Gibbs & Collette (1959); both species in Indian waters. Flesh highly esteemed.

Family APOLECTIDAE

One monotypic genus, often placed in the Carangidae. *Parastromateus niger* (Bloch) is an excellent food-fish and contributes an important fishery in Indian waters.

Family MENIDAE

One monotypic genus, *Mene. M. maculata* (Bloch & Schneider) is of minor commercial significance in India.

Family LEIOGNATHIDAE

An Indo-Pacific family. Three genera and about 20 species; all three genera with 15 species in Indian waters. James (1978) followed by Jones (1985), reviewed these fishes. Singh & Talwar (1978) rediscovered the little-known pony-fish, *Gazza achlamys* Jordan & Starks from India. Further Singh & Talwar, (1978) discovered *Leiognathus indicus* from Indian coastal waters. The silver bellies occur in good quantities along the Tamil Nadu coast and contribute a major fishery in this region.

Family BRAMIDAE

Six genera with 18 species (Mead, 1972); only *Brama dussumieri* Cuvier reported from the Indian region on the high sea.

Family EMMELICHTHYIDAE

Three genera with a total of ten species, family revision by Heemstra & Randall (1977); two genera and two species, *viz. Erythrocles acarina* Kotthaus, 1974 (discovered from Cochin), and *Plagiogenion rubiginosus* (Hutton) are reported from the Indian region.

Family LUTJANIDAE

The Lutjanidae is a family composed of 17 genera and 103 species of mostly reef-dwelling marine fishes collectively known as snappers, recently revised by Allen (1985); nine genera with 41 species in Indian waters. Snappers are important food fishes.

Family LOBOTIDAE

One monotypic genus. *Lobotes surinamensis* (Bloch) inhabits coastal waters and enters estuaries in India and is rated highly as a food fish.

Family DATNIOIDIDAE

This family was recently established by Roberts (1989) for the monotypic genus *Datnioides*. *D. quadrifasciatus* (Sevastianov) is fairly common in the estuaries of the Ganga and the rivers of Burma. It is not esteemed as a food fish.

Family GERREIDAE

Eight genera with about 40 species; three genera and 10 species in the Indian region, these Indian species have been reviewed by Talwar (1984) and Talwar & Jhingran (1991). These fishes are small to medium-sized, about shallows of tidal creeks, lagoons, coral reefs, etc.; often enter fresh water.

Family HAEMULIDAE

Seventeen genera with about 175 species (Nelson, 1984); four genera with 17 species in the Indian region (Talwar, 1984). Some species contribute to an important component in the trap fishery for perches in the Gulf of Mannar.

Family SPARIDAE

Twenty-nine genera with about 100 species; six genera with eight species in the Indian region (Talwar, 1984). Fishes of this family are excellent foodfishes and of considerable commercial importance in Indian waters.

Family LETHRINIDAE

Five genera with about 30 species (Springer, 1982); four genera in Indian waters, *viz. Lethrinus* (15 species), monotypic *Gnathodentex*, *Gymnocranius* (one species), *Monotaxis* (one species) and doubtfully *Wattsia*. Sato (1978) revised the Indo-Pacific species of *Lethrinus*; *Lethrinus rubrioperculatus* was discovered from the Andaman Sea.

Family NEMIPTERIDAE

Nemipterids are common in shallow tropical reef areas and offshore waters to 100 m. Four genera with at least 40 species; all four genera with 28 species in Indian waters. The genus *Nemipterus* was reviewed by Wongratana (1973). The genus *Parascolopsis* was recently synonymised with *Scolopsis* by Rao & Rao (1981), but is now recognised as a distinct genus; six species in Indian waters (Talwar, 1984). Rao & Rao (1981) reviewed the genus *Scolopsis*.

Family SCIAENIDAE

Sciaenids are common in warm coastal waters and estuaries of the world. Some species attain a large size and are of considerable economic importance. About 50 genera with about 210 species; twenty genera with 40 species in the Indian region and these have been reviewed by Talwar (in press) in the *Fauna of India* series.

Family MULLIDAE

Goatfishes are important as a food fish. Six genera worldwide with 55 species (Nelson, 1984); three genera with 20 species in Indian waters (Talwar, 1984; Fischer & Bianchi, 1984).

Family MONODACTYLIDAE

Two genera with three species; one genus, *Monodactylus*, with two species in Indian waters (Talwar, 1984). *M. argenteus* (Linnaeus) is common in the coastal waters and trawling grounds of India. This species is a favourite of aquarists since it does well in captivity, living for a number of years.

Family PEMPHERIDIDAE

Two genera with about 20 species; both genera in Indian waters, *viz. Parapriacanthus* (one species) and *Pempheris* (three species) (Talwar, 1984).

Family BATHYCLUPEIDAE

Rare fishes of deep water. One genus, *Bathyclupea*, with about four species; one species in Indian waters. Berg (1940) placed this family in its own order, Bathyclupeiformes.

Family TOXOTIDAE

One genus, *Toxotes*, with six species, revised by Allen (1978); three species in Indian waters and these have been reviewed by Talwar & Jhingran (1991); of minor interest to fisheries.

Family KYPHOSIDAE

Three genera with nine species (Smith & Heemstra, 1986); one genus, *Kyphosus*, with three species in Indian waters (Talwar, 1984). edible but of poor quality. Although they are not of significant commercial importance, they are taken by artisanal fisheries on hook and line, and by gillnets.

Family EPHIPPIDIDAE

Five genera with six species; three genera in Indian waters, *viz.* monotypic genera *Tripterodon* and *Ephippus*, and *Platax* (one species). The occurrence of *Tripterodon orbis* Playfair in the Indian region is not very definite.

Family DREPANIDAE

One genus, *Drepane*, with two or three species (Smith & Heemstra, 1986); two species in the Indian region (Murthy, 1969). Both species are common in the trawl catches and support a seasonal fishery at several places along the Indian coast.

Family SCATOPHAGIDAE

Two genera with probably four species (Nelson, 1984); one genus, *Scatophagus*, with two species in Indian waters (Talwar, 1984).

Family CHAETODONTIDAE

This family was recently revised by Burgess (1978). Ten genera with 114 species (Allen, 1980); three genera with 29 species in Indian waters (Talwar, 1984). Most species are associated with coral reefs, and are very colourful. The young of butterfly fishes are popular aquarium fishes.

Family POMACANTHIDAE

Widespread and frequenting reefs, angelfishes are among the most beautifully adorned and graceful of all creatures. Family reviewed by Steene (1978) and Allen (1980). Seven genera with nearly 80 species (Smith & Heemstra, 1986); six genera with eight species in the Indian region. These fishes generally occur near coral reefs at depths of less than 20 m.

Family PENTACEROTIDAE

Recently revised by Hardy (1983) who recognises twelve species in seven genera; *Histiopterus typus* Temminck & Schlegel reported by Talwar (1975) from Indian seas. Silas (1969) lists the genus *Quinquarius* (= *Pentaceros*) off the Kerala coast. These fishes are recorded from rather deep (to 600 m) water in all oceans.

Family NANDIDAE

This family comprises a fascinating group of relatively small fishes, most of which are well known to the tropical fish hobbyists. Seven genera with about ten species (Nelson, 1984); three genera with four species in Indian waters, reviewed by Talwar & Jhingran (1991). Liem (1970) made an osteological study of *Nandus;* and Barlow *et. al.*, (1968) reviewed the monotypic genus *Badis.*

Family CICHLIDAE

Cichlids form an important group of relatively large and often colourful aquarium fishes (Axelrod, 1973; Goldstein, 1973). Primarily freshwater fishes; 84 genera and 680 species (Nelson, 1984); only one genus, *Etroplus*, with three species in the Indian region. Further, *Oreochromis mossambicus* (Peters) has been introduced in India for cultural purposes. The Tilapiine fishes have been revised by Trewavas (1983).

Family POMACENTRIDAE

Small fishes of no commercial importance except as aquarium pets. Twenty-five genera with about 300 species; ten genera with 56 species in Indian waters. Considerable morphological diversity exists in many of the genera. Allen (1975) has published a monograph on the biology and classification of the group of fishes of the genus *Amphiprion*. Jones & Kumaran (1980) discovered *Abudelduf manikfani* from the Minicoy Islands and also listed several new records of this group from Indian waters. The genus *Dascyllus* has been revised by Randall & Allen (1977).

Family CIRRHITIDAE

Hawkfishes are usually small and richly coloured fishes that live in rocky and coral habitats. Nine genera and 35 species (Smith & Heemstra, 1986); four genera with four species in Indian waters. Randall (1963) reviewed the family.

Family CEPOLIDAE

Four genera with about 20 species (Smith & Heemstra, 1986); three genera in Indian waters, *viz. Owstonia* (one species), *Acanthocephela* (one species) and *Cephola* (one species). Talwar (1972) discovered the deep-water fish, *Owstonia whiteheadi* off the southwest coast of India.

Suborder MUGILOIDEI

Family MUGILIDAE

Circumglobal fishes of commercial importance. Thirteen genera containing about 70 species (Nelson, 1984); seven genera with 15 species in the Indian region (Talwar, 1984). Luther (1975) proposed a new genus *Osteomugil* for *Mugil* to accept the new generic name for this mugilid.

Suborder SPHYRIENOIDEI

Family SPHYRAENIDAE

One genus, *Sphyraena*, with 20 species; ten species in Indian waters. Indian Ocean species have been reviewed by Williams (1959) and de Sylva (1975). Talwar (1968) discovered the unique holotype of *Sphyraena acutipinnis* Day in the collections of the ZSI. The barracudas are caught in sizeable quantities along the Indian coast and these have been reviewed by Talwar (1984). The large varieties are in good demand due to their delicate flesh.

Suborder POLYNEMOIDEI

Family POLYNEMIDAE

Threadfins are used extensively as food in the tropics where they are usually taken by nets. Seven genera with about 35 species; three genera with 12 species in Indian waters (Talwar, 1984).

Suborder LABROIDEI

Family LABRIDAE

This is the second largest family of marine fishes and the third largest perciform family. Most species very colourful, some with complex patterns. Wrasses are popular aquarium fishes. About 57 genera with 500 species (Nelson, 1984); 24 genera and 72 species in Indian waters (Day, 1889; Jones & Kumaran, 1980; Talwar, in press).

Family SCARIDAE

This group of fishes is aptly named the parrotfishes, as they possess beak-like jaws and many of the species are gaudily coloured. Nine genera with 68 species; five genera and 25 species in Indian waters. The Indo-Pacific Sparisomatinae have been revised by Randall & Bruce (in press). Parrotfishes are abundant on coral reefs, along rocky shores, and in seagrass beds; often they are the largest component of the fish biomass.

Suborder ZOARCOIDEI

Family ZOARCIDAE

Generally small, deep-living bottom fishes of polar and cold-temperate seas. About 40 genera and about 150 species; Silas (1969) lists a species of *Lycodes* from off the southwest coast of India and this report is perhaps the only record of a member of this family from Indian waters.

Suborder TRACHINOIDEI

Family OPISTOGNATHIDAE

Three genera, with about 70 total species many of which lack scientific names (Smith & Heemstra, 1986); one genus *Opistognathus*, with three species in Indian waters (Day, 1889; Eibesfeldt & Klausewitz, 1961). *Gnathyopopsrosbergi annulata* Eibesfeldt & Klausewitz, 1961, described from the Andaman Sea, is referable to the genus *Opistognathus*.

Family CONGROGADIDAE

Ten genera with 17 species; only *Helidesmus thomaseni* (Nielsen, 1960) in Indian waters. Nielsen (1960) described *Pholioides thomaseni* from rock pools near Karachi (Pakistan). Mohan (1969) relegated *Tentaculus waltairiensis* Rao & Dutt, 1965, described from Waltair, to the synonymy of *Pholioides thomaseni*, and reported the species from the Gulf of Kutch. Recently

Talwar *et. al.*, (in press) recorded the species from Digha (West Bengal).

Family CHIASMODONTIDAE

Chiasmodontids are oceanic and mesopelagic or bathypelagic piscivorous fishes. Three genera with a total of eleven species; all three genera with three species in Indian waters. The most recent revisions are those of Norman (1929), Johnson (1969) and Johnson & Cohen (1974).

Family CHAMPSODONTIDAE

One genus, *Champsodon*, with about six species known from depths of 100 - 400 m in the Red Sea and Indo-Pacific region; two species reported from Indian seas, *viz. C. capensis* Regan and *C. vorax* Gunther (*vide* Alcock, 1899; Herre, 1941).

Family URANOSCOPIDAE

Stargazers are benthic predators. Eight genera and about 25 species; three genera in Indian seas, *viz. Uranoscopus* (three species), *Ichthyoscopus* (one species) and the monotypic genus *Pleuroscopus* (listed by Silas, 1969). They appear to be uncommon and none is of commercial importance.

Family TRICHONOTIDAE

One genus, *Trichonotus*, with 3 or 4 species (Smith & Heemstra, 1986); two species in Indian waters, *viz. T cyclograptus* (Alcock) and *T setigerus* Bloch & Schneider.

Family CREEDIIDAE

An Indo-Pacific family of small cryptic fishes occurring on sand and gravel bottoms; rarely seen in life. Seven genera with 14 species; only *Chalixodytes tauensis* Schultz; 1943, reported (Jones & Kumaran; 1967) from Indian waters.

Family PERCOPHIDAE

Rather small fishes of deepish water (100 600 m). Twelve genera with about 35 species; two genera with two species in Indian water. *Chrionema chlorotaenia* (Mackay, 1971) was reported from Indian waters (as *C. chryseres*) by Talwar (1974). The various species of *Bembrops* listed from Indian waters are all referable to *B. platyrhynchus* (Alcock) (Iwamoto & Staiger, 1976; Nelson, 1978).

Family MUGILOIDIDAE

Four genera with about 60 species; only the genus *Parapercis* with six species, in Indian waters. Most species are too small to be important as food-fishes or to be caught with hook and line.

Suborder BLENNIOIDEI

Family TRIPTERYGIIDAE

Small, cryptically coloured benthic fishes. About 16 genera and probably in excess of 130 species (smith & Heemstra, 1986); three genera in India waters, *viz. Helcogramma* (two species), *Tripterygion* (three species) and *Norfokia* (one species) (Herre, 1944; Mohan, 1968, 1971; Talwar & Sen, 1971; Jones & Kumaran, 1980). The genus *Helcogramma* was revised by Hansen (1986).

Family CLINIDAE

Twenty genera and about 80 species; only *Springeratus xanthosoma* (Bleeker) in the Indian region (*vide* Springer, 1971; Mohan, 1974).

Family BLENNIIDAE

Benthic fishes in a wide variety of shallow inhabits, ranging from fresh and brackish water to coral reefs; distributed worldwide in temperate and tropical waters. Fifty-three genera with about 301 species (Nelson, 1984); 21 genera with 56 species in Indian waters. Springer (1968) gives a listing of most of the nominal genera and a detailed osteological description of *Entomacrodus*. Springer (1971) revised the Indo-Pacific genus *Escenius*, and later (Springer, 1972) characterised the tribe Omobranchii and revised all genera of this tribe except the genus *Omobranchus*. Springer & Gomon (1975) revised the genus *Omobranchus* and presented a list of the nominal taxa of this genus with their current identification. The blennids of the Godavari estuary were studied by Visweswara Rao (1974) wherein he described a new species, *Cruantus smithi*, which has now (Talwar & Jhingran, 1991) been relegated to the synonymy of *Omobranchus ferox* (Herre, 1927). The genus *Cirripectes* has been revised by Williams (1988).

Suborder SCHINDLERIOIDEI

Family SCHINDLERIIDAE

Small neotentic fishes that show no adult characteristics. One genus, *Schindleria*, with two species; both in Indian waters, reported from the Laccadive Sea (Jones & Kumaran, 1964, 1980).

Suborder AMMODYTOIDEI

Family AMMODYTIDAE

These curious fishes occur in sandy areas of most seas. Three genera with about 12 species (Nelson, 1984); only *Bleekeria kallolepis* Gunther in Indian waters.

Suborder CALLIONYMOIDEI

Family CALLIONYMIDAE

Nine genera with a total of about 125 species, the Indo-Pacific species revised by Fricke (1983); three genera and 12 species in Indian waters, *viz.* monotypic *Eleutherochir*, *Callionymus* (nine species) and *Synchiropus* (revised by Fricke, 1981; two species). *Callionymus jonesii* Mohan, 1970, described from the Palk Bay, was relegated to the synonymy of *C. hindsi* Richardson; and *Pogonymus goslinei* Rao, 1975, described from the Ennore estuary (Madras), to the synonymy of *Eleutherochir opercularis* (Valenciennes) by Fricke (1983). Fricke (1981) discovered *Callionymus octostigmatus* from the Andaman Sea and later (Fricke, 1983) described *Callionymus io* from off Burma based on the R.I.M.S *Investigator* material. These fishes are not of any commercial importance.

Suborder GOBIOIDEI

Family GOBIIDAE

Gobiidae, probably the most speciose of all living fish families, contains the world's smallest fishes (and vertebrates). Worldwide with about 220 genera and 1600 species (Smith & Heemstra, 1986); 46 genera with 92 species in the Indian region (Koumans, 1941, 1953; Talwar & Jhingran, 1991). Miller (1973) reformalised the gobioid classification on osteological characters, in a system intended to reflect phylogeny. House & Winterbottom (1979) relegated the genus *Konmaniasis* Rao, 1968, to the synonymy of *Bathygobius*. Inger (1958) reviewed the genus *Brachygobius*; and Larson and Miller (1986) reviewed the genus *silhouetta*. Rao (1970, 1971) discovered *Chiramenu fluviatilis* and *Silhouetta indicus* from the Godabvari estuary. Akihito & Meguro (1975) reviewed the genus *Glossogobius*. Lachner & Mc Kinney (1978) revised the genus *Gobiopsis* and relegated *Barbatogobius asanai* Koumans, 1941, to its synonymy. Pezold & Larson (1986) gave the generic definition for *Oxyurichthys*. Talwar & Jhingran (1991) reviewed the inland gobioid fauna of the Indian region.

Family ELECTRIDIDAE

Worldwide with some 40 genera and about 150 species; 14 genera with 25 species in Indian region. The status of *Andameleotris roai* Herre, 1939, is uncertain according to Koumans (1941). Akihito (1967) reviewed the genus *Eleotris;* Akihito & Meguro (1974) the genera *Ophieleotris* and *Ophiocara* and Lachner & Karnella (1980) the genus *Eviota*. Rao (1971) discovered *Incara multisquamatus* from the Godavari estuary. Talwar & Jhingran (1991) relegated *Waitea buchanani* Rao, 1972, described from the Godavari estuary, to the synonymy of *Mahidolia mystacina* (Valenniciennes).

Family GOBIOIDIDAE

Eight genera with about 19 species; four genera with eight species in the Indian region (Koumans, 1941; Talwar & Jhingran 1991).

Family TRYPAUCHENIDAE

Five genera with ten species; four genera with four species in the Indian region (Koumans, 1941).

Family KRAEMERIIDAE

Four genera with ten species (Nelson, 1984); two genera with two species in the Indian region (Menon & Talwar, 1972; Jones & Kumaran, 1980).

Suborder KURTOIDEI

Family KURTIDAE

This family contains a single genus with two species; *Kurtus indicus* Bloch is caught all along the east coast of India and sporadically enters estuaries. Tominaga (1968) gives additional features for this group of fishes.

Suborder ACANTHUROIDEI

Family ACANTHURIDAE

Nine genera and 57 species; five genera in Indian waters (Talwar, 1984). The largest genus, *Acanthurus*, is represented by five species in the Atlantic; all remaining acanthurines are Indo-Pacific in distribution. Randall (1955) analysed the genera of surgeonfishes. The following genera (with the number of species in Indian Seas) are : *Acanthurus* (revised by Randall, 1956; 14 species), *Ctenochaetus* (revised by Randall, 1955; two species), monotypic genus *Paracanthurus*, *Naso* (six species) and *Zebrasoma* (two species). Ths surgeonfishes are not of great commercial value, though in insular and coastal regions with coral reefs they may be locally important.

Family ZANCLIDAE

A single species of the tropical Indo-Pacific. *Zanclus canescens* (Linnaeus) is a very attractive fish and is fairly common in coral reef areas of the Indian region.

Family SIGNIDAE

Two genera with 27 species; both genera with 14 species in Indian Seas. *Lo magnifucus* Burgess is restricted to the Andaman Sea in the Indian region.

Suborder SCOMBRIODEI

This suborder includes species that are probably the world's fastest swimming fish. **Sailfish,** swordfish and the bluefin tuna have had speeds between 60 and 100 km/hr attributed to them.

Family GEMPYLIDAE

Large, swift predators found in all oceans, usually in depths of 200-500 m, but often migrating to the surface at night. Most species attain more than 1 m. Fifteen genera and 16 species; seven genera in Indian Seas, *viz.*, monotypic *Gempylus*, monotypic *Lepidocybium*, *Neoepinnula* (one species), *Promethichthys* (one species), *Rexea* (one species), monotypic *Ruvettus* and the monotypic *Thyristoides* (Jones, 1960; Narayana Rao, 1965; Talwar & Sathiarajan, 1974; Silas & Regunathan, 1975; Talwar, 1975, 1984). The genus *Lepidocybium* which has many scombrid characters, was placed in Gempylidae by Parin & Bekker (1973). there appears to be no special fishery for any of the species in Indian waters.

Family TRICHIURIDAE

Voracious predators distributed in all tropical and temperate seas. They generally inhabit deeper waters over the continental shelf and the slope, but several species are common in shallow coastal waters. Nine genera with about 17 species (Nelson, 1984); five genera in Indian waters, *viz.* *Benthodesmus* (one species), *Lepidopus* (reviewed by Parin & Mikhailin, 1982; one species) *Eupleurogrammus* (two species), *Lepturacanthus* (two species) and *Trichuirus* (three species). These fishes have been adequately studied by Tucker (1965), Silas & James (1960), James (1967), Gupta (1966), Dutt & Thankam (1966), Wheeler (1971), Silas & Rajagopalan (1975), Talwar (1984) and Fischer & Bianchi (1984).

Family SCOMBRIDAE

Scombrids are swift, epipelagic predators; some species occur in coastal waters, others far offshore. Fifteen genera and 48 species, recently reviewed by Collette & Nauen (1983); eleven genera with 23 species in Indian Seas, reviewed by Talwar (1984). Many species form large schools and most are of great importance as food-fishes.

Family XIPHIIDAE

One genus with only one species, found in open water of all oceans. *Xiphias gladius* Linnaeus usually occurs in deep water beyond the limit of the continental shelf. The flesh of the swordfish is greatly esteemed.

Family ISTIOPHORIDAE

These wide-ranging pelagic fishes are found in all oceans. Three genera with a total of nine species; all three genera in Indian waters, *viz. Istiophorus* (revised by Morrow & Harbo, 1969; one species), *Makaira* (reviewed by Nakamura *et. al.*, 1968 three species) and *Tetrapterns* (reviewed by Nakamura et al., 1968, two species). All billfishes are of commercial value and provide excellent food.

Suborder STROMATEOIDEI

The stromateoid fishes, generally referred to as butterfishes and their relatives, are a diverse group occurring worldwide in coastal and oceanic waters of tropical and temperate regions.

Family CENTROLOPHIDAE

Seven genera with about 22 species, keyed by Haedrich & Horn (1972); only one genus, *Psenopsis* (revised by Haedrich, 1967; two species) in Indian Seas. Occur in rather deep water (between 250 and 300 m), forming small schools.

Family NOMEIDAE

Three genera with about 15 species; two genera in Indian waters, *viz. Cubiceps* (revised by

Butler, 1979; one species) and *Psenes* (reviewed by Ahlstrom, Butler & Sumida, 1976; one species). The specific identity of *Cubiceps squamiceps* (Lloyd) has been discussed by Talwar (1974).

Family ARIOMMATIDAE

One genus, *Ariomma*, with eight species, revised by Horn (1972); *Ariomma indica* (Day) only in Indian waters.

Family STROMATEIDAE

Three genera with about 15 species; only *Pampus* (with two species) is found in Indian Seas, reviewed by Pati (1983). The pomfrets are abundant in the coastal waters of the Indian region and are amongst the best of the tablefishes.

Suborder ANABANTOIDEI

These fishes are freshwater and indigenous to Africa and southern Asia. A comparative classic account of the osteology and phylogeny of these fishes is given by Liem (1963). Most anabantids are good aquarium material. Nearly all the species are useful in their native haunts as destroyers of mosquito larvae.

Family ANABANTIDAE

Three genera recognised; only one, *Anabas*, with two species in the Indian region (Rao, 1968). Both species are of considerable fisheries interest.

Family BELONTIIDAE

This is the largest and most diverse family of anabantoids, with eleven genera and more than 30 species; seven genera in Indian waters, *viz. Belontia* (one species endemic to Sri Lanka), monotypic *Ctenops* (reviewed by Tilak, 1976), *Macropodus* (reviewed by Regan, 1909; one species), monotypic *Malpulutta* (endemic to Sri Lanka), *Colisa* (four species), monotypic *Parasphaerichthys* (endemic to Burma) and *Trichogaster* (one species introduced in Sri Lanka). The fishes of this family are known for their beauty and many of them have been kept as pets in the aquaria. *Betta splendens* Regan, an exotic fish, is common in aquaria in India. *Trichogaster trichopterus* (Pallas) is erroneously listed by Innes (1935) from India.

Family HELOSTOMATIDAE

This family, endemic to south-east Asia, comprises a single species. *Helotoma temminkii* Cuvier, the kissing goramy, was introduced in Sri Lanka, and is a valuable food fish.

Family OSPHRONEMIDAE

Comprises of a single species. Although its suprabranchial organ is especially elaborate, it should not be placed in a monotypic family (Roberts, 1989). *Osphronemus goramy* Lacepede, the giant goramy, was introduced into India and Sri Lanka, and is an important species in freshwater aquaculture.

Suborder CHANNOIDEI

Family CHANNIDAE

Two genera with about 25 species (Roberts, 1989); one genus, *Channa*, with eight species in the Indian region (Reddy, 1978). These fishes are a very conspicuous element of the fish life in almost every part of India.

Suborder MASTACEMBELOIDEI

Family MASTACEMBELIDAE

Four genera with 33 species (Travers, 1984); two genera with nine species in the Indian region, recently reviewed by Talwar & Jhingran (1991). Sufi (1956), followed by Roberts (1980, 1986) and Travers (1984), revised the genera *Mastacembelus* and *Macrognathus*. Talwar & Jhingran (1991) relegated *Macrognathus jammensis* Malhotra & Singh, 1975, to the synonymy of *M. aral* (Bloch & Schneider).

Family CHAUDHURIIDAE

Travers (1984) considered the two species of *Pillaia* and *Garo*, placed in their own family, Pillaiidae, congeneric with *Chaudhuria caudata* Annandale, the type-species of the genus *Chaudhuria*. Roberts (1980) extended the distribution of *C. caudata* to Thailand.

Order PLEURONECTIFORMES

This is a very distinctive group. Most flatfishes occur in depths of 10 to 200 m, a few live in deeper water, and some are found close inshore, even in estuaries. Many species are highly valued as food-fishes and are taken in considerable quantities by trawlers. Six families are currently recognised (Nelson, 1984); all six are represented in the Indian region.

Family PSETTODIDAE

Psettodids are considered the most primitive of the flatfishes, one genus, *Psettodes*, with three species; only one species in the Indian region. *Psettodes erumei* (Schneider) lives on muddy and sandy bottoms of the continental shelf down to about 100 m. It forms an important fishery at Bombay and Madras.

Family CITHARIDAE

Four genera and five species; one genus, *Brachypleura* with one species, *B. novae - zeelandiae* Gunther in Indian seas.

Family BOTHIDAE

Bothids comprise 37 genera with about 212 species (Nelson, 1984); twelve genera with 38 species in Indian seas. They are found in all tropical and temperate seas, and several species are of commercial importance. The fishes of this family have been reviewed by Norman (1927). Subsequent to this important work, Talwar (1975) reported *Arnoglossus arabicus* Norman from Indian waters and also extended the range of distribution of *Cephalopsetta ventrocellatus* Dutt & Rao, 1965, from the Bay of Bengal to the Arabian Sea. Further, Talwar (*op. cit.*) relegated *Lioglossina punctata* Abraham, 1969, described form Kerala, to the synonymy of *Cephalopsetta ventrocellatus* Dutt & Rao. The genus *Chascanopsetta* has recently been revised by Amoka & Yamamoto (1984).

Family PLEURONECTIDAE

Pleuronectids comprise some 45 genera and about 100 species; four genera in Indian Seas, *viz. Marleyella* (one species), *Poecilopsetta* (two species), *Samaris* (one species) and *Samaricus* (two species).

Family CYNOGLOSSIDAE

Tonguefishes are found in warm waters of all oceans. Most species occur in shallow water or estuaries. A recent revision of the genus *Cynoglossus* (Menon, 1977) recognises three genera in this family with about 103 species; all three genera in Indian waters with 21 species. The genus *Paraplagusia* was reviewed by Menon (1980). Most species of *Symphurus* are found on the continental slopes (200 - 1000 m) and the genus is in dire need of revision. *Cynoglossus macrostomus* Norman is the object of an important fishery on the south-west coast of India.

Family SOLEIDAE

Soles are benthic, neritic fishes occurring in all oceans. Thirtyone genera and 120 species; nine genera with 22 species in Indian waters (Norman, 1928; Talwar & Chakrapani, 1966; Menon & Joglekar, 1983; Talwar, 1984). Some species are of considerable economic importance in the Indian region. The taxonomy of this family needs revision.

Order TETRAODONTIFORMES

The Tetraodontiformes (also known as the Plectognathi) are a morphologically diverse and highly specialised group of teleosts. Tyler (1980) has produced a profusely illustrated and comprehensive work on the osteology and higher classification of the tetradontiforms. This classification agrees fairly well with the cladistic classification proposed by Winterbottom (1974) based on myology of 46 species. Eight families with approximately 92 genera and 330 extant species.

Family TRIACANTHODIDAE

Moderate-sized fishes (less than 25 cm) found near the bottom in depths of 46-600 m or greater. Eleven genera with 20 species; only five genera with six species in Indian waters, *viz. Halimochirurgus* (one species), *Macrorhamphosodes* (one species), *Mephisto* (one species), *Triacanthodes* (one species) and the monotypic genus *Tydemania*. The monotypic genus *Mephisto*, established by Tyler (1966), was known from two specimens (one from off Somalika and the other from the Andaman Sea). Talwar (1975) collected a specimen of this rare fish from off the Kerala coast at a depth of 300 m. Tyler (1966) recorded *Tydemania navigatoris* Weber in the Andaman Sea, and Talwar (1975) reported *Macrorhamphosodes platycheilus* Fowler for the first time from Indian seas.

Family TRIACANTHIDAE

Tripodfishes are benthic, occurring usually on flat, sandy or weed covered bottoms. Four genera with eight species; three genera in Indian seas, *viz.* monotypic genera *Pseudotriacanthus* and *Trixiphichthys*, and the genus *Triacanthus* with three species. Regan (1903) discovered *T. indicus* from India, a species now considered (De Beaufort & Briggs, 1962) a subspecies of *brevirostris*.

Family BALISTIDAE

Most species occur on coral reefs where these fishes often dart for shelter into crevices. Recent works on the Balistidae are Tyler (1981), dealing with osteology, generic and higher level classification. Eleven genera with about 40 species; ten genera with 14 species in Indian waters. Randall & Klausewitz (1973) discovered *Melichthys indicus* from the Andaman Sea.

Family MONOCANTHIDAE

These fishes are primarily benthic, dwelling around coral and rocky reefs or on sand and mud bottoms and seagrass beds. Only large individuals of some filefish species are eaten, but many are collected as a trash fish in commercial bottom trawls. About 31 genera with about 95 species (Nelson, 1984); eight genera with 12 species in the Indian region. *Pseudalutarius nasicornis* (Temminck & Schegel) was listed from India for the first time by Silas (1969); *Oxymonacanthus longirostris* (Bloch & Schneider) was also reported from Indian waters by Talwar (1974). "*Balistes*" *ellioti* Day, 1889, based on Elliot's figure, is an indeterminate species. Jones & Kumaran (1980) described *Rhinecanthus rectangulus* (Schneider) from the Laccadive Sea, but this appears to be *R. echarpe* (Lacepede).

Family OSTRACIIDAE

Slow benthic tropical and subtropical fishes. Fourteen genera with about 37 species; four genera with seven species in Indian waters. Not eaten in India; many species are reported to have toxic flesh. Kuthalingam *et. al.*, (1971) recorded *Tetrosomus contcatenatus* (Bloch) for the first time from India.

Family TRIODONTIDAE

A single species, *Triodon macropterus* Lesson in tropical Indo-Pacific down to 300 m. Day (1878, 1889) reported this species (as *T bursarius*) from the seas of India, but this species is presently not represented in Zoological Survey of India collections.

Family TERRAODONTIDAE

Tetraodontids are circumglobal in tropical and temperate waters; most species are marine, but several enter estuaries and some live only in freshwater. The taxonomy of this family is in dire need of revision, as several of the genera are poorly defined and many of the species are difficult to distinguish. Sixteen genera with about 118 species; nine genera in Indian waters, *viz.* monotypic genus *Amblyrhynchotes, Arothron* (seven species), *Canthigaster* (revised by Allen & Randall, 1977; two species), *Chelonodon* (two species), *Lagocephalus* (four species), *Sphoeroides* (a deep-water species, *S. pachygaster* (= *Liosaccus cutaneus*) reported by Talwar, 1980), *Tetraodon* (revised by Dekkers, 1975; two species), *Torquigener* (one species) and the monotypic genus *Xenopterus*. Talwar & Jhingran (1991) reviewed the inland tetraodontids of the Indian region.

Family DIODONTIDAE

Adults inhabit inshore waters while the young are pelagic..reputed to be poisonous, but some species safely eaten in Pacific. About nine genera with a total of about 19 species; six species in four genera in the Indian Seas, *viz.* monotypic genus *Chilomycterus, Cyclichthys* (one species), *Diodon* (revised by Leis, 1978; three species) and the monotypic genus, *Lophodiodon* reported from the Laccadives by Jones & Kumaran (1980).

Family MOLIDAE

Sunfishes are found in the open ocean, often drifting at the surface as if basking in the sun. Three monotypic genera are generally recognised; two genera in the Indian region, *viz. Ranzania* and *Mola.*

Current Studies

As a result of the study of the various collections of fishes made from different regions of India, substantial progress in our knowledge of the fish fauna has been achieved. The chief advance made by these reports on the fish fauna is in respect of the problems of Indian zoogeography, a field in which several new ideas have been developing. Despite the poor fossil record for fishes and difficulty of working with the often fragmentary fossils, the last decade has seen a substantial contribution from palaeontology towards the solution of certain zoogeographical problems. In that period there has been a great deal of active research into the phylogeny of fishes as well as in the field of continental drift or plate tectonics. The most spectacular advances have been made, with the result that the zoogeography have a scientific understanding of the past land masses against which to review the present distribution of fishes.

The Survey in the forthcoming years has programmed to do intensive mopping-up surveys of the entire country for its fish life by resorting to state-wise exploration and analysis. By 2000 AD, survey of the entire country is likely to be completed. The continental shelf of India has remained virtually a *mare incognitum* as regards the species diversity. Such a programme of work naturally depends on suitable trawlers for exploratory work.

Conservation of Fish Fauna of India

There has been a severe decline in the freshwater fish fauna of India in general and food and game fishes in particular. This decline is mainly due to indiscriminate fishing, dynamiting of rivers, construction of dams across rivers, over utilization of water, cutting down of forest trees, mismanaged farm lands and erosion, pollution by factory chemicals, competition from introduced species, etc.

Dams and weirs at higher reaches of the tributaries of the major rivers of India have affected the world famous game fishes, the Mahseers of India. The spawning runs of Mahseers (*Tor* spp and *Neolissochilus hexagonolepis* (McClelland)) have been affected. Mahseers which used to grow to a size of 150 cm and a weight of 25 - 30 kg in earlier days, have depleted and now catches more than 5 kg size are rare. Dams and increased large-scale extraction of gravel stones (spawning niche of mahseer), silting of lakes and reservoirs are the causes or threats for the decline (Pathani, 1979). Menon (1988) compiled a list of endangered, threatened and rare freshwater fishes of India. These are :

(a) Endangered Fishes

Enobarbichthys maculatus (Day)
Cyprinion semiplotus (McClelland)
Raiamas bola (Hamilton - Buchanan)
Tor chelynoides (McClelland)

(b) Threatened Fishes

Notopterus chitala (Hamilton - Buchanan)
Neolissochilus hexagonolepis (McClelland)
Labeo fimbriatus (Bloch)
Labeo kontius (Jerdon)
Lobeo potail (Sykes)
Tor khudree (Sykes)
Tor tor (Hamilton - Buchanan)
Tor putitora (Hamilton - Buchanan)
Puntius carnaticus (Jerdon)
Puntius jerdoni (Day)
Gonoproktopterus curmuca (Hamilton - Buchanan)
Cirrhinus cirrhosus (Bloch)
Schizothorax richardsonii (Gray)
Schizothoraichthys progastus (McClelland)
Silonia childreni Sykes
Pangasius pangasius (Hamilton - Buchanan)
Bagarius bagarius (Hamilton - Buchanan)

To this list we may add several more names and these have been indicated by Talwar & Jhingran (1991). In view of the high percentage of fishes found in freshwater in India and man's increasing modification of this environment, it is vital that research is drastically increased on the basic systematics of freshwater fishes while this is still possible.

TABLE 1

Numerical Analysis of Genera/Species of Indian Region Collated with World's Fish Fauna

Order/Family		*Indian Region*		*World*	
		Genera	*Species*	*Genera*	*Species*
Order	Chimaeriformes				
Family	Chimaeridae	1	1	2	20
	Rhinochimaeridae	3	3	3	10
Order	Hexanchiformes				
Family	Hexanchidae	1	1	3	4
Order	Squaliformes				
Family	Echinorhinidae	1	1	1	2
	Squalidae	4	4	17	67
Order	Orectolobiformes				
Family	Rhiniodontidae	1	1	1	1
	Hemiscyllidae	1	4	2	11
	Stegostomatidae	1	1	1	1
	Ginglymostomatidae	1	1	2	3
Order	Lamniformes				
Family	Odontaspididae	1	2	2	4
	Pseudocarchariidae	1	1	1	1
	Alopiidae	1	2	1	3
	Lamnidae	1	1	3	5
Order	Carcharhiniformes				
Family	Scyliorhinidae	4	6	15	89
	Proscyllidae	1	1	4	6
	Triakidae	2	2	9	34
	Hemigaleidae	3	3	4	5
	Carcharhinidae	10	26	12	46
	Sphyrnidae	2	4	2	9
Order	Pristiformes				
Family	Pristidae	2	4	2	7
Order	Torpediniformes				
Family	Torpedinidae	1	4	1	14
	Narkidae	3	5	5	10
	Narcinidae	2	4	4	15
Order	Rajiformes				
Family	Rajidae	3	5	9	200
	Rhinobatidae	4	10	9	52
Order	Myliobatiformes				
Family	Myliobatidae	3	5	5	27
	Mobulidae	2	3	2	10

	Dasyatidae	7	26	10	89

Order/Family		*Indian Region*		*World*	
		Genera	*Species*	*Genera*	*Species*
Order	Osteoglossiformes				
Family	Notopteridae	1	2	3	6
Order	Elopiformes				
Family	Elopidae	1	1	1	6
	Megalopidae	1	1	1	2
	Albulidae	1	1	2	5
Order	Notacanthiformes				
Family	Halosauridae	2	5	3	16
	Notacanthidae	1	1	2	9
Order	Anguilliformes				
Family	Anguillidae	1	2	1	19
	Moringuidae	1	3	2	12
	Muraenidae	8	35	14	200
	Nemichthyidae	2	2	3	8
	Synaphobranchidae	2	3	12	18
	Ophichthidae	13	24	59	220
	Nettastomatidae	2	2	5	25
	Colocongridae	1	1	1	4
	Muraenesocidae	5	7	7	14
	Congridae	13	18	34	95
	Serrivomeridae	1	1	3	10
Order	Clupeiformes				
Family	Clupeidae	14	33	56	180
	Pristigasteridae	4	13	9	33
	Chirocentridae	1	2	1	2
	Engraulididae	5	35	16	139
Order	Gonorhynchiformes				
Family	Chanidae	1	1	1	1
Order	Cypriniformes				
Family	Cyprinidae	50	261	194	2074
	Parasilorhynchidae	1	3	1	3
	Psilorhynchidae	1	5	1	5
	Balitoridae	7	87	32	340
	Cobitidae	8	24	15	60
Order	Siluriformes				
Family	Bagridae	6	30	27	205
	Siluridae	5	11	10	45
	Schilbeidae	7	16	16	60

	Pangasiidae	1	1	6	25
Order/Family		*Indian Region*		*World*	
		Genera	*Species*	*Genera*	*Species*
	Amblycipitidae	1	1	2	5
	Akysidae	1	2	3	8
	Sisoridae	18	65	20	68
	Clariidae	2	5	15	100
	Heteropneustidae	1	2	1	2
	Chacidae	1	2	1	3
	Olyridae	1	4	1	4
	Ariidae	6	23	20	120
	Plotosidae	1	3	8	30
Order	Salmoniformes				
Family	Argentinidae	1	1	5	50
	Alepocephalidae	8	14	26	66
	Platytroctidae	2	2	12	31
	Galaxiidae	-	-		
	Salmonidae	-	-		
Order	Stomiiformes				
Family	Gonostomatidae	4	9	6	27
	Sternoptychidae	4	7	10	45
	Photichthyidae	3	4	7	21
	Chauliodontidae	1	2	1	8
	Stomiidae	1	2	2	11
	Astronesthidae	1	3	5	35
	Melanostomiidae	1	1	15	200
	Malacosteidae	2	2	3	17
	Idiacanthidae	1	1	1	4
Order	Aulopiformes				
Family	Chlorophthalmidae	4	8	7	38
	Scopelarchidae	1	1	4	17
	Synodontidae	3	18	4	50
	Harpadontidae	1	3	1	3
	Paralepididae	4	6	12	50
	Evermannellidae	1	1	3	7
	Alepisauridae	1	2	1	2
Order	Myctophiformes				
Family	Neoscopelidae	2	2	3	6
	Myctophidae	13	39	30	235
Order	Gadiformes				
Family	Moridae	1	2	15	60
	Bregmacerotidae	1	1	1	7

Order/Family		*Indian Region* *Genera*	*Species*	*World* *Genera*	*Species*
Order	Ophidiiformes				
Family	Ophidiidae	14	20	39	135
	Carapidae	3	5	6	30
	Bythidae	7	8	23	200
	Aphyonidae	1	1	5	20
Oreder	Batrachoidiformes				
Family	Batrachoididae	2	2	19	64
Order	Lophiiformes				
Family	Lophiidae	3	6	4	25
	Antennariidae	3	8	13	40
	Chaunacidae	1	2	1	12
	Ogcocephalidae	5	13	9	60
	Oneirodidae	2	2	15	55
	Diceratiidae	1	1	2	4
Order	Cyprinodontiformes				
Family	Exocoetidae	5	12	7	60
	Hemiramphidae	7	21	12	80
	Belonidae	5	10	10	32
	Oryziidae	1	1	1	7
	Horaichthyidae	1	1	1	1
	Aplocheilidae	1	4	15	210
	Cyprinodontidae	1	1	29	268
	Poeciliidae	-	-		
Order	Atheriniformes				
Family	Atherinidae	3	6	29	120
	Notocheiridae	1	1	2	6
Order	Lampriformes				
Family	Veliferidae	1	1	2	2
	Lophotidae	1	1	2	2
	Regalecidae	1	1	2	2
	Ateleopodidae	1	2	4	1·2
Order	Beryciformes				
Family	Monocentridae	1	1	2	4
	Trachichthyidae	2	3	5	26
	Berycidae	2	2	2	7
	Holocentridae	4	19	8	61
	Polymixiidae	1	1	1	6
	Melamphaidae	1	2	5	33

Order/Family		*Indian Region*		*World*	
		Genera	*Species*	*Genera*	*Species*
Order	**Zeiformes**				
Family	**Zeidae**	2	2	5	9
	Caproidae	1	2	2	11
	Grammicolepididae	2	2	3	5
Order	**Indostomiformes**				
Family	**Indostomidae**	1	1	1	1
Order	**Pegasiformes**				
Family	**Pegasidae**	2	2	4	5
Order	**Syngathiformes**				
Family	**Aulostomidae**	1	1	1	3
	Fistulariidae	1	2	1	4
	Macrorhamphosidae	1	1	3	12
	Centriscidae	1	1	2	5
	Solenostomidae	1	1	1	2
	Syngnathidae	18	38	52	205
Order	**Dactylopteriformes**				
Family	**Dactylopteridae**	2	5	2	7
Order	**Synbranchiformes**				
Family	**Synbranchidae**	2	6	4	15
Order	**Scorpaeniiformes**				
Family	**Scorpaenidae**	23	48	60	310
	Synanceiidae	6	14	9	29
	Caracanthidae	1	2	1	4
	Aploactinidae	2	3	15	38
	Triglidae	2	7	10	69
	Peristediidae	3	6	4	30
	Platycephalidae	8	12	12	60
	Psychrolutidae	1	1	7	29
Order	**Perciformes**				
Family	**Ambassidae**	4	17	9	41
	Centropomidae	2	2	4	18
	Acropomitidae	2	2	4	15
	Serranidae	12	56	48	320
	Dinopercidae	1	1	2	2
	Grammistidae	4	4	7	18
	Pseudochromidae	1	4	8	60
	Plesiopidae	1	4	6	20
	Acanthoclinidae	1	1	3	5
	Teraponidae	2	4	15	37

Order/Family	*Indian Region*		*World*	
	Genera	*Species*	*Genera*	*Species*
Kuhliidae	1	2	2	7
Priacanthidae	3	5	3	12
Apogonidae	9	45	26	192
Sillagnidae	2	10	3	25
Malaeanthidae	2	3	5	34
Lactariidae	1	1	1	1
Promatomidae	1	1	1	1
Rachycentridae	1	1	1	1
Echeneididae	4	5	4	8
Carangidae	19	53	25	140
Coryphaenidae	1	2	1	2
Apolectidae	1	1	1	1
Menidae	1	1	1	1
Leiognathidae	3	15	3	20
Bramidae	1	1	6	18
Emmelichthyidae	2	2	3	10
Lutjanidae	9	41	17	103
Lobotidae	1	1	1	1
Datnioididae	1	1	1	1
Gerreidae	3	10	8	40
Haemulidae	4	17	17	175
Sparidae	6	8	29	100
Lethrinidae	4	18	5	30
Nemipteridae	4	28	4	40
Sciaenidae	20	40	50	210
Mullidae	3	20	6	55
Monodactylidae	1	2	2	3
Pempherididae	2	4	2	20
Bathyclupeidae	1	1	1	4
Toxotidae	1	3	1	6
Kyphosidae	1	3	3	9
Ephippididae	3	3	5	6
Drepanidae	1	2	1	2
Scatophagidae	1	2	2	4
Chaetodontidae	3	29	10	114
Pomacanthidae	6	8	7	80
Pentacerotidae	2	2	7	12
Nandidae	3	4	7	10
Cichlidae	1	3	84	680

Order/Family	*Indian Region*		*World*	
	Genera	*Species*	*Genera*	*Species*
Pomacentridae	10	56	25	300
Cirrhitidae	4	4	9	35
Cepolidae	3	3	4	20
Mugilidae	7	15	13	70
Sphyraenidae	1	10	1	20
Polynemidae	3	12	7	35
Labridae	24	72	57	500
Scaridae	5	25	9	68
Zoarcidae	1	1	40	150
Opistognathidae	1	3	3	70
Congrogadidae	1	1	10	17
Chiasmodontidae	3	3	3	11
Champsodontidae	1	2	2	6
Uranoscopidae	3	5	8	25
Trichonotidae	1	2	1	4
Creediidae	1	1	7	14
Percophidae	2	2	12	35
Mugiloididae	1	6	4	60
Tripterygiidae	3	6	16	130
Clinidae	1	1	20	80
Blenniidae	21	56	53	301
Schindleriidae	1	2	1	2
Ammodytidae	1	1	3	12
Callionymidae	3	12	9	125
Gobiidae	46	92	220	1600
Eleotrididae	14	25	40	150
Gobioididae	4	8	8	19
Tryhpauchenidae	4	4	5	10
Kraemeriidae	2	2	4	10
Kurtidae	1	1	1	2
Acanthuridae	5	25	9	57
Zanclidae	1	1	1	1
Siganidae	2	14	2	27
Gempylidae	7	7	15	16
Trichiuridae	5	9	9	17
Scombridae	11	3	15	48
Xiphiidae	1	1	1	1
Istiophoridae	3	6	3	9
Centrolophidae	1	2	7	22

Order/Family		*Indian Region*		*World*	
		Genera	*Species*	*Genera*	*Species*
	Nomeidae	2	2	3	15
	Ariommatidae	1	1	1	8
	Stromateidae	1	2	3	15
	Anabantidae	1	2	3	40
	Belontiidae	7	10	11	30
	Helostomatidae	-	-		
	Osphronemidae	-	-		
	Channidae	1	8	2	25
	Mastacembelidae	2	9	4	33
	Chaudhuriidae	1	3	1	3
Order	Pleuronectiformes				
	Psettodidae	1	1	1	3
	Citharidae	1	1	4	5
	Bothidae	12	38	37	212
	Pleuronectidae	4	6	45	100
	Cynoglossidae	3	21	3	103
	Soleidae	9	22	31	120
Order	Tetraodontiformes				
	Triacanthodidae	5	6	11	20
	Triacanthidae	3	5	4	8
	Balistidae	10	14	11	40
	Monocanthidae	8	12	31	95
	Ostraciidae	4	7	14	37
	Triodontidae	1	1	1	1
	Tetraodontidae	9	21	16	118
	Diodontiodae	4	6	9	19
	Molidae	2	2	3	3
	Total	969	2546		

Expertise

INDIA

In ZSI

P. K. Talwar, Dehradun

G. M. Yazdani, Pune

K. V. Rama Roa, Hyderabad

S. Chakrapani, Madras

T. Venkataswarlu, Berhampur

A. Husain, Dehradun

T. K. Sen, Calcutta

T. K. Chatterjee, Digha

H. S. Mehta, Solan

N. Sen (Miss), Shillong

Elsewhere

N. C. Datta, Dept. of Zoology, Calcutta University, Calcutta, Freshwater fishes

P. S. B. R. James, Central Marine Fisheries Research Institute, Cochin, Marine fishes

M. S. Johal, Dept. of Zoology, Punjab University, Chandigarh, Freshwater fishes

K. C. Jayaram, Zoological Survey of India, Southern Regional Station, Madras, Freshwater Fishes.

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G. Luther, Central Marine Fisheries Research Sub-Station, Waltair, Mugilidae, Marine Fishes.

R. S. Lal Mohan, Central Marine Fisheries Research Sub-Station, Kozhikode, Marine fishes

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V. Ramaiyan, Centre of Advances Studies in Marine Biology, Porto Novo, Clupeoid fishes

K. Srinivasa, Rao, Dept. of Zoology, Andhra University, Waltair, Marine fishes

B. V. D. N. R. Seshagiri Rao, College, Bhimavaram, (A.P.), Clupeoid fishes

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ABROAD

There are numerous ichthyologists working on the taxonomy of fishes (both freshwater and marine) of the Indo-West Pacific region and the Oriental region which have a bearing on the Indian ichthyofauna. It would rather unwieldy to list them out, but the names of these distinguished ichthyologists (with their field of specialization) could easily be retrieved from the recent numbers of the 'Newsletter of Systematic Ichthyology' issued by the Department of Ichthyology, California Academy of Sciences.

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AMPHIBIA

Introduction

Amphibia includes the salamanders, cicilians, toads and frogs, and more than 5000 species are known from the world. They are found in varied ecological conditions from plains to mountains, low to heavy rainfall areas, from riverbeds to ponds, and even in the deserts. Several species prefer to stay permanently in water, a few of them live in small bushes near the water source, while some others live under boulders, rocks, stones or under decaying logs. A few of them are arboreal or prefer the crevices of rocks and trees, niches among foliage and leaf litters or among loose soil.

Amphibians are least harmful in nature and are found throughout the world from the sea level up to an altitude of about 3500 m. They do not cause any depredation to agricultural crops, fruits, vegetation, etc., on the contrary their food mainly consists of small insects and their larvae, algae, snails, etc., which are pests to crops and vectors of some diseases. It is rather unfortunate that these innocent creatures are subjected to indiscriminate killing for commercial purposes. As a result, the food chain is disturbed which consequently invite pests and other harmful vectors to multiply causing a threat to the ecosystem. Many species in recent years, have declined so much so that active consideration has now been made for their protection.

The Class Amphibia is divided into three orders, namely Gymnophiona, Caudata and Anura.

Gymnophiona: These are limbless, snake-like amphibians which constitute the smallest order among the group. Example, cicilians.

Caudata: These are tailed amphibians. Example, newts and salamanders.

Anura: These are tailless and limbed amphibians and constitute the largest order among the group. Example, toads and frogs.

Historical Resumé

i) Pre-1900

Herpetologists carried out research on the taxonomy and distribution of Indian amphibians. Some of the important work are by Günther (1858, 1861), Cope (1865), Jerdon (1870), Anderson (1871), Stoliczka (1872), Theobold (1872), Thruston (1888), Boulenger (1882, 1883,1890), Sclater (1892), Gostling (1895), etc. Among them, Boulenger made a comprehensive account of the Indian amphibians in the *Fauna of British India.*

ii) 1901-1947

During this period, significant research was carried out on the Indian amphibians. This may be due to the recognition of the economic importance of the group. A few of the important work to mention with are by Fergussion (1904), Annandale (1917-1921), Chibber (1911), Kemp (1911-1912), Rao (1915-1937), Smith (1917-1935), Wall (1918-1922), Hora (1923), Kampen (1923), Zutshi (1926), Smith (1927,1936), Parker (1928-1934), Mahendra (1929), Gray (1934), McCann (1938-1946), Myers (1942), Seshachar (1939), Ramaswamy (1942), Romer (1948), etc.

The Indian Museum took a prominent part in giving encouragement to research on Indian amphibians. T.N. Annandale, founder Director of the Zoological Survey of India, published several interesting findings in the field of Indian amphibians. Kemp (1911-1912) lead the Abor Expedition and increased our knowledge of the Indian amphibians by recording a number of interesting species

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from the above region. Hora (1921-1922) made some important observations on the larval stages of amphibians with special reference to torrential streams. Kampen (1923) made a comprehensive account on the amphibian fauna of Indo-Australian region. Smith (1927-1935) made some valuable contributions on the amphibians of Brahmaputra valley, Assam. Parker (1928-1934) published on the microhylid frogs.

iii) 1948-1990

For the last four decades, the scientists of the Zoological Survey of India and a few from outside have been working on the Indian amphibians. The study includes the revision of taxa, life history studies and faunal inventory of states. Acharjee and Kriplani (1951) studied the amphibian fauna of Western Himalaya, Murthy (1964) of Rajasthan, Tilak and Hussain (1976) and Tilak and Roy (1985) of Uttar Pradesh, Pillai (1976-1981) of southern India with special reference to Silent Valley, and Shaffer and Koshey (1984) of Kerala. Mukherjee (1975) in his paper on the 'Sundarban of India and its biota' has also touched the amphibian fauna of that area. Amphibians of central and western Himalayas was studied by Dubois (1978-1980), of Jammu and Kashmir by Duda and Sahi (1977), of Tripura and Andaman and Nicobar Islands by Mansukhani and Sarkar (1980-1981) and Mehta and Rao (1987), of Calcutta (West Bengal) and Gujarat by Sarkar (1984), and of Madhya Pradesh by Saksena, Sarkar and Tiwari (1988). Pillai and Chanda (1973-1981), and Chanda (1986-1990) have made comprehensive studies on the amphibian fauna of northeastern India, Darjilling (West Bengal) and Sikkim. Sarkar and Sanyal (1985) have studied the amphibians of Namdapha National Park, Arunachal Pradesh. Amphibians from Orissa and West Bengal have also been studied.

A number of new taxa have been described from northeastern and southern India by the scientists of ZSI, namely, *Philautus cherrapunjiae* Roonwal and Mansukhani 1961, a new genus *Bufoides* by Pillai and Chanda (1973) and a new species *Bufoides meqhalayana* Yazdani and Chanda 1971, *Rana danieli* Pillai, *Rana murthii* Pillai, *Rana mawphlangensis* Pillai, *Micrixalus nudis* Pillai, *M. thampii* Pillai, *Microhyla chakrapani* Pillai, *Bufo silentvalleyensis* Pillai, *Philautus shillongensis* Pillai and Chanda, *Rana bilineata* Pillai and Chanda, *Rana mawlyndipi* Chanda, *Rana sinchalensis* Chanda, and *Philotus swamrupus* Chanda.

Yazdani and Chanda (1971) studied the breeding biology of *Bufoides meghalayana*. Chanda and Talukdar (1973) studied the life history of the tree frog of the family Rhacophoridae. Jayaram (1974) contributed on the distribution of some species of Indian amphibians. Inger and Dutta (1986) catalogued the amphibian species from Indian region.

Daniel (1962-1973) and Abdulali (1954-1962) studied the taxonomy, distribution and ecology of the Indian amphibians. Satyamurthy (1967) worked on the preserved collection of amphibians present in the Madras Government Museum, Madras.

Dutta (1985) from the Utkal University contributed on the burrowing habits of some species of amphibians from Orissa. Paranjape and Mulherkar (1979) from the University of Pune have made an account of amphibians from Pune. Sahu and Khare (1978-1980) from the Northeastern Hill University have studied the larval taxonomy. Khare and Kiysetuo (1987) have studied the taxonomy and distribution of the amphibian fauna of Nagaland. Singh (1987) reported the occurrence of the Himalayan Newt, *Tylototriton verrucosus* at Manipur. Mallick and Das (1987) made some observations on the spawning behaviour of frogs. Ghate and Padhye (1988) undertook some experimental studies on the microhylid frogs. Das (in press) revised the list of Indian amphibians.

Estimation of Taxa

Thirty one families consisting of 330 genera and 5145 species have so far been reported from the world. Of these, nine families, 32 genera and 204 species occur in India.

Classified estimates of different categories of Indian species in comparison to world species are given below.

Family	*Number of genera*		*Number of species*	
	World	*India*	*World*	*India*
Pelobatidae	9	3	98	6
Bufonidae	18	4	382	22
Hylidae	18	1	485	1
Microhylidae	54	5	230	15
Ranidae	40	10	609	89
Bhacophoridae	14	4	190	55
Salamandridae	9	1	53	1
Ichthyophidae	6	2	58	11
Caecilidae	4	2	43	4

The family Pelobatidae is represented by nine genera of which three *Leptobrachium, Megophrys* and *Scutiger* occur in India. Out of six Indian species under this family, *L. hasseltii* is restricted to Meghalaya and *M. robusta* is found in West Bengal. Rest of the species are found in eastern and western Himalayas. Systematics, ecology and distribution of Indian pelobatids were studied by Boulenger (1890), Acharjee and Kriplani (1951), Daniel (1962-1963), Pillai and Chanda (1973-1976), Dubois (1978-1980) and Duda and Sahi (1978).

Family Bufonidae is represented by 18 genera of which only four namely, *Ansonia, Bufo, Bufoides* and *Pedostibes* are found in India. Among them the genus *Bufoides* is endemic to India. Out of 22 Indian species, seven, *A. rubigina, B. brevirostris, B.* camortensis, *B.* silentvalleyensis, Bufoides meghalayana, *P. kempi,* and *P. tuberculosus* are endemic. About 50% of the species under this family are found in southern India. Some of the important work on the systematics, distribution and ecology of Indian bufonids are by Guenther (1875), Boulenger (1882, 1919), Soman (1963), Daniel (1962-1975), Satyamurthy (1967), Yazdani and Chanda (1973-1981), Pillai (1981), Mansukhani and Sarkar (1981), Pillai and Chanda (1973-1981), Duda and Sahi (1977), Sahu and Khare (1980), Tilak and Roy (1985), Chanda (1986), Inger and Datta (1986), Khare and Kiysetuo (1986), etc.

A single species *Hyla annectens* is the sole representative of the family Hylidae in India. This species is restricted to northeastern India. Systematics and distribution of Indian hylids have been studied by Pillai and Chanda (1973-1981); Chanda (1986), and Inger and Datta (1986).

Five genera of the family Microhylidae, *viz Kaloula, Melanobatrachus, Microhyla, Ramanella* and *Uperodon* occur in India. Out of 15 Indian species, five namely, *M. indicus, Microhyla chakrapani, R. anamalaiensis, R. minor* and *U. globulosum* are endemic. Some of the important work on the taxonomy of this family are by Boulenger (1890), Parker (1923), Rao (1937), Daniel (1963-1970), Paranjape and Mulherkar (1979), Pillai and Chanda (1973-1981), Inger (1984), Datta (1985), Chanda (1986), Khare and Kiysetuo (1986), Inger and Datta (1986), Mehta and Rao (1987), etc.

Ten genera of family Ranidae are found in India of which two, *viz Nyctibranchus* and *Ranixalus* are endemic. Some of the worth mentioning contributions on this family are by Guenther (1858-1861), Jerdon (1870), Anderson (1871), Rao (1915-1937), Smith (1917-1935), Kampen (1923), McCann (1938-1946), Abdulali (1954-1962), Satyamurthy (1967), Murthy (1964-1968), Pillai and Chanda (1973-1981), Pillai (1976-1981), Mukherjee (1975), Duda and Sahi (1977), Mansukhani and Sarkar (1980-1981), Dubois (1980), Sahu and Khare (1980), Inger *et al.* (1984), Mohanti

Hejmadi (1985), Chanda (1986), Sarkar and Sanyal (1986), Datta (1986), Khare and Kiysetuo (1986), Ghate and Padhye (1988), etc.

Four genera of family Rhacophoridae are found in India. Out of 55 Indian species 29 are endemic to this country. Some of the important work on the taxonomy and distribution of this family are by Boulenger (1882-1890), Rao (1915-1937), Kemp (1911-1912), Kmapen (1923), Daniel (1962-1975), Satyamurthy (1967), Mahanty Hajmadi (1985), Murthy (1964-1968), Pillai and Chanda (1973-1981), Pillai (1976-1981), Mansukhani and Sarkar (1980-1981), Dubois (1980), Sahu and Khare (1980), Sarkar and Sanyal (1986), Inger and Datta (1986), Chanda (1986), etc.

The Himalayan Newt, *Tylotoriton verrucosus* is the sole representative of the family Salamandridae in India. It is an endangered species. Very little attention has been paid on the study of taxonomy, distribution, and ecology of this species. Some of the work are by Boulenger (1890), Singh (1977), Inger and Datta (1986) and Das (1987).

Two genera and 11 species of the family Ichthyophidae are found in India of which 8 species are endemic to this country. Except for a few scattered references by Boulenger (1882, 1890, 1919), Taylor (1960), Satyamurthy (1967), Inger and Datta (1986), etc., there is as yet no detailed account on the taxonomy, ecology and distribution of Indian ichthyophids.

Two genera and four species of family Caecilidae are found in India of which all the species are endemic to this region. Very little work has been done on the taxonomy, distribution and ecology of this group. Some stray work are by Thurston (1888), Beddome (1870), Boulenger (1890), Alcock (1904), Taylor (1961), Satyamurthy (1967), and Pillai (1986).

Edible amphibians: Two species of frogs, *Rana tigrina* and *Rana hexadactyla* are suitable for human consumption. Their legs were exported to China, Japan and U.S.A. till recently. Now the export has been banned.

Expertise

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REPTILIA

Introduction

The reptilian fauna of India is very rich in its composition and constitutes a major component of the Indian vertebrate fauna, comprising three species of crocodiles, 32 species of turtles, 156 species of lizards and 237 species of snakes (See Table I). Reptiles are the most important group of predators, which maintain the natural balance, but very few people realise their importance. One of the reasons that people are wary of reptiles is that some snakes are poisonous, or a few crocodiles may at times turn into man eaters. Out of nearly 428 species of reptiles inhabiting India only the saltwater crocodile *(Crocodylus porosus)* and five kinds of snakes, namely, the common cobra *(Naja naja)*, King cobra *(Ophiophagus hannah)*, the common krait *(Bungarus caeruleus)*, the Russell's viper *(Vipera russelli)*, and the saw-scaled viper *(Echis carinatus)* are harmful. It is gratifying to note that more and more people are now interested to know about the reptiles, their natural history and role in the environment and to distinguish the poisonous snakes from the non-poisonous varieties. It is hoped that the newly generated awareness of the variety and richness of our reptiles change the attitude towards them whose survival is of paramount importance in the delicate balance of nature.

Man and Reptiles

Most lizards feed on different kind of insects including the pest species. Snakes consume rats and mice. Snake venom is used in the production of antevenom - an anecdote for snake bite. Crocodiles and turtles feed on the dead and decaying matters thus keep the water free from pollution. Of all reptiles, turtles are of great economic benefit to man because several freshwater turtles form the staple diet in India. The sea turtle, *Chelonia mydas* has gained worldwide reputation because of its culinary importance. The Hawksbill, *Eretmochelys imbricata* is killed in large numbers for its beautiful shell.

Historical Resumé

General

The study of reptiles has been pioneered and persecuted in the early eighteenth century by the British Naturalists while serving in the then Indian Medical Service (IMS) or the Indian Forest Service (IFS). Their papers were published mostly by the Trustees of the British Museum, London.

The monumental work on Indian reptiles, published nearly a century ago are 'The Reptiles of British India' by Günther (1864), 'Descriptive Catalogue of the Reptiles of British India' by Blyth (1876) and 'The Fauna of British India : Reptilia and Batrachia' by Boulenger (1890). Nevertheless, it was not until sometime later that information about these animals really began to accumulate in India and a few but serious workers started building up the edifice of the Indian Herpetology brick by brick. Smith's (1931, 1935, 1943) volumes stood the test of time and they constitute the standard work of reference on the subject.

Herpetologists have never been numerous in India. One reason is that this branch of natural history is never popular and another is the prevailing prejudice against creatures some of which are clammy and cold to touch, while some are poisonous. The lack of future openings for the herpetologists has also contributed to the utter negligence of the subject at the university level. However, there has been a dramatic upsurge in the studies in recent years.

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Group-wise Analysis

Crocodiles: The systematics and biology of the Indian crocodiles are fairly known by the work of Abercromby (1922), Barton (1929), Boulenger (*op. cit.*), Ferguson (1891), Gadow (1901) and Smith (1931).

Turtles: The foundation for the primary investigations on the chelonians (testudines) of India was firmly laid by Gray (1825-1875) who has admirably combined the osteological features and taxonomic characters of these animals in this work. Annandale (1912-1915) carried out detailed investigations on the systematics and distribution of the tortoises and mud-turtles found in the inland waters of India. Chaudhuri (1912) and Prashad (1914) continued the work initiated by Annandale (*op.cit.*). Studies on sea turtles occurring in the coastal waters of India and their nesting grounds were neglected till Smith (1931) focussed our attention on these giants among the sea reptiles.

Lizards: The systematics and distribution of the saurian fauna of India has been worked out by earlier naturalists like Anderson (1871-1872), Guenther (1864-1875), Murray (1884-1887), Stoliczka (1870-1873) and Annandale (1904-1921). Among these, Annandale occupies a prominant place for his investigations based on the rich material deposited in the Indian Museum, Calcutta. Blyth (*op. cit.*) carried out his work on the lizards deposited at the Royal Asiatic Society of Bengal, Calcutta. Stoliczka (*op. cit.*) paid special attention to the lizards of Andaman and Nicobar Islands which harbour a variety of species more intimately connected with the Malaysian subregion. Hora (1924) published a series of papers on the lizards of the major families deposited in the collections of the Zoological Survey of India. He also described the mechanics of the adhesive apparatus of some geckos and made a comparative study of the suction pads found on the toes of certain anurans. Beddome (1870-1978) has studied the lizards of the Western Ghats. Annandale and Blyth (*op. cit.*) should be credited with the discovery of several new skinks and agamids. Ganapati and Rajyalakshmi (1953) studied the binomics of the rare limbless skink, *Barkudia insularis.*

Snakes: In the early seventeenth century, a scientific study on the structure, habits and life-histories of the Indian snakes was taken up by British naturalists. They were indefatigable in their researches in collection, figuring and describing these interesting reptiles of India and their work and collection provided the unshakable foundation for modern ophiology. Mahendra (1935) has presented a scholarly review of the history of Indian Ophiology.

The earliest scientific references to the Indian snakes available must be credited to Patrick Russell, who may most appropriately be hailed as the 'father of Indian Ophiology' He has for the first time distinguished the venomous from the nonvenomous snakes of India. His two volumes on Indian Snakes (1796, 1801-1809) bears his stamp of authority on the subject at the time. Fayrer (1874) carried out detailed investigations on the physiology of venom of Indian snakes. Günther (1864) set the trend for the future ophiological studies on the Indian serpents on scientific lines by publishing his major work on *'The Reptiles of British India'* George Albert Boulenger's classic work is familiar to the herpetologists of India and elsewhere. His major work entitled *'Fauna of British India-Reptilia and Batrachia'* (1890) set the course for modern ophiology of India. He prepared exhaustive keys for easy recognition of Indian snakes. Indian ophiologists owe a deep debt of gratitude to Beddome (1863-1886) for his work on the obscure uropeltid snakes of South Indian hills. Wall literally dominated the field of Indian ophiology for an uninterrupted period of 25 years in early twentieth century. His major contributions are *'The Poisonous Terrestrial Snakes of our British Dominions'* (1928), and *'A popular Treatise on the common Indian Snakes'* (1905-1919). Among the early Indian herpetologists devoted to the study of snakes, Mahendra and Gharpurey stand out. Mahendra (1939) has contributed towards a better and clear understanding of the zoogeographical distribution of Indian Snakes and their similarities with the fauna of the neighbouring countries in the subcontinent. It was Colonel Gharpurey (1935) - a medical man turned Ophiologist - who attempted for the first time in India to dispel the ignorance and superstitions woven around the Indian snakes by writing a popular book entitled 'Snakes of India'.

Studies from Different Environs

Investigations on the reptiles of India have for a long time been concentrated on survey, identification and publication of the taxonomic accounts of the species recorded. ZSI, which is a repository of the vast assemblage of the ophidian collections from all over the subcontinent provides excellent opportunities for taxonomic studies. Taking advantage of the rich National Zoological collection housed in the ZSI and the material obtained from the exploratory surveys carried out from time to time in the nook and corner of the country, specialists continue to publish their findings. With the setting up of the biosphere reserves and declaration of some reserve forests as conservation areas, the last one and a half decades have seen an upsurge in ecological work on Indian reptiles. While continuing the routine survey work the specialists of the ZSI and those associated with the other organisations like the Bombay Natural History Society have been paying serious attention to the reptiles of the Wildlife Sanctuaries, National Parks and Biosphere Reserves. Studies have been completed by the scientists of ZSI on the reptile fauna of West Bengal, Orissa, Goa, Rajasthan, Andaman and Nicobar Islands and Tamil Nadu. Likewise, the studies on the reptiles occurring in the Rajaji National Park. Namdapha National Park, Arunachal Pradesh, Kalakaddu Hills of Tamil Nadu have been completed. The reptile fauna of the Chilka Lake has been investigated and the study completed. Though a lot of work has been done on the reptilian fauna of India, yet a wide area remains to be investigated. There is still scope to study the reptilian fauna of Meghalaya, Mizoram, Arunachal Pradesh, Sikkim and Manipur in the Eastern Himalaya, Telangana and Rayalaseema regions of Andhra Pradesh, Marthwada area in Maharashtra and the various hill ranges comprising the Eastern Ghats. Likewise, the reptile fauna of the estuaries and mangroves needs special attention. The turtle fauna of the peninsular rivers is little known. The systematics and biology of the sea snakes occurring in the waters of India are far from complete.

Estimation of Taxa

India's reptile fauna is rich, varied and unique. A great number of them are endemic and relict forms. As Blanford (1901) remarked, there are a few, if any, regions on the earth's surface that exceed in reptile fauna than of India in area of interest. Two regions namely, the Eastern Himalaya and the Western Ghats are herpetologically rich areas. The reptile fauna of India is largely dominated by Indo-Chinese element.

Some 428 species of reptiles belonging to 137 genera and 26 families occur in India. A group-wise critical estimation of the taxa is discussed below.

TABLE - 1

A brief synopsis of the classification and number of species of the living reptiles in India

Order	*Family*	*No. of genera*	*No. of species*
Crocodilia	Gavialidae	1	1
(Crocodiles)	Crocodilidae	1	2
Testudines	Dermochelyidae	1	1
(Turtles and tortoises)	Cheloniidae	4	4
	Emydidae	7	17
	Testudinidae	1	4
	Trionychidae	3	6
Squamata	Gekkonidae	15	54

Order	*Family*	*No. of genera*	*No. of species*
Suborder Sauria (Lizards)	Agamidae	14	43
	Chameleonidae	1	1
	Scincidae	11	44
	Dibamidae	1	1
	Lacertidae	5	8
	Anguidae	1	1
	Varanidae	1	4
Suborder Serpentes (Snakes)	Typhlopidae	2	16
	Uropeltidae	7	33
	Xenopeltidae	1	1
	Boidae	2	4
	Acrochordidae	1	1
	Colubridae	39	127
	Dasypeltidae	1	1
	Elapidae	4	15
	Hydrophiidae	8	20
	Viperidae	2	3
	Crotalidae	3	16

Crocodiles

Gharial: Family Gavialidae. This is a monotypic family. The Gangetic gharial or gavial, *Gavialis gangeticus* inhabits the Ganga and its tributaries in the north and extends as far south as Mahanadi in Orissa. It is one of the most endangered reptiles in the world.

Crocodiles: Family Crocodylidae. The family is represented in India by two species namely the Muggar, *Crocodylus palustris,* and the Saltwater Crocodile, *Crocodylus porusus*. The mugger is widely distributed throughout the Indian subcontinent whereas the saltwater crocodile is widely distributed in southern Asia. In India, it is a rare species as it is confined to parts of the east coast of the mainland and to the Bay Islands.

Turtles and Tortoises

Sea turtles: Families Dermochelyidae and Cheloniidae. Five species of marine turtles are found in coastal waters of India. Of these, the Leatherback sea tutle, *Dermochelys coriacea* is the sole representative of the family Dermochelyidae and is a rare species. The remaining four species namely the Green turtle *(Chelonia mydas)*, the Olive Ridley *(Lepidochelys olivacea)*, the Hawksbill *(Eretmochelys imbricata)*, and the Loggerhead *(Caretta caretta)* are contained in a single family, Cheloniidae. Barring the loggerhead turtles, all the other forms nest on our coasts. All the sea turtles are listed as species threatened with extinction and declared as protected species.

Freshwater turtles: Family Emydidae. Seventeen species of freshwater turtles classified in seven genera namely, *Batagur, Hardella, Kachuga, Geoclemys, Cyclemys, Heosemys,* and *Melanochelys* occur in India. Most of the emydid turtles are aquatic or semiaquatic.

The monotypic genus *Batagur* represented by its type species, *Batagur baska*, is economically important for its flesh and eggs. It is found in the estuaries of the Sunderban and is a rare turtle. The Brahminy river turtle, *Hardella thurgi* inhabits the Ganga, Brahmaputra and Indus river systems. Six species of *Kachuga* occur in India and Burma. All these turtles are used for food and considerally exploited. The Spotted pond turtle, *Geoclemys hamiltoni* occurs in the Ganga and Indus river systems. The Khasi hill tortoise, *Cyclemys dentata* and the Assam freshwater tortoise, *Cyclemys mouhoti* are Indo-Chinese representatives extending their range to the eastern India. The Kerala forest turtle, *Heosemys silvatica* is a rare species which has recently been collected since its original discovery in 1911. It is endemic to India. The genus *Melanochelys*, which ranges from India to Japan and the Malayan archipelago, has five representatives in India. These are the three keeled tortoise, *Melanochelys tricarinata*, the snail-eating turtle, *Melanochelys trijuga trijuga*, the black-necked turtle, *Melanochelys trijuga coronata* and *Melanochelys trijuga indopeninsularis* and *Melanochelys trijuga thermalis*. Of these, *M. tricarinata*, *M. trijuga trijuga*, and *M. t. coronata* are endemic to India.

Land tortoises: Family Testudinidae. There are four land tortoises in India, all placed in the genus *Geochelone*. The Indian starred tortoise, *Geochelone elegans* occurs throughout central and southern India and also extends to the east in Orissa and the west in Pakistan. The Burmese elongated tortoise, *Geochelone elongata* is an Indo-Chinese form occurring in northeastern India. The Burmese brown tortoise, *Geochelone emys* is a giant among the Asian land tortoises and is confined to the hills of eastern India and southeastern Asia. The Travancore tortoise, *Geochelone travancorica* is endemic to India. It is found mainly in the hills of southern Kerala and Coorg (Karnataka).

Flap-shelled turtles: Family Trionychidae. The flapshells or softshells include three genera; *viz. Lissemys, Trionyx*, and *Chitra* represented by five species. The Gangetic softshell, *Trionyx gangeticus* is the common turtle of the Ganges, Indus and Mahanadi river systems. The Peninsular softshell, *Trionyx leithi* is a river turtle of the Gangetic system but is also found in the rivers of peninsular India. A little known but pretty trionychid is the Peacock softshell, *Trionyx hurum* which inhabits the lower reaches of the Ganga, Brahmaputra and Indus rivers. It is endemic to India. The genus *Lissemys* includes two forms, *Lissemys punctata punctata* and *L. p. granosa*. The Chitra softshell, *Chitra indica* is a monotypic species of the genus *Chitra* and is found in the Gangetic and Indus river systems of India, Nepal and Pakistan.

Lizards

Geckos: Family Gekkonidae. Some 54 species contained under 14 genera namely, *Eubleparis, Teratolepis, Stenodactylus, Cyrtodactylus, Cnemaspis, Calodactylodes, Dravidogecko, Hemidactylus, Hemiphyllodactylus, Gekko, Ptychozoon, Phelsuma, Gehyra*, and *Lophopolis* are known. The Andaman Day Green Gecko, *Phelsuma andamanensis* is restricted to the Andamans. Another interesting gecko of Indo-Malayan origin is the Flying gecko, *Ptychozoon kuhli* which is restricted to the Nicobar Islands. The genus *Cnemaspis*, comprising about 11 species, is an assemblage of dwarfed forest geckos, endemic to the hills of southern India. The Golden tree gecko, *Calodactylodes sureus* is a monotypic form and is another rare Indian gecko found in the Eastern Ghats. Another monotypic form found in the Western Ghats is the southern forest gecko, *Dravidogeck anamallensis*.

Agamids: Family Agamidae. The agamid lizards of India are known by 43 species in fourteen genera namely, *Draco, Sitana, Otocryptis, Ptyctolaemus, Goniocephalus, Mictopholis, Oriocalotes, Japalura, Salea, Calotes, Psammophilus, Agama, Phrynocephalus*, and *Uromastix*.

The genus *Draco* represents the Indo-Chinese element in the reptile fauna of India. It includes the two so-called "Flying dragons", *Draco norvilli* found in Assam and *Draco dussumiani* of South India. The Earless lizard, *Otocryptis beddomii* is found in the Western Ghats and is endemic to India. The genus *Salea* comprises the hill species, *Salea horsfieldi* and *Salea anamallayana* both of which are endemic to India. Another genus endemic to India is *Psammophilus* which includes two species of rock lizards found in the peninsular India. The Spiny-tailed lizard, *Uromastix hardwickii* of the arid tracts of northwestern India is an endangered species as it is much sought after for its flesh and oil.

Chameleons: Family Chamaeleonidae. The Indian Chameleon, *Chameleo zeylanicus* is the sole representative of the family which is centered in Africa.

Skinks: Family Scincidae. The family of skinks is composed of 44 species distributed in 12 genera namely, *Dasia, Sphenomorphus, Chalcides, Scincella, Riopa, Ablepharus, Ristella, Mabuya, Eumaces, Ophiomorus, Barkudia* and *Sepsophis*. A great majority of the Indian skinks are migrants from Vietnam while a few are restricted to India. The genus *Ristella* comprising 4 species, is confined to the moist jungles of the Western Ghats. The genera *Barkudia* and *Sepsophis* are represented by one species each, *viz. Barkudia insularis* and *Sepsophis punctatus* both of which are exceedingly rare and endemic to India.

Worm Lizards: Family Dibamidae. The glassy-scaled Indian Worm Lizard, *Dibamus novaeguineae* is the only representative of the family in India. It is a rare species of Indo-Chinese origin and is found from the Nicobars to New Guinea.

Lacertids: Family Lacertidae. This family is an assemblage of typical lizards known by 8 species contained in 5 genera namely, *Acanthodactylus, Cabrita, Eremias, Ophisops* and *Takydromus*. The genus *Cabrita* comprises two species and is endemic to India. Another snake-eyed lacertid endemic to India is *Ophisops beddomei*.

Glass-snake Lizards: Family Anguidae. The Burmese glass snake, *Ophisaurus gracilis* is the sole representative of the family Anguidae in India. It is found in and around Darjiling (West Bengal) and the Khasi Hills, Meghalaya.

Monitor Lizards: Family Varanidae. Four species of monitor lizards comprising the single genus *Varanus* are found in India. They are the Common Indian monitor, *Varanus bengalensis*, the yellow monitor, *Varanus flavescens*, the Desert monitor, *Varanus griseus*, and the Water monitor, *Varanus salvator*. Besides the Indian subcontinent, the monitor lizards are also found in Africa, Australia and the East Indies. These giant lizards are much endangered as they are relentlessly hunted for their palatable flesh and valuable skin. All the Indian monitor lizards are protected species.

Snakes

Blind Snakes: Family Typhlopidae. There are 16 species contained in 2 genera namely, *Ramphotyphlops* and *Typhlops*. The largest blind snake of the Orient is the Beaked blind snake, *Typhlops acutus* which is endemic to India. Of the 16 species known to occur in India, the status of several forms is presently in doubt.

Shieldtails or Rough-tailed Snakes: Family Uropeltidae. This is a family of burrowing snakes restricted entirely to the mountains and foothills of southern India. There are 33 species distributed in seven genera namely, *Melanophidium, Brachyophidium, Teretrurus, Platyplectrurus, Plectrurus, Uropeltis*, and *Rhinophis*, of which four genera are endemic to India. The uropeltid snakes are under heavy pressure because of the rapid destruction of their habitat.

Rainbow or Sunbeam Snakes: Family Xenopeltidae. The family is known by a monotypic genus, namely *Xenopeltis* represented by its type species, *Xenopeltis unicolor*. This iridescent earth snake of Indo-Chinese origin, is known only from the Andamans. It is a rare snake.

Sand boas and Pythons: Family Boidae. Two species each of *Eryx* (sand boas) and *Python* (giant constrictors) make up the family Boidae in India. The Reticulate python which represents the Indo-Malayan element, is found in the Nicobar Islands. Both the pythons found in India are endangered and declared as protected species.

Wart Snakes: Family Acrochordidae. The family is represented by a single species, *Chersydrus granulatus* which inhabits the estuaries. The Indian wart snake is exceedingly common in the Chilka Lake (Orissa).

Colubrids: Family Colubridae. About 130 species distributed in as many as 39 genera, comprise the huge family of Colubridae which is widely distributed in the country in diversified habitats, exhibiting marvellous adaptations. Some are terrestrial, some are fossorial, while others are aquatic. Of the 39 genera known, two genera namely *Trachischium* (5 spp.) and *Xylophis* (2 spp) are endemic to India. The Oriental rat snake, *Ptyas mucosus* is hunted for its skin despite its proven capabilities as a destroyer of rats.

Egg-eating snakes: Family Dasypeltidae. The rare Indian egg-eater, *Elachistodon westermanni* represents the family in India. It is restricted to northern West Bengal and the adjoining territory of Bihar.

Venomous snakes: The four families, Elapidae (cobras, kraits, and Coral snakes), Hydrophiidae (Sea snakes), Viperidae (Pitless or True vipers) and Crotalidae (Pit vipers) comprise the venomous snakes of India.

Cobras, Kraits, and Coral Snakes: Family Elapidae. This is a family comprising four genera namely, *Naja* (cobras),*Bungarus* (kraits), *Calliophis* (Coral snakes), and *Ophiophagus* (King Cobra). The King Cobra or Hamadryad, *Ophiophagus hannah* is the largest venomous snake in the world. It is a rather rare snake in India being confined to a few pockets in the Himalayan foothills, dense jungles of Orissa, the rainforests of Western Ghats and the Andamans.

Sea Snakes: Family Hydrophiidae. Some 20 species of these highly venomous snakes occur in the coastal waters of India comprising 8 genera namely, *Laticauda, Praescutata, Kerilia, Enhydrina, Hydrophis, Lapemis, Microcephalophis,* and *Palamis*. This family is badly in need of revision.

True Vipers: Family Viperidae. This family is represented by three well known vipers namely, Russel's Viper *(Vipers russelli)*, Saw-scaled Viper*(Echis carinatus)*, and Leventine Viper *(Vipera lebetina)*. The Leventine Viper is restricted to the Western Himalaya.

Pit Vippers: Family Crotalidae. About 16 species representing three genera namely, *Hypnale, Agkistrodon,* and *Trimeresurus* are found in the hills and forests of India, mainly confined to the Western Ghats and the Eastern Himalaya. They are characterised by a sensory pit present on each side of the face.

Group-wise Analysis of Studies on Indian Reptiles

Crocodiles

The status of the Indian Crocodiles was so grave during the early 1970s that all the three species were notified as critically endangered species and of these, the gharial slated for immediate extinction. The Government of India sought the advice and technical expertise of the FAO and UNDP which resulted in the conservation programme for saving the crocodiles from imminent extinction. In ZSI, Biswas (1970) carried out a preliminary survey of the crocodiles along the stretch of the Kosi river in Bihar with special attention to the status of the then most critically endangered gharial. As a result of the investigations carried out by Bustard (FAO, 1975) and his band of dedicated pupils like Singh (1978), Basu (1980) and Choudhury (1979), the Centre has selected areas found suitable for the captive breeding and management of the crocodiles. The Government of India has also set up the Crocodile Breeding and Management Training Institute at Hyderabad. Whitaker (1975) has established the Madras Crocodile Bank - the only one of its kind in India - for captive breeding and mangement of the Indian crocodiles. It can now safely be assumed that the crocodiles in India are assured of a fresh lease of life and saved from extinction. The recent book entitled 'Crocodiles' by Steel (1990) is an interesting contribution and decidedly a popular account of these animals of the world.

Turtles And Tortoises

Sea turtles : The worldwide interest in the sea turrtles, created largely due to the efforts of the IUCN and WWF, has provided the required impetus to the Government of India to initiate studies on the nesting biology of these giant marine reptiles. The project to study and conserve the Olive Ridley sea turtle (*Lepidochelys olivacea*) has yielded results and led to country-wide conservation of the nesting grounds located in remote coastal zones. Bhaskar (1979) has reported on the new resting sites for the sea turtles emerging on our beaches. Murthy (1979) prepared a paper on the sea turtles of India. It is matter of great interest, herpetologically speaking, to learn that India constitutes a major breeding ground for the Olive Ridley sea turtle as some 150,000 females emerge on the Gahirmatha beach in Orissa every year to lay eggs.

Freshwater turtles and tortoises : After a lull of nearly two decades since the publication of Smith's (1931) work on Indian testudines, Acharji (1955) renewed the interest in the group by surveying the chelonians of the Gangetic river system. Jayaram (1949, 1974) discussed the distribution of the chelonians of India and their affinities with Malaysian fauna.

Lizards

The studies on Indian lizards was pursued mainly by the scientists of the ZSI notably, Biswas and Sanyal (1977), Tiwari and Sharma (1971), and Sharma (1970–1972). Mahendra (1936–1950) and his pupils in the Academy of Zoology, Agra have made invaluable contributions dealing with the anatomy and musculature of Indian lizards. Murthy (1985) has published a field guide to the lizards of the Western Ghats. Sharma (1980–1984) has described as many as six lizards as new to science.

Snakes

Smith's third volume in the Fauna of British India series (1943) on Indian snakes and his earlier classical monograph on the sea snakes (1926), are still the main source of references on the subject. Underwood (1947–1948) published good accounts on the snakes of Pune, Maharashtra and Kakinada, Andhra Pradesh. Constable (1949) published an authentic work on Indian snakes based on the material deposited in the Museum of Comparative Zoology, Harvard, USA. Deoras (1965) published a book on Indian Snakes aimed for a layman. Scientists of the Zoological Survy of India like Acharji and Kripalani (1951), Tiwari (1973), Biswas and Sanyal (1975–1980), Sharma (1971–1977) and Murthy (1972–1987) made significant contributions. Of these the last mentioned three specialists are still active in the field, contributing to the growth of our knowledge on Indian snakes. Whitaker (1969–1978), besides publishing several notes, brought out a book on the common snakes of India. J. C. Daniel and the team of his associates in the Bombay Natural History Society are publishing their occasional findings in their Society's journal.

Current Studies

Crocodiles

The crocodile sanctuaries set up in the several States of India notably Uttar Pradesh, Madhya Pradesh, Orissa, West Bengal, Andhra Pradesh and Tamil Nadu are functioning effectively. These also have crocodile rearing projects. The Nandankanan Biological Park in Orissa continues to be an efficient Crocodile Management Centre. The Nehru Zoological Park in Hyderabad is also engaged in 'rearing and release' of the gharial and the mugger.

Turtles and Tortoises

Biswas (1983) conducted a detailed survey of the nesting behaviour of the Olive Ridley sea turle on the Orissa coast besides undertaking a preliminary survey of the sea turtles of the Andhra coast. Murthy (1983) carried out a status survey of the sea turtles nesting on the sandy coasts of some villages off Kakinada Port in Andhra Pradesh and is still continuing the line of work. The status of turtles inhabiting the River Godavary in Andhra Pradesh has also been investigated by Murthy. The results of his investigation are under documentation. Murthy (1985–1987) has also studied the systematics of the turtle fauna of some of the conservation areas like the Kalakad Sanctuary in Tamil Nadu. Raj Tilak and Husain (1989) have recently reported on the turtles and tortoises found in the Rajajai National Park, Uttar Pradesh.

Lizards

Sharma has written a handbook on the Indian lizards whose systematics and biology are still poorly known. Murthy's 'Fieldbook of Indian Lizards' is also in the press. Murthy is paying special attention to the lizards of the various districts of Tamil Nadu accumulated as a result of the mopping survey programme besides concentrating on the saurian fauna of the Nilgiri Biosphere Reserve.

Snakes

Sharma has undertaken a thorough review of the systematics and biology of the Indian snakes which may probably pave the way for a revised volume in the Fauna of India series. The proceedings of the training programme on snakes and human welfare conducted early this year (1990) by the ZSI, Jodhpur are to be brought out in a handy volume for the benefit of the students of Indian Ophiology. Murthy's "Illustrated Guide to the snakes of the Western Ghat", has been published. Murthy has described the dangerous land and sea snakes that the defence personnel are likely to encounter in his forthcoming work entitled 'A pictorial book of the dangerous reptiles of India for the defence personnel' Sanyal has given an in–depth account of the snake fauna of Orissa to be published in the Records of the ZSI.

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INDIA

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Animal Resources of India : 649–658 : 1991

AVES

Introduction

Due to diverse ecological conditions ranging from the montane to the low land terrain and from the rain forest to the arid zone, birds of varied forms occur in India.

Birds play both beneficial and harmful roles in the habitat. Many of them contribute a lot towards the process of pollination of flowers, dispersal of seeds, as scavengers and also as predators of rodent and insect-pests; while many others are considered harmful as they destroy seedlings, seeds, grains, flowers and fruits of useful plants. Some of them also act as vectors of disease-causing agents like viruses, fungi, bacteria, etc., which are transmitted to other inhabitants of the area.

Birds are generally recognised as the best known and taxonomically most mature group of organisms (Mayr 1942). Linnaeus (1758) listed 564 avian species. The most recent and complete summary is a mimeographed list issued from the American Museum of Natural History by Morony, Beck and Farrand (1975) which, with addendum, lists 9,026 species. Mayr (1946) lists 8,616 species and states 'The period of new discoveries is practically at its end' Ali and Ripley (1969-1974) lists 2,110 species and subspecies, belonging to 405 genera and 78 families, from the Indian region. Of these, 350 are winter migrants, 42 are endemic, 47 are listed as threatened and two have, in all probability become extinct.

Historical Rèsumé

i) Pre-1900

In the first half of the nineteenth century the study on the birds of the Indian subcontinent was initiated by Edward Blyth, Curator of the Royal Asiatic Society of Bengal, Calcutta. He paid special attention to the birds of Calcutta and its surroundings. His enthusiasm goaded him to correspond with naturalists of wide-ranging profession throughout India, such as Col. S.R. Tickell, Capt. Hutton, Mr. B. H. Hodgson, Maj. T. Berdmore, Sir Walter Elliot, and Mr. E. L. Layard, for donation of their valuable bird collection for study and preservation in the collections of the Asiatic Society. He described a number of new species of birds and published many papers in the *Journal of the Asiatic Society of Bengal.*

Blyth (1849) compiled the *Catalogue of the Birds of the Asiatic Society's Museum* on the basis of information on Indian birds and made the foundation for all subsequent taxonomic work on Indian Ornithology.

In subsequent tenure, other important collections from different parts of India were made by the following workers :

Name of collector	Year of collection	Place of collection
W.T. Blanford	1867	Central Provinces (= Madhya Pradesh) and neighbourhood of Chanda (= Chandrapur), Maharashtra.
Lt. Col. Godwin-Austen	1868	Cachar Hills, Assam
Lt. Col. Godwin-Austen	1874 & 1875	Duffla Hills, Arunachal Pradesh.

N. Majumdar, C. S. Roy & B. K. Dutta, Zoological Survey of India, Calcutta.

Name of collector	Year of collection	Place of collection
Messrs Channel and Bellely	—	Nagaland and Garo Hills (Meghalaya)
Dr. G.E. Dobson	—	Andaman Islands
Dr. Armstrong	—	Malabar coast
Mr. V. Ball	—	Chhota Nagpur (Bihar)
Dr. J. Scully	1874	Ladakh (Kashmir)
Dr. J. Scully	1979	Kashmir

In addition, the following persons presented specimens to the Asiatic Society :-

Rev. J. Barbe and Capt. Lewes from Nicobar Islands, Mr. E. G. L. Webb and Mrs. Oakes from Darjiling and J. McClelland from Assam.

T. C. Jerdon (1862, 1964) published *Birds of India* (in two volumes) dealing with all the avian species from India, known at that period.

A. O. Hume concentrated on the study of birds' nests and eggs and also their behaviour. He explored various geographical terrains like the islands of the Bay of Bengal, western India, eastern India, etc., A. O. Hume (1869) published *My Scrap Book; or Rough Notes on Indian Oology and Ornithology*. Hume and Oates (1889 and 1890) published *Nest and Eggs of Indian Birds*, in three volumes. Hume started and edited a journal of Ornithology, *Stray Feathers* from Calcutta and with his efforts 11 volumes appeared between 1872 and 1988.

The Fauna of British India : Birds (1st ed) vols.1 and 2 were written by E. W. Oates (1889 and 1890) and subsequently the 3rd and 4th volumes of the same title by W. T. Blanford (1895 and 1898). The fauna volumes contained much of the information available during that period on the birds of India, Burma and Ceylon (= Sri Lanka).

ii) 1901-1947

E. C. S. Baker (1922-1930) published a new series of *Fauna of British India* : *Birds* (2nd ed.) in eight volumes, dealing with 86 families, 598 genera and 1672 species and subspecies. In this publication for the first time, the trinomial system was used in a systematic manner. Besides, he initiated faunal mapping and zoogeographical studies in the country. Baker (1932-1935) also published four volumes on *The Nidification of Birds of the Indian Empire*.

During this period some note-worthy expeditions/surveys were conducted in different states of India which enriched our knowledge on the taxonomy, zoogeography and general biology of Indian birds.

Some of the important area-wise contributions on the taxonomy of Indian birds are as follows.

Andhra Pradesh : Whistler and Kinnear (1930-1937) and Ali (1933, 1934, and 1938).

Assam : Coltart (1902), Stevens (1914 and 1915), Betts (1947) and Biswas (1947).

Bihar : Inglis (1904, 1907 and 1909).

Himachal Pradesh : Whistler (1919-1928), Hingston (1921), Basil Edwardes (1926), Koelz (1937 and 1939) and Jones (1947).

Jammu & Kashmir : Buchanan (1903), Magrath (1911 and 1912). Ludlow (1920), Osmaston (1923-1931), Whistler (1922-1936), Meinertzhagen (1927), La Personne (1928), Bates (1929-1949).

Karnataka : Ali (1942 and 1943).

Kerala : Ali (1935-1937).

Madhya Pradesh : D'Abreu (1935), Ali (1939-1940), Hewetson (1940) and Roonwal (1942).

Maharashtra : Ali and Whistler (1939 and 1940) and Abdulali and Ali (1940).

Manipur : Higgins (1914-1934).

Nagaland : Ticehurst (1926).

Punjab : Currie (1916), Donald (1917-1921), Jones (1921 and 1927) and Whistler (1918, 1923-1925).

Rajasthan : Whistler (1938), McCann (1942 and 1943) and Biswas (1947).

Sikkim : Stevens (1923-1925), Ali (1926), Meinertzhagen (1927) and Ludlow (1937).

Tamil Nadu : Barnes (1938 and 1939) and Koelz (1947).

Uttar Pradesh : Whymper (1902, 1907 and 1911), Osmaston (1913 and 1921), Cotton (1914), Matthews (1918), Field (1922), Gill (1923-1925), Hudson (1930) and Briggs (1931 and 1934).

West Bengal : Osmaston (1904), Finn (1917), Law (1928) and Inglis (1935-1965).

iii) 1948-1990

After independence the following area-wise contributions on taxonomy, ecology and status of birds were made.

Andaman & Nicobar Islands : Abdulali (1964, 1965, 1967, 1971), Das (1971), Dasgupta (1976).

Andhra Pradesh : Majumdar (1984).

Arunachal Pradesh : Betts (1956), Ripley (1980), Saha (1985).

Goa : Grubh and Ali (1976).

Gujarat : Dharmakumarsinhji (1954), Abdulali (1962 and 1963), and Himmatsinhji (1960-1970).

Himachal Pradesh : Alexander (1951).

Kerala : Jackson (1954-1971).

Madhya Pradesh : Hewetson (1956), and Majumdar (1984).

Manipur : Roonwal and Nath (1949).

Meghalaya : Koelz (1951).

Mizoram : Koelz (1954)

Nagaland : Ripley (1952), Das (1971).

Orissa : Mukherjee (1953), Ripley (1978), Majumdar (1978, 1979, 1981, 1988 and 1990), Majumdar and Dasgupta (in press).

Uttar Pradesh : Lavkumar (1956).

West Bengal : Saha *et al.* (1971), Gauntlett (1985), Majumdar *et al* (in press).

Revisionary studies were undertaken on a number of species. Ticehurst (1938) revised the genus *Phylloscopus*. Alexander (1948) studied the status of Dusky Willow-Warbler, *Phylloscopus fuscatus*, Biswas (1951) of Indian Plaintive Cuckoo, *Cuculus passerinus*, and Biddulph (1954) of the Pheasant-tailed Jacana, *Hydrophasianus chirurgus*. Mees (1957) revised the Indo-Australian Zosteropidae. Majumdar (1978) resuscitated the Eastern Ghats' population of the Rufous-bellied Munia, *Lonchura kelaarti vernayi* as a distinct subspecies. Majumdar (1980) reviewed the taxonomic status of South Indian Black-headed Oriole, *Oriolus xanthornus maderaspatenus* and showed that Orissa population belonged to the southern Indian subspecies. Majumdar (1981) synonymized the Eastern Hill Myna, *Gracula religiosa peninsularis* with the Northern Hill Myna, *Gracula religiosa intermedia*. Ripley (1984) studied the status of *Brachypterix cryptica*.

Breeding Biology

Betham (1903) studied the birds nesting around Pune and elsewhere. Ludlow (1920) worked on the nidification of several birds in Ladakh. Ali (1931), Ali and Ambedkar (1956 and 1957), Ambedkar (1958) and Crook (1960) studied various aspects of breeding of the Baya (*Ploceus philippinus*). Betts (1952) studied the breeding biology of some species of birds in the hills of southern India, and Betts and Lowther (1952) of those in Kashmir. Bates (1960) studied the nesting habits of the Goldfinch, *Carduelis carduelis* and *C. caniceps*, Gee (1960) the breeding biology of the Grey or Spottedbilled Pelican, *Pelecanus philippensis*, and Ali (1960) on the nesting behaviour of Rosy Pelican, *Pelecanus onocrotalus* in the Runn of Kutch. George (1963) studied the breeding behaviour of the Indian Robin, *Saxicoloides fulicata*. Lamba (1963-1970) studied the nidification of the Common Indian House Crow, Black Drongo, Common Myna, Indian Roller, Indian Pond Heron, Spottedbilled or Grey Pelican, Indian Hoopoe, Indian Jungle Crow, Roseringed Parakeet, Indian Purple Sunbird, Koel, Purplerumped Sunbird and Indian Shikra. Sengupta and Brahmachari (1968) studied the food habits of cormorants in the breeding season. Singh and Kumar (1982) studied the breeding biology of *Psittacula krameri*.Field (1982) published a rough list with notes on the breeding birds in Gonda district.

Feeding habits

Mason and Maxwell-Lefroy (1912) studied the feeding habits of birds in India. Bates (1943) studied the feeding habits of the Little Bittern (*Ixobrychus minutus*). Beresford (1944) studied the winter food of birds in Kashmir. Kirkpatrick (1943) worked on feeding habits of the Indian Pond Heron (*Ardeola grayii*). Abdulali (1964) studied the feeding and other habits of the Greater Flamingo, *Phoenicopterus roseus* in India. Mukherjee (1969, 1972 and 1975) worked on the feeding habits of the waterbirds of the Sunderban, West Bengal. Ramzan (1971) worked on Avian fauna of Ludhiana district and food and feeding habits of some of the common birds of Punjab. The feeding habits of Roseringed Parakeet, *Psittacula krameri* has been studied by Sidhu (1973). Simwat and Sidhu (1974) and Toor and Ramjan (1974). Toor and Ramzan (1974) studied seasonal food and feeding habits of birds of Punjab. Mukherjee and Saha (1975) and Hamid Ali *et al*. (1978) studied the food and feeding habits of Common Baya. Gupta (1975) studied the stomach contents of the Great Indian Bustard, *Choriotis nigriceps*. Simwat (1977) studied the feeding habits of the House Sparrow, *Passer domesticus*, and its nestlings in Punjab. Mathew *et al*. (1980) studied the feeding habits of certain species of birds affecting agriculture. Narang and Lamba (1980, 1984) studied the feeding habits of five species of Indian Myna.

Ecology

Ali (1932) worked on the birds attracted by flowers in India. The same author (1945) also studied the ecology of Flamingoes in Kutch (=Kachchh). Ecological studies have been conducted on Baya (Mathew, 1972) and Weaver bird (Mathew, 1976). Sharma (1976) worked on pestilence of grain crops by birds. Toor and Sandhu (1980) worked on seasonal and diurnal fluctuations in the population of bird fauna in natural vegetation in the vicinity of Halwara Airfield, Punjab. Khajuria and Sharma (1983) studied the habits of some high altitude birds of Western Himalayas. Majumdar and Brahmachari (1988) and Rehmani (1988) reviewed the bird communities of the major grassland types of India.

Migration

Donald (1952) studied migration of birds across the Himalaya, and Ali (1962) on wagtails in

Kerala. In between 1963 and 1969, Biswas studied bird migration in southern west Bengal with a view to collect data regarding the pattern of migration, period of stay in the wintering area, time taken for journey, etc, George (1964) studied the same in Bihar. Mathew (1971) reviewed the recovery data obtained by the Bombay Natural History Society's Bird Migration Study Project. Khacher (1976 and 1978) studied migration across the Himalaya.

Hazards in aviation

The damage caused to aircrafts by birds like vulture, kite, hawk, pigeon, crow, etc., have increased alarmingly in recent years, and runs to crores of rupees. The four international airports at Bombay, Calcutta, Delhi and Madras account for nearly 60% of bird hit cases. Hazards in aviation caused by different species of birds in India and its associated managements have been studied by Singh (1982), Barnwal (1982), Rao (1982), Joseph (1982), Sharma (1982), Agarwal and Bhatnagar (1982) and others.

Control

Bindra and Toor (1972) worked on the harmful birds of agriculture. Chahal. *et al.* (1973) worked on bird-pest of crops. Sidhu and Simwat (1973) studied the control of the House Crow (*Corvus splendens*) through poison-baiting. Simwat (1975) worked on control of Roseringed Parakeet in Punjab. Bhatnagar (1976) studied significance of bird management and also worked on bird-pests of agriculture and their control. Dhindsa and Toor (1978) worked on the role of birds in controlling insect-and rodent-pests. Bhatnagar (1980) studied the avian depredation and its control in certain agricultural crops. Dhindsa (1980) worked on the ecology of the weaver birds of Punjab and Sandhu and Toor (1981) on harmful birds and their control. Bhatnagar and Singh (1981, 1982) studied damage caused by birds to barley. Bhatnagar and Bhattacharjee (1982) studied bird damage in soybean and its control. Sandhu and Dhindsa (1982) and Shivanarayan (1982) studied the damage by Roseringed Parakeet to crops and its management. Bhatnagar *et al.* (1982) made on appraisal of bird damage in Pearl Millet and its control. Sandhu and Toor (1984) worked on some pestiferous birds of agriculture and their management in Punjab. Majumdar and Brahmachari (1987) studied the major avian predators of insect-and rodent-pests of paddy in India and their management.

Distribution

Abdulali (1953) studied the distribution of the greenbilled Malkoha (*Rhopodytes viridirostris*) and Ara (1951) of the Bluebearded Bee-eater (*Nyctyornis athertoni*).

Majumdar (1989) studied the past and present wintering distribution of the White Stork in India and made suggestions for its conservation.

Morphology

Bhaduri and Biswas (1947, 1954) worked on caeca and the main cervical and thoracic arteries of some Indian birds, Bhaduri *et al.* (1957) studied the arterial system of the domestic pigeon (*Columba livia*). Bhattacharjee (1980, 1982, 1985, 1987 and 1989) worked on jaw and tongue muscles of some Indian birds. Majumdar and Roy (1989) studied the caeca of 70 species and subspecies of birds belonging to 31 families and 12 orders.

Conservation

Mukherjee (1981) and Rahmani (1988) worked on the conservation of Bengal Florican. Bharat Bhushan (1986) rediscovered the Jerdon's Courser in Cuddapah district of Andhra Pradesh and the area has now been declared as Srilankamalleswara Wildlife Sanctuary. Ali (1981, 1983) and Rahmani (1987) worked on the status and conservation of the Great Indian Bustard. Another endangered species of bird, Whitewinged Wood Duck is getting protection in Bordubai Tea State and at the Gauhati Zoo Park where it successfully breeds. The status of the Nicobar Megapode has been worked out by the Zoological Survey of India.

Estimation of Taxa

Changes in bird species names are now more a matter of taxonomic revaluations than new discoveries, although new species continue to be discovered (Lowery and Tallman, 1976). Total number of avian species recorded from the world (Walters, 1980) as well as from India (Ali and Ripley, 1969-74) and the number of species represented in the National Zoological Collections of the Zoological Survey of India are indicated below :

Order	Family	Approximate No. of species		
		World	India	ZSI Collection
Gaviiformes	Gaviidae	4	2	nil.
Podicipediformes	Podicipediae	20	4	3
Procellariiformes	Procellaridae	80	9	1
	Hydrobatidae	22	3	1
Pelicaniformes	Phaethontidae	4	3	Nil
	Pelicanidae	8	2	2
	Sulidae	9	3	Nil
	Phalacrocoracidae (family Anhingidae included)	41	5	3
	Fregatidae	5	3	Nil
Ciconiiformes	Ardeidae	70	20	11
	Ciconiidae	17	8	3
	Threskiornithidae	31	4	4
	Phoenicopteridae	6	2	1
Anseriformes	Anatidae	158	44	28
Falconiformes	Accipitridae (family Pandionidae included)	223	53	21
	Falconidae	61	13	8
Galliformes	Megapodidae	121	1	1
	Phasianidae	185	45	38
Gruiformes	Turnicidae	15	3	3
	Gruidae	14	6	2
	Rallidae	162	15	10
	Heliornithidae	3	1	Nil
	Otitidae	25	6	3
Charadriiformes	Jacanidae	8	2	2
	Hcmatopodidae	9	1	Nil
	Charadriidae	152	57	40

Order	Family	Approximate No. of species World	India	ZSI Collection
	Rostratulidae	2	1	1
	Recurvirostridae	8	3	1
	Dromadidae	1	1	Nil
	Burhinidae	9	2	1
	Glareolidae	16	5	2
	Stercorariidae	7	2	Nil
	Laridae	90	32	20
Columbiformes	Pteroclididae	16	8	5
	Columbidae	306	29	9
Psittaciformes	Psittacidae	360	15	8
	Cuculidae	130	23	22
Strigiformes	Strigidae	158	39	27
	Podargidae	26	2	Nil
Caprimulgiformes	Caprimulgidae	80	7	4
Apodiformes	Apodidae	87	18	8
	Trogonidae	38	3	3
Coraciiformes	Alcedinidae	90	12	12
	Meropidae	26	5	5
	Coraciidae	17	3	3
	Upupidae	11	1	1
	Bucerotidae	49	8	8
Piciformes	Capitonidae	85	10	9
	Indicatoridae	13	1	1
	Picidae	216	32	24
Passeriformes	Eurylaimidae	14	2	1
	Pittidae	25	5	4
	Alaudidae	77	21	7
	Hirundinidae	80	13	10
	Laniidae	78	9	6
	Oriolidae	28	4	4
	Dicruridae	20	8	8
	Artamidae	10	2	1
	Sturnidae	110	19	16
	Corvidae	111	21	21
	Bombycillidae	8	1	Nil
	Campephagidae	72	16	14

Order	Family	Approximate No. of species World	India	ZSI Collection
	Irenidae	14	6	5
	Pycnonotidae	126	21	19
	Muscicapidae	933	344	258
	Troglodytidae	65	1	1
	Cinclidae	5	2	2
	Prunellidae	12	8	Nil
	Paridae	45	19	15
	Sittidae	22	9	8
	Certhiidae	6	4	4
	Motacillidae	54	18	13
	Dicaeidae	58	9	6
	Nectarinidae	116	14	13
	Zosteropidae	86	2	1
	Ploceidae	270	25	15
	Fringillidae	123	42	30
	Emberizidae	283	16	11

Current studies

In the Zoological Survey of India the following projects on birds are in progress :

i) Avifauna of Tripura, ii) Avifauna of Meghalaya, iii) Avifauna of Gujarat, iv) Avifauna of Manipur, v) Avifauna of Uttar Pradesh, vi) Avifauna of Arunachal Pradesh, vii) Avifauna of Southern Bihar.

Majumdar and Roy have compiled a catalogue of the type-specimens of birds present in the Zoological Survey of India.

Other than the Zoological Survey of India, scientists at the Andhra Agricultural University, Hyderabad; Punjab Agricultural University, Ludhiana; Gujarat Agricultural University, Anand; Indian Agricultural Research Institute, New Delhi; and Kalyani University, Kalyani are engaged in the study of birds of agricultural importance. Studies on physiological aspects (*i.e.*, endocrinology and reproductive physiology) have been undertaken in the Zoology Departments of the universities of Calcutta, Banaras and Kalayani. Various workers of the Bombay Natural History Society, Bombay, are engaged in the status survey of Jerdon's Courser, Great Indian Bustard, Siberian Crane and Blacknecked Crane. S. Sengupta of the Zoological Survey of India is engaged in the study of mysterious behaviour of birds in Jatinga Village of Haflong, Assam.

Outside India

International Council for Bird Preservation based at Cambridge, England have launched many conservational projects on birds all over the world. Smithsonian Institution Washington, U.S.A., is engaged in taxonomic studies of the Indian avifauna. Ms Poonwad of Mahidal University, Bangkok has undertaken a project on breeding behaviour and conservation of hornbills of the world. International Crane Foundation in U.S.A. is engaged in captive breeding of cranes and also maintaining the natural populations all over the world. The World Pheasant Association in England is involved in captive breeding programme of rare species of pheasants including those of India.

Expertise

INDIA

In ZSI

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MAMMALS

Introduction

About 9% of the total number of mammalian species occur in India. Indian mammals are found in all types of habitat, from the snowy heights of the Himalaya to the plains, and show all types of adaptation, *viz*. - arboreal, fossorial, volant, aquatic, etc. Some species have become so numerous as to cause great strain on agriculture and forestry. Some others are causative agents of human and veterinary diseases. hence, control of their population has become a necessity. In recent times, however, many species are facing catastrophic decline in number, so much so that several species have become scarce or rare, and have been given asylum in reserve forests, wildlife sanctuaries, national parks, etc. Adequate and systematic knowledge of Indian mammalian fauna through taxonomic, distributional and biological studies are necessary so that ways for their conservation or control may be devised.

Though descriptions of Indian mammals are available in standard literature, yet there are many whose status is not clear and lack distributional, behavioural and ecological information. Many species and subspecies are based on small variations, with considerable amount of overlap. Also, the distributional pattern of many species are changing rapidly, commensurate with the man-made changes in their habitats. Hence, a State of the Art Report on Indian mammals was felt necessary.

Over seven thousand publications, including books and articles, the latter mostly scattered in a number of journals and periodicals, are available on Indian mammals. During the last few decades, about one thousand publications have been accumulated on rodents alone. The number of publications by the scientists of the Zoological Survey of India, on different species of mammals, have crossed 400, since 1950. The work done in recent years have been mostly on taxonomy, distribution, status, ecology, ethology, biology, population control, morphology, anatomy, cytotaxonomy, etc. Some work has also been undertaken on zonal fauna. A glimpse of the work done on Indian mammals during the pre - and post-independence periods may be had through the publications of Kinnear (1952), Agrawal (1974, 1976), Chakraborty (1984) and Roonwal (1988).

It is impossible to give coverage to the vast literature on Indian mammals within this short communication. However, an attempt has been made in this review to highlight some of the important literature that have been published so far in widely scattered journals and periodicals, for the facility of mammalogists, and to ensure a proper understanding of this large and economically important group.

Historical Resumé

Knowledge about mammals of India is very old. Descriptions of some mammals are available in the 'Vedas' and even in Pre-Vedic edicts (Rao 1957, Bhaduri, Tiwari and Biswas 1972). Authorities of the 'Ayurvedic' and 'Unani' systems of medicine were aware of the medicinal values of some products obtained from certain species of mammals. Mughal emperors Babur and Sahjahan took much interest in game animals. However, elaborate studies on Indian mammals have been conducted only during the last two centuries or so.

i) Pre-1900

Studies on Indian mammals can be considered to have started as early as the eighteenth century, when the tenth edition of *Systema Naturae* by Karl von Linné was published (1758), which provided binomial names to many Indian mammals. This was followed by scattered accounts of mammalian fauna of Rajasthan, Maharashtra, Assam, Uttar Pradesh, Karnataka, Bihar and

V. C. Agrawal, P. K. Das and R. K. Ghose, Zoological Survey of Inida, Calcutta.

Andaman Islands by Boyes, Elliot, Griffith, Hutton, Sykes, Tickell, and Tytler, respectively, during the second quarter of the nineteenth century. Important collections of mammals made by French collectors such as Charles Belanger, Jean Bantise Leschenault, Medard Diard, Alfred Duvaucel, Dussumier, Victor Jacquemont, during this period, were studied by authorities like Cuvier, Geoffroy and Blainville. Based on the material obtained by these workers, Belanger also published his *Voyage aux Indes Orientalis*, in 1838. Other workers, such as Pallas, Erxleben, Schreber also made important contributions. Lt. Col. Thomas Hardwicke (1756-1835) made most outstanding contribution during the period, including the descriptions of a number of new species. Gray published many illustrations got prepared by Hardwicke between 1830 and 1835, in his book, *Illustrations of Indian Zoology*. Brain Houghton Hodgson (1800-1894) and Edward Blyth (1810-1873) are two other most active workers on Indian mammalogy who made commendable work on the mammals of Indian sub-region. Hodgson was posted at Kathmandu, Nepal, and worked mostly on Nepalese birds and mammals. Subsequently, he also described a number of species from the present Darjiling district of West Bengal. Blyth was the curator of the Royal Asiatic Society of Bengal, Calcutta, and worked on his own collection made from Calcutta and surrounding areas as also on material received by the Society from different collectors. Their contributions provide considerable original data. However, a consolidated account of Indian mammals was provided for the first time by Thomas Caverhill Jerdon (1867) in his book entitled, *The mammals of India; a natural history of all the animals known to inhabit continental India*, dealing with the morphology, habits and distribution. Sternadale (1884) gave some interesting popular accounts of common Indian mammals. A few years later, W. T. Blanford wrote *The Fauna of India, Mammalia*, which was published in two parts (in 1888 and 1891). This work, though old, is still the best recognised handbook of Indian mammals. Anderson (1881) and Sclater (1891) published catalogues of the mammalian collection present in the Indian Museum, Calcutta, which included synonyms, distribution, variations of Indian species of mammals, along with keys for their identification. Flower and Lydekkar (1891) in their book, *Mammals of the World*, dealt with Indian mammals as well. Manuscript of a book on mammals of India (unpublished, with the Zoological Society of London) by S.R. Tickell, manuscript of *Popular account of mammals of northwestern India* (unpublished) by T. Hutton, and *Catalogue of species of mammals found in southern Maharatta country* by W.E. Elliot, etc., are some other important contributions of this period.

ii) 1901-1947

In the twentieth century, our knowledge about Indian mammals increased tremendously, chiefly through the collections made from 1911 to 1928 by the Bombay Natural History Society's Mammal Survey of India (subsequently termed as Mammal Survey of India, Burma and Ceylon). These collections were reported in different issues of the Society's journal, between 1912 and 1929, by various workers. R. C. Wroughton (1918-1920) summarised the account of the collection made up to that time and provided keys for the identification of various taxa of Indian mammals. This study was carried out at the British Museum by such highly experienced mammalogists as O. Thomas, R. I. Pocock, J. R. Ellerman, M. A. C. Hinton, R. C. Wroughton, T. C. S. Morrison-Scott, T. B. Fry, K. V. Ryley, H. M. Lindsay, and others. These studies ushered in the modern trinomial nomenclature of Indian mammals and resulted in the publication of a number of excellent papers. A revised edition of Sterndale's popular book, *Mammals of India* was brought out in 1929 by Frank Finn. One of the most important out-come of the 'Mammal Survey' was the publication of the second edition of the *Fauna of British India, Mammalia*, in two volumes, covering the orders Primates and Carnivora, by R.I. Pocock (1939, 1941). Simpson (1945) provided the much needed solid foundation to the classification of mammals, both living and extinct. In addition to the above, Indian mammalogy is greatly indebted to the contributions made by Cabera (1914), Ogrov (1928-1948), Osgood (1932), Phillips (1935), Kuroda (1928), Allen (1938, 1940), Bobrinskii *et al.* (1944), etc., which deal with mammals of the neighbouring countries, along with Indian species.

iii) 1948-1990

Notable features of the study of mammals in India in the post independence period, *i.e.*, after 1947, are extensive taxonomic studies, assisted by important ecological and ethological observations, and publication of excellent photographs of animals in their natural habitats. On the other hand, many revisionary monographic studies on different groups of mammals on world-wide basis have been made, which also include Indian mammals.

A portion of the significant material, including almost all of the wet-preserved specimens, obtained by the 'Mammal Survey', mentioned earlier, was purchased* by the Zoological Survey of India, from the Bombay Natural History Society, during the late 1950's (the other portion of the material,including the type-specimens, was retained by the British Museum). Thus, the British Museum (Natural History), London, the Bombay Natural History Society, Bombay, and the Zoological Survey of India, Calcutta, became the three centres where good taxonomic researches on Indian mammals were possible. During this period, the study at the British Museum resulted in a number of papers, in addition to that of a *Checklist of Palaearctic and Indian mammals 1758 to 1947* by J. R. Ellerman and T.C.S. Morrison-Scott (1951, 2nd. ed. 1966). This book provides revisions of the orders Insectivora, Carnivora, Artiodactyla and Lagomorpha, and also a list of Indian mammals with their synonyms, distribution, etc. The second edition of the *Fauna of India* (vol. 3), *Mammalia, Rodentia,* in two parts, by Ellerman (1961, with an appendix by Roonwal and Biswas) provides a detailed revision of Indian rodents. From the Bombay Natural History Society was published an excellent semipopular book entitled, *The Book of Indian Animals,* by S.H. Prater (1948, rev. eds. 1965, 1971, 1980) which gave interesting account of Indian mammals, with several colour, and black and white plates.

In the Zoological Survey of India, taxonomic work on Indian mammals began mostly in the post-independence period, and till now about 400 papers on taxonomy, distribution, ecology, breeding biology, behaviour, status, zonal fauna, etc., have been published. Important contributions have been made by M. L. Roonwal, V. C. Agrawal and S. S. Saha (Rodentia, Primates); B. Biswas (Rodentia, Insectivora, Artiodactyla); H. Khajuria (Primates, Chiroptera); P. K. Das and Y P. Sinha (Chiroptera); R. K. Ghose (Rodentia, Lagomorpha, Carnivora, Insectivora); B. Nath, S. Chakraborty and Ajoy Kumar Mandal (Rodentia). G. U. Kurup, R. P. Mukherjee, J. R. B. Alfred and J. P. Sati (Primates), and S. M. Ali (Artiodactyla, Proboscidea). The names of others deserving mention are : Y Chaturvedi, R. Chakraborty, S. Ghosh and T. K. Chakraborty (Rodentia); J. P. Lal, T. P. Bhattacharyya and M.K. Ghosh (Chiroptera). Highlights of the work of this team are provided in later chapters.

Scientists attached to other Indian institutions who have made notable contributions on Indian mammals are : Ishwar Prakash and V. Dhanda (Rodentia); S. M. Mohnote (Primates); H. R. Bhat and his colleagues, A. Gopalakrishna and his students, and M.K. Chandrashekaran and his students (Chiroptera). Some of the foreigners who have made highly praise-worthy contributions on Indian species of mammals are : G. H. H. Tate, J. E. Hill, A. Brosset, G. Topal (Chiroptera); W. C. Osman Hill, J. Fooden (Primates); G. H. H. Tate, J. C. Moore, H. Abe, G. S. Musser, J. Marshall (Rodentia), and C. P. Groves (Primates, Artiodactyla).

Some outstanding books published during this period are : *Mammals of the World* by E. P. Walker (1964; 2nd. and 3rd. ed. in 1968 and 1975 by J.L. Paradiso; 4th. ed. in 1983 by R.N. Nowak and J. L. Paradiso; 4th. ed. in 1983 by R.N. Nowak and J.L. Paradiso), *Mammals of Borneo : field keys and an annotated checklist* by Lord Medway (1965, 2nd. ed. 1977), *Wild*

* A small portion of the 'Mammals Survey' material was received by the Zoological Survey of India in its earlier days, in lieu of the contribution made by the then Federal Government of India towards the cost of the 'Mammal Survey'. The entire mammal collection of the Indian Museum, Calcutta, however, formed the core of the mammalogical collection of the Zoological Survey of India, at its inception in the year 1916. The Indian Museum in its turn, received the whole of the mammalian collection of the Royal Asiatic Society of Bengal, Calcutta (Das 1984).

mammals of Burma by U. T. Yin (1967), *Wild mammals of Malaya* by Lord Medway (1969), *The Mammals of Pakistan* by T. J. Roberts (1977) and *Mammals of Thailand* by B. Lekagul and J. A. McNeely (1977), *The wild mammals of Malaya (peninsular Malaysia) and Singapore* by Lord Medway (1978), *A field guide to the mammals of Borneo* by J. Payne, C. M. Francis and K. Phillips (1985), etc., which also included descriptions of Indian species, along with detailed information on taxonomy, distribution, ecology, habits, etc. Two more books of which the one entitled, *The mammals of Palaearctic Region : a taxonomic review* by G. B. Corbet (1978, 1980), is a taxonomic review in the light of recent researches, with key to the identification of Palaearctic species, and the other, *A world list of mammalian species* by G. B. Corbet and J. E. Hill (1980, 2nd. ed. 1986), also include Indian species. *Mammal species of the World : a taxonomic and geographic reference* edited by J. H. Honacki, K. E. Kinman and J. W. Koeppl (1982), is also a review of world species by mammalogists throughout the world, and provides recent nomenclature, distribution, etc., of Indian mammals as well.

Studies from Different Environs

India is a vast country. It has varied ecological zonations. The montane ecosystem of the Himalaya, the mangrove ecosystem of the Sundarban, the desert ecosystem of the Thar desert of Rajasthan, the insular ecosystem of Andaman & Nicobar Islands, and the Lakshadweep, the cave-ecosystem of various caves such as the Siju Cave in Meghalaya, and other caves, the tropical rain forest ecosystem of north-eastern India and Western Ghats, etc., are all to be found in the Indian Union. All these ecosystems have their characteristic mammalian fauna. Besides, the tropical deciduous forests of central India, the semi-arid tracts of peninsular India, the Gangetic plains of northern and eastern India – all have their own peculiar mammalian fauna.

It is heartening to note that mammalian fauna of all the ecological zones of India have been worked out to a greater or lesser extent. These are given in the following paragraphs.

Hardwicke collected in West Bengal, Uttar Pradesh and Kashmir, during 1778 to 1823, and prepared numerous drawings of mammals through local artists. A number of species were also described by him. So far as the Indian Union is concerned, Hodgson collected in the Darjiling district of West Bengal from where he also described some species of mammals. Jerdon made extensive explorations in southern and central India, Kashmir and various hill stations of the Himalaya. Result from his extensive collecting work appeared in his book mentioned earlier. Blyth took considerable interest in scientific collection of mammals in and around Calcutta, during mid-nineteenth century, and published many papers. Blanford collected a number of specimens from southern and central India.

Other important explorations made on mammals of various areas up to 1900 and studies made thereon are : Assam by W. Griffith and J. McClelland; Andaman & Nicobar Islands by Tytler, J. Barbe, and W. L. Abbot; south-eastern part of Bihar by S. R. Tickell; Khasi Hills (Meghalaya) by R. W. Frith; central India by Whitehead; Dharwad (Karnataka) by W. Elliot; Kashmir by C. H. Stockley, W. L. Abbot, F. Stoliczka, J. Scully, Baron von Hugel and A.E. Ward; Kumaon and Mussoorii (Uttar Pradesh) by Tytler, T. Hutton and Stwart; Pune (Maharashtra) in Western Ghats by A. L. Adams; Punjab by Bitrel and Dunn; Southern India, including Madras by W. H. Sykes and Heath; Travancore (Kerala) by H. Furguson, and Tripura by J. Barbe, etc.

The 'Mammal Survey' of India and adjoining areas was started by the Bombay National History Society from 1911 with a view to modernising taxonomic knowledge of Indian mammals on the basis of freshly killed material from selected localities at different seasons, with detailed field data on habitat, behaviour, etc. Areas explored during these surveys are Arunachal Pradesh (Mishmi Hills), Assam, Bihar (in part), Gujarat (Kutch, Palanpur, Kathiawar), Himachal Pradesh (Kangra-Chamba), Jammu & Kashmir (Islamabad district), Karnataka (Coorg, Dharwar), Kerala (Travancore), Madhya Pradesh (East Khandesh, Berar, Nimar, Gwalior), Maharashtra (Koyana

Valley, Poona), Nagaland (Naga Hills), Orissa (in part), Punjab (Gopalpur), Sikkim, Tamil Nadu (Palni Hills, Coimbatore, Nilgiri, Madura, Nelliampathy) and West Bengal (in part).

Altogether 25,000 specimens were collected by the 'Mammal Survey' the most prominent among the collectors who made untiring efforts to procure such a large collection are : C. Primrose, C. A. Crump, C. McCann, G. C. Shortridge, H. W. Wells, N. A. Baptista, Ryley O'Brain, and others. To make this large collection, special assistance was also received from different persons throughout the country. Some material, particularly large carnivores, were also received as donations. Study of these material by competent authorities resulted in a number of excellent publications which appeared in the various issues of the Journal of the Bombay Natural History Society, during 1912 to 1929.

With the inception of the Zoological Survey of India, a number of surveys were conducted by this department in diverse types of ecological zones, to procure fresh material of mammals for study. The areas covered by this department are Andaman & Nicobar Islands (some major islands only), Andhra Pradesh (Nagarjuna Konda, Adilabad district), Assam, Arunachal Pradesh (in part), Goa, Gujarat (in part), Jammu & Kashmir (in part), Karnataka (Western Ghats), Maharashtra (Western Ghats), Madhya Pradesh, Mizoram (in part), Meghalaya, Orissa, Rajasthan, Sikkim, Tripura, Uttar Pradesh (in part) and West Bengal. Some specimens have also been received by the department from different joint expeditions with foreign institutes.

The material obtained from the surveys of the above areas, along with the collection of the Royal Asiatic Society of Bengal, the Indian Museum, part of the 'Mammal Survey' specimens, received in this department, and other stray specimens obtained by way of donations from various sources, have been studied. Some important State Fauna of mammals completed by the scientists of the Zoological Survey of India are those of Manipur, with special reference to rodents (Roonwal 1950); undivided Assam (Kurup 1966); Goa (Agrawal 1973); Tripura (Agrawal and Bhattacharyya 1977); Orissa (Das *et. al.*, in press); Jammu & Kashmir (Chakraborty 1983); Rajasthan (Ghose, in press); Namdapha National Park, Arunachal Pradesh (Saha 1985), and Andaman & Nicobar Islands (Bhattacharyya 1975, Saha 1980, Das 1980, Chaturvedi 1980).

Collection and study of material have also been done on cave fauna : Siju Cave, Garo Hills, Meghalaya (Kemp 1924) and Borraguhalu Cave, Andhra Pradesh (Das in press). Considerable interests have also been taken in the study of high altitude mammals of northern and north-eastern India (Khajuria and Ghose 1970, Ghose and Saha 1981, Mahajan and Mukherjee 1974, Ghosh 1981). The Mangrove fauna of the Sundarban has been worked out by Mandal and Ghose (1989).

Estimation of Taxa

A total of 13 orders of mammals (Insectivora, Scandentia, Chiroptera, Primates, Pholidota, Carnivora, Proboscidea, Sirenia, Perissodactyala, Artiodactyla, Lagomorpha, Rodentia and Cetacea, as against 20 orders known so far throughout the world, is reported form the Indian Union. These 13 orders are spread over 45 families and 169 genera (Corbet and Hill 1986). Out of 4,232 living mammal species in the world, 372 species occur in India. The National Zoological Collections of India (housed in the Zoological Survey of India, Calcutta), possesses mammalian specimens representing 542 species from different localities of India and other countries.

An order-wise break-up of families, genera and species found in India (Corbet and Hill 1986), as against the total number found throughout the world (in parentheses), is given in the following table.

In the mammalian fauna of India, as stated above, genera such as *Anathana* (Scandentia), *Latidens* (Chiroptera), *Tetracerus, Boselaphus, Antilope* (Artiodactyla), *Caprolagus* (Lagomorpha), *Biswamoyopterus, Platacanthomys, Cremmomys* and *Diomys* (Rodentia) are indigenous to India. The number of endemic species is much more.

Orders	*Families*		*Genera*		*Species*	
Insectivora	3	(6)	9	(61)	17	(354)
Scandentia	1	(1)	2	(5)	3	(16)
Chiroptera	8	(18)	34	(189)	109	(988)
Primates	3	(12)	5	(58)	15	(181)
Pholidota	1	(1)	1	(2)	2	(7)
Carnivora	8	(12)	29.	(108)	57	(266)
Proboscidea	1	(1)	1	(2)	1	(2)
Sirenia	1	(2)	1	(3)	1	(5)
Perissodactyla	2	(3)	2	(6)	3	(18)
Artiodactyla	5	(10)	19	(76)	30	(192)
Lagomorpha	2	(2)	3	(12)	10	(59)
Rodentia	4	(29)	43	(393)	99	(1,738)
Cetacea	6	(9)	20	(39)	25	(78)
Total	45	(106)	169	(954)	372	(3,904)

Altogether 75 species of mammals have been included in Schedule I of the Indian Wild Life (Protection) Act of 1972, as amended up to date. Out of these, some 25 species appear to be highly endangered. These are Lion-tailed Macaque (*Macaca silenus*), Phayre's Leaf Monkey (*Presbytis phayrei*), Chinese Pangolin (*Manis pentadactyla*), Malayan Sun Bear (*Helarctos malayanus*), Red Panda (*Ailurus fulgens*), Ratel (*Mellivora capensis*), Malabar Civet (*Viverra megaspila*), Desert Cat (*Felis sylvestris*), Caracal (*F. caracal*), Marbled Cat (*F. marmorata*), Golden Cat (*F. temmincki*), Indian Lion (*Pathera leo persica*), Snow Leopard (*P. uncia*), Indian Wild Ass (*Equus hemionus khur*), Pygmy Hog (*Sus salvanius*), Musk Deer (*Moschus moschiferus*), Thamin (*Cervus eldi*), Four-horned antelope (*Tetracerus quadricornis*), Yalk (*Bos grunniens*), Indian Wild Buffalo (*Bubalus bubalis*), Himalayan Tahr (*Hemitragus jemlahicus*), Markhor (*Capra falconeri*), Bharal (*Pseudois nayaur*), Hispid Hare (*Caprolagus hispidus*) and Small Travancore Flying Squirrel (*Petinomys fuscocapillus*). The Hunting Leopard (*Acinonyx jubatus*) is supposed to be extinct from India.

Status Survey of Endangered Species

Status survey of some of the endangered species of Indian mammals have been conducted. The details are given below :

1) Bonnet Monkey, *Macaca radiata* (Kurup 1984).
2) Lion-tailed Macaque, *Macaca silenus* (Sugiyama 1968, Green *et. al.*, 1977, Kurup 1979, Ali 1982, Karanth 1985).
3) Crab-eating Macaque, *Macaca fascicularis* (Das and Ghosal 1977, Devaraj 1983).
4) Rhesus Macaque, *Macaca mulatta* (Tiwari *et. al.* 1982).
5) Hanuman Langur, *Presbytis entellus* (Tiwari *et. al.* 1982, Tikader 1984).
6) Golden Langur, *Presbytis geei* (Mukherjee and Saha 1974, Mukherjee 1978, 1981, Saha 1984).
7) John's Langur, *Presbytis johni* (Poirier 1970, Kurup 1973, 1975, 1979, Oates 1978).

8) Capped Langur, *Presbytis pileatus* (Mukherjee 1978, 1982).

9) Phayre's Leaf Monkey, *Presbytis phayrei* (Mukherjee 1982a, 1982b, 1990).

10) Hoolock Gibbon, *Hylobates hoolock* (Chivers 1979, Tilson 1982, Mukherjee 1982, Alfred and Sati 1990).

11) Malabar Civet, *Viverra megaspila* (Karanth 1986, Kurup 1987).

12) Tiger, *Panthera tigris* (Sankhala 1979, census reports).

13) Indian Lion, *Panthera leo persica* (Rashid 1986, census reports).

14) Indian Elephant, *Elephas maximus* (Ali 1978, Singh 1978, Sankhala 1979, Daniel 1980, Nair *et al.* 1980, Shahi 1980, Lahiri-Choudhury 1985, Shahi and Lahiri-Choudhury 1985, Gupta 1985, Sukumar 1986).

15) Great One-horned Rhinoceros, *Rhinoceros unicornis* (Spillet 1966, Lahan 1982).

13) Indian Wild Ass, *Equus hemionus khur* (Ali 1946, Wynter-Blyth 1956, Gee 1963, Schaller and Simon 1970, Kuper 1978).

17) Pygmy Hog, *Sus salvanius* (Mallinson 1977, Oliver 1978).

18) Musk Deer, *Moschus moschiferus* (Inayatullah 1981, Green 1986).

19) Swamp Deer, *Cervus duvauceli* (Martin 1977, Sankhala 1979).

20) Thamin, *Cervus eldi* (Gee 1960, Ranjitsinh 1974, Ali 1978, Mukherjee 1979, Desai 1986).

21) Hangul, *Cervus elaphus hanglu* (Schaller 1969, Schaller and Wani 1971, Kurt 1976, 1978, Holloway 1980, Mishra 1986).

22) Indian Wild Buffalo, *Bubalus bubalis* (Daniel and Grubh 1966, Goodwin and Holloway 1972, Waller 1973, Divekar 1976).

23) Blackbuck, *Antilope cervicapra* (Sheshadri 1969, Nair 1977).

24) Himalayan Tahr, *Hemitragus jemlahicus* (Schaller 1973).

25) Nilgiri Tahr, *Hemitragus hylocrius* (Schaller 1971, Waller 1973, Davidar 1976, 1978).

26) Markhor, *Capra falconeri* (IUCN Red Data Book).

27) Hispid Hare, *Caprolagus hispidus* (Gee 1964, Mallinson 1971, Oliver 1978, 1980, 1981, 1985, Ghose 1978, 1981, 1984).

28) Gangetic Dolphin, *Platanista gangetica* (Kasuya and Haque 1972, Jones 1982, Upreti and Majupuria 1982, Singh and Sharma 1986, Gupta 1986).

Classified Treatment of Groups

Mammalian fauna of India comprises 13 orders, 45 families, 169 genera and 372 species (Corbet and Hill 1986). A number of Indian species of mammals are each represented by more than one subspecies in India. Studies of the Alpha and/or Beta taxonomy of these orders and the distribution of various species have been done to a great extent. In certain orders such as Primates, specially in the family Cercopithecidae, some studies have also been made up to the Gamma level. Apart from these, studies on the anatomy, biology, ecology, status, etc., of many species of Insectivora, Chiroptera, Primates, Carnivora, Perissodactyla, Artiodactyhla, Proboscidea and Rodentia, have been made to some extent. It may be mentioned here that so far, very little work has been done on Indian aquatic mammals, and our knowledge is mostly limited to stray specimens stranded on beaches or to those collected by chance. Because of their extensive movement and absence of distributional barrier, books and monographs available on world-wide basis, however, provide us information on this group of Indian fauna, to some extent.

Order Insectivora

The order Insectivora in India consists of three families (Erinaceidae, Soricidae and Talpidae), nine genera and 17 species. Agrawal (1974) discussed the status of *Erinaceus blanfordi* and *E. jerdoni*. Biswas and Ghose (1970) reviewed the status of different species of the genus *Paraechinus* and described a new species and subspecies from Rajasthan and Gujarat. Anderson (1877) described a number of new species and commented on some other species of Insectivora presented in the Indian Museum. Dobson (1882-1890) have dealt with the taxonomy and anatomy of some Indian insectivores, particularly species of the family Soricidae. Thomas (1914, 1922) worked on the insectivores of Mishmi Hills. Hinton (1922) reviewed *Soriculus nigrescens*. Lindsay (1929) and Ellerman and Morrison-Scott (1951) reviewed Indian species of the genera *Suncus* and *Crocidura*, respectively. Verma (1962) discussed the structure of the skulls of Indian hedgehogs. Jenkins (1976) reviewed Eurasian Soricidae. Chakraborty (1978) described a new species of *Crodidura* from the Andaman Islands. Mandal and Das (1970) established that *Anourosorex assamensis* should be considered as a valid subspecies of *Anourosorex squamipes*. Mandal and Biswas (1970) recorded the behaviour of this burrowing shrew. Khajuria (1972, 1982) recorded the genus *Crocidura* from central India and Madras, respectively. Ghose (1976) reported the occurrence of *Suncus murinus griffithi* in Darjiling. Hoffman (1986) reviewed the genus *Soriculus*. It is to be mentioned that our knowledge on Indian Insectivora is very meagre and revision of the order is urgently needed.

Order Scandentia

The systematic position of tree shrews comprising the family Tupaiidae has long remained controversial. Recently, a separate order, *viz.*, Order Scandentia has been erected to accommodate these animals. Simpson (1945) and earlier workers placed them under Primates, but Ellerman and Morrison-Scott (1951) and many others considered them under Insectivora. In recent times, few workers again consider Simpson's placing of it under Primates to be correct. Perhaps Luckett (1980) is correct in considering it a natural group.

In India, this family is represented by only two genera (*Anathana*, indigenous to India, and *Tupaia*) and three species.

Lyon (1913) published a monograph on this family. An evolutionary relationship of the tree shrews has been given by Cambel (1974). Agrawal (1975) has revised the subspecies of *Tupaia glis*. Saha (1980) has studied the subspecies problem in the Nicobar Tree Shrew.

Order Chiroptera

The order Chiroptera is represented in India by eight families, 34 genera and 109 species, as against 18 families, 189 genera and 988 species found throughout the world (Corbet and Hill 1986). A number of species of bats have more than one subspecies in India.

Hodgson (1847*a*, *b*) and Blyth (1844, 1846, 1852, 1853, 1863) published a number of papers on different species of Indian bats. Jerdon (1867) provided the natural history of the Indian species of bats known at that time. Hutton (1872) published an account of bat fauna of northwestern Himalaya. However, the first comprehensive account on the Indian bats was given by Dobson (1876) in his *Monograph of the Asiatic Chiroptera*. Wroughton (1899) published a paper on some bats of Konkan area.

In the beginning of the twentieth century, Andersen (1905-1911, 1918) published a series of papers, mostly on the leaf-nosed bats of the families Megadermatidae, Rhinolophidae and Hipposideridae, and Pteropodidae. The same author's (Andersen 1912) most comprehensive work on the Megachiroptera (*Catalogue of the Chiroptera in the collection of the British Museum. 1. Megachiroptera*) contained detailed information on the taxonomy and distribution of

Megachiroptera of the world. Another epoch-making contribution of this period is the *Family and genera of bats* by G.S. Miller (1907), which gave detailed characters and keys to the identification of families and genera of all bats known at that time.

G.H.H. Tate (1941-1942) published a series of papers on the bats obtained by the Archbold Expeditions, which included a number of Indian species of bats as well.

Bacular structure of bats have some bearing on the classification of bats. Work on this aspect of Indian bats have been done by Vamberker (1958), Agrawal and Sinha (1973), Topal (1975), Khajuria (1982), Hill and Harrison (1987), and others. Karyological studies on Indian populations of some species of bats have been done by Pathak and Sharma (1969), Ray-Chauduri *et al.* (1971), and others.

During the post-independence period, bat fauna of certain regions of India have been worked out. Thus, Brosset (1961-1963) have studied the taxonomy, distribution and biology of the bats of central and western India. Bat fauna of Andaman & Nicobar Islands (Hill 1967), Rajasthan (Prakash 1956, 1960, 1963, and Sinha 1980), Jabalpore district, Madhya Pradesh (Khajuria 1979, 1980), Gujarat and Bihar (Sinha 1981, 1986, respectively), and Silent Valley, Kerala (Das 1986b) have been worked out.

Das (1986*b*) has shown that *R. 1. leschenaulti* is the only form of *Rousettus* which occurs in India. Hill (1958) treated *Pteropus satyrus* as a subspecies of *Pt. melanotus*. Agrawal (1973) has synonymised *Cynopterus sphinx gangeticus* with the nominate subspecies. *C. brochyotis ceylonensis* has been recorded from Goa (Agrawal 1973) and Kerala (Das 1986b). The genus *Megaerops* (as *M. ecaudatus*) was added to the Indian list of Chiroptera by Saha (1984). According to Koopman (1989), however, the Indian population represents the species recently described from Thailand, as *M. niphanae* (Yenbutra and Feltan 1983). *Sphaerias blanfordi* has been recorded from Uttar Pradesh (Bhat 1968*b*) and Arunachal Pradesh (Saha 1984). A new genus and species of fruit bat, *Latidens salimalii*, has been described from Madurai district, Tamil Nadu, (Thonglongyia 1972). *Eonycteris spelaea* has been reported from Kumaon, Andaman Islands, Assam, Karnataka and Meghalaya (Bhat 1968*a*, Bhattacharyya 1973, Ghose and Bhattacharyya 1976, Bhat *et. al.* 1980, and Sinha 1990). Lekagul and McNeely (1977) have considered *Macroglossus sobrinus* as a distinct species.

Aellen (1961) has shown that *Rhinopoma kinneari* should be regarded as a subspecies of *Rhinopoma microphyllum*. Hill (1977*a*) has reviewed the family Rhinopomatidae.

Felten (1962) has concluded that *Taphozous kachhensis* should be considered as a subspecies of the widely distributed species *Taphozous nudiventris*, though authors like Sinha (1970) and others still maintain *kachhensis* as a species.

Sinha (1977) has reviewed the Oriental members of the genus *Megaderma* and recognised only the nominate subspecies of both *Megaderma spasma* and *Megaderma lyra* as occurring in the Indian Union.

Sinha (1973) has reviewed the Indian species of the genus *Rhinolophus*. Hill and Yoshiyuki (1980) have shown that the specific name *pusillus* should be used (in place of *cornutus*) for the Indian populations of the Little Horseshoe Bat, and *Rhinolophus monticola* is a subspecies of *Rhinolophus rouxi*. Lal (1983) has reported *Rhinolophus rouxi sinicus* from Arunachal Pradesh. Hill (1987) has established that *Rhinolophus pearsoni* and *Rhinolophus yunanensis* are distinct species, and both occur in India.

Hill (1963) has reviewed the genus *Hipposideros*. In respect of Indian taxa of this genus, this author has concluded that the two species, *Hipposideros pomona* and *H. bicolor* as recognised by Ellerman and Morrison-Scott (1951), should be divided into three species, each having two subspecies. *viz. Hipposideros bicolor* (*H. b. pomona* and *H. b. gentilis*), *H. fulvus* (*H. f. fulvus* and *H. f. pallidus*) and *H. ater* (*H. a. ater* and *H. a. nicobarulae*). He (Hill 1963) has also concluded that *H. nicobarenis* is a subspecies of *H. diadema*. Sinha (1973) has treated *H. speoris* as a monotypic species. Khajuria (1970) has described a new subspecies of bat, *Hipposideros cineraceus durgadasi*, from Madhya Prtadesh, which has subsequently been regarded as a distinct species (Topal 1976, Khajuria 1982). Hill (1983) has considered *Hipposideros cineraceus* as a monotypic species. Hill *et al.* (1986) have shown that not *Hippsideros bicolor*, but *Hipposideros pomona* occurs in India.

Genera *Vespertilio* (*vide* Corbet and Hill 1980, Honacki *et al.* 1982, Corbet and Hill 1986, and others) and *Nycticejus* (Sinha and Chakraborty 1971, Hill 1974*b*) have been removed from the Indian list, while genera *Ia* (Topal 1970*b*) and *Scotoecus* (Hill 1974*b*) have been added. The genus *Scotozous* which was treated as a subgenus of the genus *Pipistrellus* (Ellerman and Morrison-Scott 1951), has finally been accepted as a distinct genus (*vide* Corbet and Hill 1986, Hill and Harrison 1987).

Major revisionary studies undertaken under the family Vespertilionidae include those on the genera *Murina* (Hill 1964), *Kerivoula* (Hill 1965), *Scotoecus* (Hill 1974*b*) and *Hesperoptenus* (Hill 1976), and the subfamily Vespertilioninae (Hill and Harrison 1987).

Myotis mystacinus and its different Indian subspecies, as understood by Ellerman and Morrison-Scott (1951), have undergone considerable taxonomic changes. *Myotis muricola* (with *caliginosus* as subspecies) and *Myotis montivagus* (with *peytoni* as subspecies) have been separated from *Myotis mystacinus* (with *nipalensis* as subspecies) as distinct species (Hill 1962, 1983, Corbet 1980). Topal (1970) has reviewed *Myotis blythi*. The same author (Topal 1971*a*) has shown that *Pipistrellus annectans* is to be regarded as *Myotis annectans*, with *Myotis primula* as its synonym. Hill (1977*b*) has shown that both *Myotis dryas* and *Myotis peshwa* are to be regarded as distinct species. Sinha (1980) has synonymised *Pipistrellus mimus glaucillus* with the nominate subspecies. Lal (1984) has reviewed the Indian subspecies of *Pipistrellus ceylonicus*. Pathak and Sharma (1969) have reported *Pipistrellus affinis* from India. Agrawal (1973) reviewed the subspecies problem in *Pipistrellus dormeri*. Roberts (1977) reported *Eptesicus bottae* from Kashmir. Neuhauser and DeBlase (1974) have shown that *Nyctalus leisleri* and *Nyctalus montanus* should be considered as distinct species. Hill and Thonglongya (1972) have proved that the smaller of the Indian scotophiles should be called as *Scotophilus kuhli kuhli*, not *S. temmincki wroughtoni*. According to Corbet (1980), *Plecotus homochrous* is a subspecies of *P. auritus*, with *P. puck* as its synonym, while *P. wardi* is a subspecies of *P. austriacus*.

Hill (1964*b*) has shown that *Murina tubinaris* should be regarded as a species distinct from *M. huttoni*. Das (1986*a*) has critically discussed the different taxa described under the genus *Harpiocephalus* and has synonymised *H. harpia madrassius* with *H. h. lasyurus*.

Significant extension of distributional range of certain taxa of this family has been done by Bhattacharyya (1977), Ghosh (1989) and Das (1990).

Hill (1961) has reviewed the Indo-Australian bats of the genus *Tadarida*. Chaturvedi (1964), after examining the type-material, has concluded that *Tadarida tragata* and *T aegyptiaca* are same. Hill (1964*a*) has added *Tadarida teniotis* to the Indian list. Sinha (1970) has synonymised *T aegyptiaca gossei* with *T ae. thomasi*.

Many taxa of Indian bats need revision, of which the Indian species and subspecies of the genus *Myotis* demand immediate attention.

Order Primates

Order Primates is represented in India by three families, five genera and 15 species, out of a total of 12 families, 58 genera and 181 species found throughout the world.

The first account on the taxonomy and distribution of Indian non-human Primates was given by Blanford (1888). A detailed review of the world-species, including those of India, was, however, made available by Elliot (1913). Later, Pocock (1927-1934) published a series of papers on Primates, which were precursor to his *Fauna of British India* on this order, in 1939. Subsequently, catalogues of the collection of Primates present in the Zoological Survey of India as well as in the British Museum (Natural History) were published by Khajuria (1953-1958) and Napier (1976-1985), respectively. Osman Hill (1953-1974) discussed the comparative anatomy and taxonomy of primates of the world. But, due to his untimely death, he could only cover the Indian subfamily Cynopithecinae of the family Cercopithecidae. The subfamily Cercopithecinae dealing with the genus *Presbytis* could not be completed. This lacuna was, however, partially filled by Napier's catalogue. Roonwal and Mohnot (1977) provided an exhaustive review of primates of south Asia, including their taxonomy, ecology and behaviour. A recent publication entitled, *The Lesser Apes*, edited by Presuehoft *et al.* (1984), deals with the taxonomy, behaviour and evolution of gibbons of south and southeast Asia.

Out of the three families, the family Loriside is known in India, by two genera and an equal number of species. The taxonomy, distribution, and external and dental characters of the genus *Loris* have been given by Blanford (1888), Osman Hill (1933) and Pocock (1939). Some stray work are also available on the general habits (Rao 1927, Osman Hill 1937, Ilse 1955, Subramaniam 1957, Seth 1963), feeding (Phillips 1931), breeding (Kinnear 1919, Osman Hill 1935, Nicholls 1939, Ramaswamy *et al.* 1962, Manley 1967), longevity (Rahman and Parthasarthy 1970) and population (Devaraj 1981) of this animal.

The systematics of the genus *Nycticebus* has been dealt with by Blanford (1888) and Pocock (1939), and recently reviewed by Groves (1971). Stray reports are also available on its occurrence in northeastern India (Agrawal and Bhattacharyya 1977, Mukherjee 1982, Pillai *et al.* 1973). Roonwal and Mohnot (1977) have summarised the available information on the two Indian species of Lorisidae.

Family Cercopithecidae is represented by two genera (*Macaca* and *Presbytis*) and 12 species. The taxonomy of the genus *Macaca* has been reviewed by Osman Hill (1974) and Fooden (1975-1983). The skull-structure has been studied by Kurup (1963, 1966). Fooden *et al.* (1981) have redefined the southern limit of distribution of *M. mulatta*. Substantial work has been done on the ecology and social behaviour of these monkeys in India, which has been summarised by Roonwal and Mohnot (1977). The genus *Presbytis* has been reviewed by Napier (1985). Khajuria (1954) described a new species of langur, *Presbytis geei*. Agrawal (1974), and Khajuria and Agrawal (1979) have discussed the taxonomic status of *P. barbei*. Skull-structure of langurs was studied by Kurup (1964, 1966). Roonwal (1979-1989) studied the subspecific variation, distribution and tail-carriage of *P. entellus*.

Family Hylobatidae is represented in India by a single species, *Hylobates hoolock*. The genus *Hylobates* has been reviewed by Groves (1967-1972). Other aspects like ecology and behaviour (Chivers 1977, Tilson 1977, Gittens and tilson 1984, Mukherjee 1986, Alfred and Sati 1986, 1990), colour-phase (Fooden 1969, 1971), breeding (Carpenter 1941, Mathews 1946, Osman Hill *et al.* 1959, Alfred and Sati 1988), status (Chivers 1977, Mukherjee 1982, Tilson 1984, Alfred and Sati 1990), etc., have also been studied.

Order Pholidota

One genus and two species of the order Pholidota occur in India. Pocock (1924) has dealt with the diagnostic features of Indian pangolins. Simpson (1945) has referred all the pangolins to a single genus, *Manis*. good accounts of Indian pangolins are available in Jerdon (1867), Blanford (1891), Finn (1929), Prater (1965), Walker (1968), etc. Ray-Chaudhuri *et al.* (1969) and Chakraborty *et al.* (1982) have studied karyotypes of Indian species of *Manis*.

Order Carnivora

Order Carnivora, in India, comprises eight families, 29 genera and 57 species. The taxonomy and distribution of Indian carnivores have been given by Blanford (1891) and Pocock (1939, 1941).

Oken (1816) dealt with the generic names, and Mivart (1881) and Elliot (1883) provided original information on Indian species of cats. Pocock (1971) reviewed the classification of the family Felidae. Comparative study of the appendicular skeleton of the genus *Panthera* (Mandal 1970) and of *Lynx* and *Caracal* (Mandal and Talukdar 1975) have been made. Status survey of Lesser Cats in northeastern India was undertaken by Biswas and Ghose.

Mivart's (1890) monograph of Canidae also deals with Indian species. Apart from taxonomic work, Burton (1941), Davidar (1965, 1974, 1975), Cohen (1977), Fox (1971, 1975, 1978, 1984) and Johnsingh (1979, 1982) have studied the ecology and behaviour of the Wild Dog, *Cuon alpinus*.

Allen (1938) referred the genus *Ailurus* to the family Procyonidae.

The Indian subspecies of *Viverricula indica* was reviewed by Chakraborty (1983) and of *Viverra zibetha* by Agrawal *et al.* (in press). Ali *et al.* (1988) have described a new species of palm civet, *Paradoxurus jorandensis*, from Orissa, which has been found to be an albinistic from of *P hermaphroditus* (Das *et al.*, in press).

Family Mustelidae was reviewed by Pocock (1922). Ghose (1989) dealt with the status of the Indian viverrids and mustelids.

Subfamily Herpestinae was reviewed by Pocock (1919). Honacki *et al.* (1982) treated it as a family. Ghose (1965) described a new species of mongoose, *Herpestes palustris*, from the Salt Lakes, near Calcutta. He (Ghose 1978) also merged *H. edwardsi ferrugineous* with *H. e. nyula*.

Order Proboscidea

Order Proboscidea is known in India by one species, namely, *Elephas maximus*. General accounts on its taxonomy, distribution and ecology are available in Jerdon (1867), Blanford (1888), Finn (1929), Pocock (1943), Prater (1965) and Walker (1968). Ali (1977, 1980, 1981) has studied the appearance of tusk, *Musth* and breeding habits of this species. Nair and Gadgil (1978, 1980), Singh (1978) and Gupta (1985) and Lahiri Choudhury (1985) have reviewed its status and distribution in southern, northern and northeastern India.

Order Sirenia

One species of the Order Sirenia, namely *Dugong dugon*, occurs in Indian waters. Its taxonomy has been discussed by Blanford (1891). Further accounts are available in Norman and Fraser (1938), Pocock (1940), Prater (1965), Norris (1966), Coffey (1977) and Tikader (1984). A sort of dugong fishery was practiced in earlier days in the gulf of Mannar and Saurashtra coast. But, since this species has now become exceedingly rare, the Gulf of Mannar has been declared as a Biosphere Reserve for the protection of dugong.

Order Perissodactyla

Order Perissodactyla is represented in India by two families, two genera and three species. A good account of these species is available in Blanford (1891), Prater (1965) and Walker (1968).

Family Equidae is known by two species, namely, *Equus kiang* and *Equus hemionus*. Taxonomy of this group has been reviewed by Groves and Mazak (1967).

At present, the family Rhinocerotidae is represented in India by the lone species, *Rhinoceros unicornis*. Genus *Rhinoceros* has been reviewed by Pocock (1945). Further studies on its taxonomy (Groves 1967), skull-structure (Chakraborty 1973), etc. have been made. A catalogue of the collection of Asian rhinoceroses present in the Zoological Survey of India, is also available (Groves and Chakraborty 1983).

Order Artiodactyla

The order Artiodactyla is represented in Indian by five families, 19 genera and 32 species. Brief accounts on the taxonomy, distribution and ecology are available in Blanford (1891), Lydekker (1913-1965), Prater (1965) and Walker (1968).

Lydekker (1898) gave descriptions of deer species of the world, including those of India. Pocock (1923) discussed the external characters of Indian cervids. The taxonomy of genera *Muntiacus* and *Moschus* was reviewed by Groves (1975, 1980).

Sclater and Thomas (1894-1900) dealt with the Indian antelopes, along with other species of the world. Pocock (1918, 1919) discussed the external characters of ruminants. The taxonomy of genera *Procapra, Gazella* and *Antilope* was reviewed by Groves (1967, 1969, 1980). Schaller (1978) gave accounts on the natural history of wild sheep and goats of the Himalaya. Biswas (1976) dealt with the economically important wild cattle, sheep and goats of India.

Order Lagomorpha

This order, in India, consists of two families, three genera and 10 species. The first comprehensive account on Indian lagomorphs was given by Blanford (1888). Forsyth Major (1899) and Cureev (1964) revised the recent and fossil lagomorpha of the world, including the Indian forms. Kloss (1918) made a taxonomic review of the genus *Lepus,* based on the specimens present in the collection of the Indian Museum, Calcutta. Allen (1938) also dealt with some Indian lagomorphs. Ellerman and Morrison-Scott (1951) provided a key for the identification of different species. Corbet (1978) treated some of the Indian species of lagomorphs along with the Palaearctic forms. Kao and Feng (1964) gave a systematic review on the subspecies of *Lepus oistolus,* with a key to their identification. Angermann (1966, 1967, 1983) dealt with the taxonomic status of *Caprolagus hispidus; Lepus oistolus* and *Lepus* species of India. Taxonomy, ecology and behaviour of *Caprolagus hispidus* have been studied by Hodgson (1847) and Ghose (1978, 1981). Ghose (1967, 1972) made taxonomic and ecological study on *Lepus nigricollis mahadeva.* Chakraborty (1977) recorded *Lepus arabicus* for the first time from (Jammu & Kashmir) India.

Not much work has been done on the mouse-hares of the family Ochotonidae in India. However, Thomas (1920, 1922) described three new species and three new subspecies. Ghose (in press) has recently studied the pikas of Jammu & Kashmir and has described a new species. Feng and Kao (1974) made a systematic review of the subspecies *Ochotona thibetena.* Mitchell (MS : unpublished) gave a taxonomic review of Asian species of the genus *Ochotona.* The daily activity and social pattern of *Ochotona macrotis* and *O. roylei* have been studied by Kawamichi (1971).

The status and conservation of the Hispid hare have been discussed by several workers (Mallinson 1971, Ranjitsinh 1972, Tessier-Yandell 1972, Oliver 1979, 1980, 1981, 1985 and Ghose and Ghosal 1984).

Order Rodentia

Order Rodentia comprises 29 families, 393 genera and 1,738 species of which four families, 43 genera and about 99 species occur in India (Corbet and Hill 1986).

The first comprehensive account on the taxonomy, distribution and ecology of the Indian species of mammals, including rodents was given by Blanford (1891), which included the earlier work of Jerdon (1867) and Sterndale (1884) on the natural history of these species. Subsequently, family Sciuridae was reviewed by Robinson and Kloss (1918). Ellerman (1940, 1941, 1949) enlisted the rodent species of the world, including those of India. Later, he (Ellerman 1961) gave a detailed taxonomic account and distribution of the Indian species. Of late, new classifications of the order have been proposed (Missone 1969, Honacki *et al.* 1982, Anderson and Jones 1984, and Corbet and Hill 1986).

Out of the four families of rodents found in India, family Sciuridae is represented by 12 genera and 29 species. It includes squirrels (both nocturnal and diurnal) and marmots. The latter are Palaearctic in distribution, occurring in India along the Himalaya. The taxonomy of diurnal species of squirrels have been reviewed by Moore and Tate (1965), Agrawal and Bhattacharyya (1977) and Agrawal and Chakraborty (1979). A catalogue of the collection of Sciuridae present in the Zoological Survey of India, Calcutta, is also available (Agrawal and Chakraborty 1979). The genus *Petaurista* has been reviewed by Saha (1977, 1978) and Ghose and Saha (1981), and two new taxa, namely, *P. nobilis singhei* and *P. magnificus hodgsoni* have been added. A new genus and species of flying squirrel, *Biswamoyopterus biswasi* was described from Namdapha National Park, Arunachal Pradesh (Saha 1981). The Small Flying Squirrel, *Petinomys fuscocapillus* has been rediscovered in Kerala, after a gap of 140 years. The distributional range of *Eupetaurus cinereus* has been extended from Jammu & Kashmir to Sikkim (Agrawal and Chakraborty 1970). The taxonomy of genus *Callosciurus* has been reviewed (Chakraborty 1985) and the species, *Hylopetes baberi* resuscitated (Chakraborty 1982). The subspecies of *Ratufa indica* have been studied (Abdulali and Daniel 1952). *Marmota himalayana* is now considered as a full species (Corbet and Hill 1986).

Of the Indian species of squirrels, only two species, namely, *Funambulus pennanti* and *F. palmarum* are considered to be of economic importance. Hence, their biology and habits have been studied by a number of workers (Bannerji 1955, 1957, Louch *et al.* 1965, Agrawal 1965, Prasad *et al.* 1966, Purohit *et al.* 1966, Prakash and Kametkar 1969, Seth and Prasad 1969, Khan and Khan 1980, Bhat 1981, and others). Chromosomes of these species have also been worked out (Chopra and Pai 1965, Sharma *et al.* 1970, Satya Prakash and Aswathanarayana 1973).

Within the Indian limits, family Hystricidae is represented by two genera and three species, namely, *Hystrix indica*, *Hystrix hodgsoni* and *Atherurus macrourus*. The genus *Hystrix* has recently been reviewed by Van Weers (1979, 1983). The biology of *Hystrix indica* has been studied by a number of workers (Blanford 1891, Thomas 1922, Roonwal 1949, Walker 1968, Taber *et al.* 1967, Prakash 1971, Prakash *et al.* 1971, Prakash and Ghosh 1975, Roberts 1977, and others).

The Palaearctic family Zapodidae is represented in India by a single genus and species, *Sicista concolor*, which occurs in Jammu & Kashmir. Its biology and ecology have been reported by Roberts (1977).

Family Muridae is grouped into 15 subfamilies. Out of these, six subfamilies, Cricetinae, Gerbillinae, Microtinae, Murinae, Platacanthomyinae and Rhizomyinae occur in India (Corbet and Hill 1986). This family is represented in India by 28 genera and about 66 species.

Subfamily Cricetinae is Holarctic in distribution and has spilled over to India in Jammu & Kashmir. It is known by one genus and two species, *Cricetulus migratorius* and *C. alticola*. The biology and ecology of these species have been dealt with by Roberts (1977).

Subfamily Gerbillinae is mainly Ethiopian in distribution, but extended east up to arid and subarid regions of India. Three genera and four species occur in India. The genus *Gerbillus* is represented by two species - *G. nanus* and *G. gleadowi* instead of three reported by Ellerman (1961). The taxonomy of *Tatera indica* has been reviewed by Agrawal and Chakraborty (1981). Skull-structure of all the three genera has been studied by Agrawal (1967). Due to economic importance of the group, its biology, ecology and control have been extensively worked out by Prasad (1954-1961), and Prakash (1956-1990) and his school.

In India, subfamily Microtinae is known by four genera and seven species. All are denizens of high elevations in the Himalaya. The taxonomy of the group has been dealt with by Hinton (1926) and Ellerman (1961). Some work on the biology, ecology, intraspecific variations, nomenclature, etc., are also available (Roonwal 1953, Khajuria 1959, Khajuria and Ghose 1969, Ghose and Guha Roy 1972, Roberts 1977).

The subfamily Murinae, within the Indian limits, is represented by 20 genera and about 50 species.

Only one species of the genus *Apodemus*, *A. sylvaticus*, occurs in India, instead of two reported by Ellerman (1961). Intraspecific variations have been studied in *Golunda ellioti*, *Vandeleuria oleracea* and *Bandicota bengalensis*, and their subspecies redefined (Agrawal and Chakraborty 1976, 1980, 1982). Based on the study of molar characters and karyotypes, the genus *Rattus* (*sensu* Ellerman 1961) has been splitted into six genera, namely, *Rattus*, *Millardia*, *Cremnomys*, *Leopoldamys*, *Berylmys* and *Niviventer* to accommodate the Indian species of rats. Under the new arrangement, the species *blanfordi* has been accommodated under the genus *Cremnomys*, the *bowersi* group of rats from northeastern India under *Berylmys* and the *niviventer* group of rats under a newly erected genus *Niviventer* (Missone 1969, Agrawal 1969, Marshall 1976, Musser 1981, Musser and Newcomb 1983). Within the genus *Rattus*, three new taxa, *Rattus ranjiniae* (Agrawal and Ghosal 1969), *Rattus holchu* (Chaturvedi 1966) and *Rattus rattus brevicaudus* (Chakraborty 1975), have been added. Chakraborty (1983) resuscitated *Rattus vicerex* as a full species. A new taxa, *Niviventer niviventer monticola* (Ghose 1964), under the genus *Niviventer*, and two more under the genus *Millardia*—*Millardia kondana* (Misra and Dhanda 1975) and *Millardia meltada singuri* (Mandal and Ghosh 1981), have been added. The Indian subspecies *Rattus cremoriventer indosinicus* from northeastern India has been synonymised with *Niviventer langbianis* from Thailand (Musser 1973).

Based on the morphology, karyology and ectoparasites, Marshall (1977) has reviewed the genus *Mus*. Under this genus, *Mus platythrix* (*sensu* Ellerman 1961) has been splitted into *Mus platythrix* and *Mus saxicola*, and *Mus booduga* into *Mus booduga* and *Mus dunni*. Another subspecies *Mus cervicolor phillipsi* has been raised to specific level.

A number of murine species are not only tremendously destructive to crops and other material possessions, but are also reservoirs of many dreadful diseases of man and livestock. Some of the important species are *Rattus rattus*, *Mus musculus*, *Mus booduga*, *Mus cervicolor*, *Mus platythrix*, *Millardia meltada*, *Bandicota indica*, *Bandicota bengalensis* and *Nesokia indica*. Tremendous work has been done on various aspects of their biology, ecology and control. A glimpse of the same may be had from bibliographies on rodents (Parrack 1966, Spillet 1968, Chakraborty 1984, Roonwal 1988).

The subfamily Platacanthomyinae is known by one genus and species, *Platacanthomys lasiurus*, which is found in Kerala. It is an aberrant species. Except for the skull-structure (Agrawal 1967), practically no work has been done on this species.

Subfamily Rhizomyinae is represented by two genera and an equal number of species, found in northeastern India. Nothing much is known about their ecology and biology.

Order Cetacea

Order Cetacea is represented in India by six families, 20 genera and 25 species. Little work has been done on the taxonomy and ecology of marine mammals found in Indian waters. Most of the work is limited to reports of their stranding on Indian coasts. Taxonomic accounts of some of the species of this order is available in Blanford (1891), Norman and Fraser (1938), Prater (1965), Norris (1966), and Walker (1968). James and Sundararajan (1979), De Silva (1988) and Alling (1989) have recorded the stranding of different species of whales and dolphins along the Indian coasts, and gave their diagnostic characters.

Family Platanistidae is known in India by a single genus and species, *Platanista gangetica*. It is the only fresh water form found in the country in the Ganga-Brahmaputra river systems. Anderson (1879) dealt with the status, distribution, biology and anatomy of this species. Its taxonomy has been reviewed by Pilleri and Gihr (1971) and Kasuya (1972). Work on its ecology and behaviour are by Pilleri (1970), Geisler and Pilleri (1971), Pilleri *et al.* (1972), Nath (1974), Gupta (1986) and Singh and Sharma (1986), and on its distribution and seasonal movement by Kasuya and Haque (1972). Useful work on organ-weight relationship (Pilleri and Gihr 1970, Kamia and Yamasuki 1974), cerebral anatomy (Pilleri 1970), tongue (Arvy and Pilleri 1970), osteology (Pilleri and Gihr 1971, 1976), embryology (Pilleri and Gihr 1976, Arvy and Pilleri 1976, Pilleri 1977), sound production (Anderson and Pilleri 1970), and growth and determination of age (Kasuya

1972) have also been done. The population status has been studied by Kasuya and Haque (1972), Jones (1982), Upreti and Majupuria (1982), Gupta (1986), and Singh and Sharma (1986).

Family Delphinidae consists of 11 genera and 14 species. Practically no work has been done on the taxonomy of this family in India. Anderson (1879) worked on the anatomy of *Orcaella brevirostris*. The species *Stenella dubia* and *S. malyanus* have been synonymized with *Stenella attenuata* (*vide* Honacki *et al.* 1892). Van Bree and Gallagher (1978) reported the occurrence of *Delphinus tropicalis* in Indian waters and treated it as a species distinct from *D. delphis*.

Family Phocoenidae is known from India by the lone genus and species, *Neophocaena phocaenoides*. Some work on its taxonomy (Pilleri and Peixun 1980), body colour (Pilleri *et al.* 1976), habits (Pilleri and Pilleri 1979), reproduction (Harrison and McBrearty 1973-1974), foetus and juvenile (Balan 1976, Hafeezullah 1984), population status and breeding (Kasuya and Kureha 1979), sonar system (Pilleri *et al.* 1980) are also available.

Family Physeteridae is represented by two genera and three species. *Physeter catodon* has been synonymized with *Physeter macrocephalus*. James and Sundararajan (1979) reported the stranding of this species at Krusadai Island in the Gulf of Mannar, and furnished its diagnostic features.

Family Ziphiidae consists of two genera and three species. Occurrence of *Mesoplodon densirostris* has been reported from the Indian Ocean (McCann 1964).

Family Balaenopteridae is known from India by two genera and six species. Gibson-Hill (1950) analysed the published records of rorquals (*Balaenoptera* sp.) stranded on the coasts of India and Sri Lanka, and gave their diagnostic characters. The anatomy of *B. edeni* (Anderson 1879) and *B. musculus* (Moses 1940) have also been worked out.

Platanista gangetica, *Neophocaena phocaenoides* and *Orcaella brevirostris* are protected in India under Schedule I, and the rest of the species under Schedule II (as Cetacea) of the Indian Wild Life (Protection) Act of 1972, as amended up to date.

Current Studies

The Zoological Survey of India, with its regional offices, is now an epitome of mammalian studies in India. This department has completed the regional fauna of Andaman & Nicobar Islands, Jammu & Kashmir, Goa, Orissa, Rajasthan, Tripura, West Bengal, etc., Other State fauna which are currently being studied are of Arunachal Pradesh, Gujarat, Meghalaya, Sikkim, Manipur and Uttar Pradesh. Country-wide primatological survey was undertaken by the department as a special project. The study of the fauna of several conservation areas, including Tiger Reserves, have been completed by this department. The remaining areas will be surveyed as per programme within 2000 A.D. The study on the mammals of the faunistically rich habitats and fragile ecosystems of the Himalaya, arid zone and tropical rain forests have been given priority. Writing up of the Red Data Book on endangered species of mammals, based on the status survey of different species, has also been counted as the priority programme of the department. Apart from these, stress has been given on the taxonomic and revisionary studies on various economically important groups of mammals such as Chiroptera, Rodentia, Carnivora, Lagomorpha, etc.

Outside the Zoological Survey of India, researches on mammals are being carried out in some institutes and universities in India. They are : Central Arid Zone Research Institute, Jodhpur (ecology and control of desert mammals, specially rodents). National Institute of Virology, Pune (studies on virology in relation to hosts and their cytogenetic bearing on taxonomy), Central Food Research Institute, Mysore (ecology and control of urban rodents), Agricultural Universities in Ludhiana, Jabalpur, Junagad, Hyderabad and Bangalore (ecology and control of rodents), Madurai Kamraj University, Madurai (Chronobiology of bats), Institute of Sciences, Nagpur (embryology and breeding biology of bats), etc. Several sporadic studies on various aspects of Indian mammals are being carried out by individuals associated with institutions and universities in India and abroad.

Expertise

INDIA

In ZSI

(a) New Alipur building (Zoological Survey of India, 'M' Block, New Alipur, Calcutta 700 053).

J. R. B. Alfred, [Primates (ecology, behaviour and zoogeography)].

V. C. Agrawal, [Rodentia, Primates, Scandentia, (taxonomy, zoogeography, ecology)].

R. K. Ghose, [Lagomorpha, Carnivora, Insectivora, Rodentia (taxonomy, zoogeography, ecology)].

Sujit Chakraborty, [Rodentia, Perissodactyla, Insectivora (taxonomy, zoogeography, ecology)].

P. K. Das, [Chiroptera (taxonomy, zoogeography and biology)].

S. S. Saha, [Systematics, ecology, behaviour].

A. K. Mandal, [Rodentia (taxonomy, ecology)].

R. P. Mukherjee, [Primates (ecology, behaviour)].

J. K. De, [Ultra-structure of mammalian hair].

T. P. Bhattacharyya, [Systematics, distribution].

M. K. Ghosh, [Systematics, distribution].

J. P. Lal, [Chiroptera (taxonomy)].

T. K. Chakraborty, [Systematics].

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A. P. Jain, Central Arid Zone Research Institute, Jodhpur, Rajasthan. [Rodentia (behaviour, breeding, control of arid zone species)].

K. Srihari, Department of Vertebrate Zoology, Agricultural University, Bangalore, Karnataka. [Rodentia (ecology, control)].

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INVERTEBRATE PALAEOZOOLOGY

Introduction

Comparatively most of the fossils of invertebrate species are not only chronologically older than the vertebrates, but also more abundant in the primitive palaeozoic rocks. Species (mostly extinct) of Foraminifera, Coelenterates (corals), Polychaetes (Annelida), Brachiopods, Echinoderms, Trilobites (Crustacea), Gastropods and Pelecypods (Mollusca), occur in primitive Cambrian and post Cambrian rocks, which in cases are older than 450 million years, but strangely in more or less codified manner. Lamarck was the pioneer in the study of invertebrate fossils. Almost 95% of the invertebrate fossil species occur in the marine depositions. Trilobites an extinct group of Crustacea were abundant in Cambrian and thrived upto Carboniferous, but couldn't survive after the Permian: The Brachiopods (Lamp Shells) evolved in the Palaeozoic, became less numerous in Mesozoic, but were able to persist till date presenting about 250 species. The Ammonites which appeared in Late Silurian, became extinct by Cretaceous. The insects appeared during Carboniferous.

Many of the invertebrate species are considered as Index fossils as they represent particular geological horizon and epoch (or era). However, in some cases particular species could manage to thrive unchanged, defying the drastic ecological changes like King crabs, scorpions, etc.

In the context to the study of fossil invertebrates in India, mention should be made to those pioneers like Forbes (1945-46), Stoliczka (1871), Waagen (1879), Oldham, (1886), Kossamat (1897), Krafft (1909), etc.

Historical Resumé

Cockerell (1917-1920) was the first to study the insect fossils present in the Burmite, or the Burmese amber, reported to have drifted from some higher reaches in an unknown area of Burma and collected by Swinhoe. Subsequently, Sahni and Trivedi (1943, 1944) reported microfossil arthropods from the Salaine Series of the Salt Ranges (now in Pakistan) collected from Salt marl, dolomites, and oil shales. Mani (1945) published brief descriptions of these fossils and added additional comments later (Mani 1946). Mani (1947) published a note on a fossil weevil from the Intertrappean beds near Nagpur. While the Salt range fossils were believed from Eocene those of Nagpur definitely dates back to Cretaceous. George (1952) published detailed descriptions of these Salt Range fossil arthropods as well as those collected by Mani, Moghe and Gee from Nagpur and Bombay. Lakshminarayana (1963) redescribed *Chironomus primitivus* Mani, based on a second rare specimen and briefly discussed the evolution of male genitalia in the genus *Chironomus*.

In the Palaeozoology Division, Lakshminarayana and Talukdar (together with Jana, Roy, Saha, Paul, and Dutta for certain orders) have nearly completed an exhaustive bibliography on fossil insects of the World (perhaps the only one such attempt since the publication of Scudder in the last Century (1883).

Estimation of Taxa

Considering the insect faunal diversity, and endemism of our fauna, normally we should expect fairly a large number of insect orders, families, genera and species in the Indian region among the fossils also. But unfortunately, the country being mainly a land of agriculture from time immemorial, and lack of interest on insect fossil collection on the part of palaeontologists,

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zoologists including entomologists, we have a poor record of our fossil insect wealth.

Areas covered

(a) *Family wise* : Most of the fossils reported by Sahni, Trivedi, Mani and George are based on fragments, and therefore, family allotment or even naming of the genera and species was not attempted by the authors. However, these fossils belong to Collembola (Poduridae), Thysanura (Lepismatidae), Orthoptera (Acrididae). Dermaptera, Psocoptera, Heteroptera (Cimicidae ?), Homoptera (Aphididae, or Aleyrrodidae), Lepidoptera (Microlepidoptera, and Sphingidae), Hymenoptera (Ichneumonoidea, Chalcidoidea (Encyridae and Chalcididae). Diptera (Nemotocera fragments, Phycetophilidae, Chironomidae, Psychodidae, and Itionididae) and Coleoptera (Carabidae, Dytiscidae, and Dermestidae).

Cockerell (1917-1920) reported Thysanura (Lepismatidae), Dermaptera, (Labiduridae), Embioptera (Embiidae), Isoptera (Termitidae), Psocoptera (Psocidae), Heteroptera (Enicocephalidae), Homoptera (Fulgoridae, Delphacidae Aelyrodidae), Lepidoptera (Micropterygidae), Trichoptera (Odontoceridae ?), Hymenoptera (Evaniidae, Bethylidae, and Trigonalidae), Diptera (Mycetophilidae, Chironomidae, Itionididae, Psychodidae, Empididae), and Coleoptera (Buprestidae, Elateridae, Pedilidae, Rhipiphoriddae, Dermestidae and Ipidae) from the Burmese Amber.

(b) *Survey wise* : Maharashtra, Salt Range (Pakistan) and Burma. G.S.I. has obtained some Blattid specimens from Kota Maleri and probably Kashmir. Recently Dutta (1977) described a fossil blattid from Daltonganj coalfield, Bihar.

Present work of the survey in relation to work done in other Institutes in India

At present George is working on Arthropod fossil at Christ Church College, Kanpur. Besides him, only Lakshminarayana in Z.S.I., is paying attention to insect fossil problem. The proposed insect fossil bibliography will help not only to those interested in insect fossil work, but also those systematists engaged on modern insects, and perhaps pave the way for others to take more active interest on fossils. Lakshminarayana also had the opportunity of examining Baltic Amber fossils and Solenhofen fossils from Bavaria Poland, German Democratic Republic and British Museum (Natural History) London.

(a) *Survey wise* : A beginning has been made to pay special attention while making other fossil collections in Madhya Pradesh and Maharashtra. Likewise, while surveying in different states, one can look for those fossils especially in freshwater deposits, limestone deposits, and oil shales. Since fossil finding is more a chance discovery, even those non-Palaeozoology teams should pay attention to fossiliferous beds and their collection during their surveys, without which much headway cannot be made.

(b) *Family wise* : As stated in item 2, there is a great scope for encountering several orders and families considering the modern faunal diversity, whose ancestors must have definitely occurred in the remote past.

Studies on fossil Annelids from Trichinopoly Cretaceous

Historical

Forbes (1856) was the first to discuss fossil annelida from India. Stoliczka (1873) was the next worker to study the fossils of this group from the Trichinopoly Cretaceous. This author (1858) also erroneously associated three species of annelids in his monograph on fossil Mollusca, which are now transferred to their proper position by Lakshminarayana and Saha (in press). The latter two authors revised the fossil annelids from Trichionopoly Cretaceous based on the collections made by Lakshminarayana and the material present in the Geological Survey of India, studied earlier by

Stoliczka. These studies resulted in the proper alignment of the known speices as well as in the description of two new species.

No. of families, genera and species estimated in the country

1 family, 2 genera, 12 species in India and 1 family, 1 genus and 6 species in Trichinology Cretaceous beds.

Areas covered

(A) *Family wise* : Serpulidae.

(B) *Survey wise* : Trichinopoly Cretaceous beds (other areas in Sind and Salt Range (Pakistan); Kutch (India).

Present work of the survey in relation to work done in other Institutes

Since 1873 no one paid attention to this group in India and from Trichinopoly Cretaceous. The group is studied in Z.S.I. only in the recent times.

Areas to be explored

(A) *Survey wise* : NIL

(B) *Family wise* : NIL

Other workers abroad are as follows :- Bignot, G.; Howell, B. F.; Regenhardt, H.; Ware, S.; Wrigley, A.

Studies on fossil Pelecypoda

(a) *Bibliography on fossil Arcacea, Pectinacea & Cardiacea from Trichinopoly createceous* :

Historical

Species belonging to the genera *Arca, Pectan* and *Cardium* have been described by pioneer authorities from India like Forbes (1846), Stoliczka (1871), Foote (1879), Kossmat (1897) and Nostling (1897). During nineteenth century, Hayden (1913-14), Bion (1925), Cossmann & Pissanro (1927), Cox (1931), Pascoe (1950); and Hertlein & Cox (1969) discussed the relative statigraphic zonation or evolutionary importance of these fossil groups. The Trichionopoly Cretaceous has a representative fauna of these genera. While working out these fossils, it was felt desirable to compile a bibliography of work on these fossil genera from the world since no consolidated work is so far available.

No. of families, genera and species estimated in the country

3 families, 49 genera and 281 species.

Areas covered

(A) *Family wise* : Arcidae, Pectinidae and Cardiidae.

(B) *Survey wise* : Kashmir, Himachal Pradesh, Siwalik ranges, Kumaon, Assam, Garo and Khasi Hills, Sikkim, Rajasthan, Gujarat, Madhya Pradesh, Tamil Nadu, Pondicherry, Andhra Pradesh and Orissa states. (Besides several reports from Afghanistan, Pakistan, Nepal & Burma are also available).

Present work of the survey in relation to work done in other Institutions in India

(A) *Survey wise* : Z.S.I. conducted surveys from Madhya Pradesh, Maharashtra, Andhra Pradesh and Tamil Nadu and the Geological Survey of India explored other regions mainly.

(B) *Family wise* : The 3 aforesaid families.

5. *Areas to be explored*

(A) *Survey wise* : Rest of the areas other than mentioned in 4(A).

(B) *Family wise* : All the 3 families.

C. S. Roy published a note on *Ptarotrigonia (Scabrotigonia) scabra* (Lamarck) (Mollusca : Bivalvia : Trigoniidae) from Trichinopoly, Tamil Nadu, a new record from this area.

(c) *Studies on fossil Pinna (Mollusca : Pelecypoda)* from *Trichinopolly cretaceous*

1. *Historical* : Forbes (1846) described the first fossil *Pinna* from India (Pondicherry). Stoliczka (1871) described three more species from the Trichinopoly Cretaceous. Warth (1895) and Pascoe (1959) merely listed the species given by Stoliczka (*vide supra*). Lakshminarayana, Subba Rao, and Saha (1976) studied the fresh material collected by the first author along with material studied by Stoliczka available in the Geological Survey of India. These studies resulted in the redescription of the known species from India along with a key to their identification, as well as invalidating *P. latisulcata* Stol. as a *nomen nudum* and also a junior homonym of *P. latisulcata* Woodw. The genus has not received much attention in the fossil state.

2. *No. of the families, genera and species estimated in the country* : 1 family, 1 genus, 7 species.

3. *Area covered*

(A) *Family wise* : Pinnidae.

(B) *Survey wise* : Trichinopoly Cretaceous (Pondicherry & Tamil Nadu) (also Burma).

4. *Present work of the Survey in relation to work done in other Institutions in India*

(A) *Survey wise* : After the preliminary reports of Forbes and Stoliczka, no other party in G.S.I. has so far collected these fossils. Z.S.I. collected all the known fossil species from Tamil Nadu.

(B) *Family wise* : One.

5. *Area wise* : One family.

(d) *Studies on Spondylus species from Trichinopoly Cretaceous*

1. *Historical* : The genus *Spondylus* is well represented in fossil rocks and often utilized in stratigraphic zonation. Forbes (1845-46) was again the first author to describe the species from India. Several papers by D'Archiac & Haime (1853-54), Stoliczka (1871), Noetling (1897, 1970), Kossmat (1897), Hayden (1907, 1913-14), Douville (1916), Bion (1924-25) and Cossman and Pissarro (1927) have appeared dealing with the *Spondylus* species. Hartlein and Cox (1969) recently revised the genus.

Species from Trichionopoly Cretaceous beds were described by Forbes, Stoliczka, and Kossmat (*vide* supra). The material collected by Lakshminarayana were studied along with the material examined by Stoliczka and Kossmat available in the Geological Survey of India, by Lakshminarayana & Roy in this division. Both the species described by Forbes, were considered as conspecific by subsequent workers, but strangely they used the specific name of the second species in preference to the first one, for no particular reason, and therefore, erroneous under *International Rules of Nomenclature*. Therefore, Lakshminarayana and Roy (1978) corrected this erroneous practice giving priority to the first named species of Forbes (*op. cit.*). A new subspecies was described along with redescriptions and key to all the known species of this region. A list of all the world species is provided in this paper inview of its strategraphic importance. The present day active workers are : Cox, L. R., Hertlein, L. G. and Zavarei, A.

2. *No. of families, genera and species estimated in the country* : 1 family., 1 genus, 11 species.

3. *Areas covered*

(A) *Family wise* : Spondylida.

(B) *Survey wise* : Trichinopoly Cretaceous (Pondicherry & Tamil Nadu) [Baluchistan and Sind (Pakistan), Tibet].

4. *Present work of the survey in relation to work done in other Institutions in India*

(A) *Survey wise* : After the preliminary report of Forbes, Stoliczka, and Kossmat, no other survey was conducted for these fossils. Z.S.I. has surveyed and obtained all the species from Tamil Nadu and encountered a new subspecies also.

(B) *Areas to be explored*

(A) *Survey wise* : Pondicherry.

(B) *Family wise* : One family.

(4) *Studies on Rhyncholites from Trichinopoly Cretaceous*

1. *Historical* : Rhyncholites have been first reported by Till (1910) from India. Sahni and Jain (1962) added one more species, and Sastry, Mamgain, and Rao (1965) reported two more species including a new one. Lakshminarayana collected the species described earlier by Sastry *et al.*, and also the already well known species, *R. guinguecarinatus* Pictet & Campiche besides another species new to science. These collections along with the collections present in the Geological Survey of India were studied by Lakshminarayana and Saha (1979). The outcome of the studies was that *R. guinguecarinatus* Pictet & Campiche (sensu Sastry *et al.*) is in fact composed of two species and the second one has also been described as a species new to science (Lakshminarayana & Saha) (in press). Lakshminarayana also took advantage of his visit to Poland in studying the collections of Gasiorowski and discussing with the possible development of Rhyncholites in a new angle. It is hoped that after examining the mandibles of few living cephalopods the new hypothesis can be published jointly.

2. *No. of families, genera and species estimated in the country* : 1 family (uncertain), genus (possibly one more), 5 species.

3. *Areas covered*

(A) *Family wise* : Uncertain.

(B) *Survey wise* : Trichinopoly Cretaceous (Tamil Nadu).

4. *Present work of the survey in relation to work done in other Institutions in India*

(A) *Survey wise* : Department of Geology, Punjab University, Chandigarh and Geological Survey of India described three species, Z.S.I. explored the same area, obtained the two species, in addition to another new species, and also described another new species from G.S.I. collections from Tamil Nadu.

(B) *Family wise* : One.

5. *Areas to be explored*

(A) *Survey wise* : More surveys can be conducted in Tamil Nadu.

(B) *Family wise* : One.

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VERTEBRATE PALAEOZOOLOGY

Introduction

Palaeontology (Palaios = ancient + ont = being) deals with the fossils entombed as remains of animals (also plants) of bygone periods. The study of fossils help scientists to assess past evolutionary changes and to find out the chronology of ancient rock formations. 'Vertebrate Palaeontology' deals with those animal fossils which possessed vertebrae or notochord in their living stage. Georges Cuvier (1769-1832) was the pioneer in the systematic study of vertebrate fossils.

The earliest forms of vertebrates or protochordates, very likely evolved or appeared in fresh water, but most of them escaped preservation. Some, however, were washed down and entombed in the marine deposits. Oldest forms, the ostracoderms have occurred in the Ordovician rocks *i.e.* 350 million years ago. Primitive jawed vertebrates or the Placoderms are found from Silurian rocks. This group flourished to a maximum in Devonian, by which time the ostracoderms declined. By the end of this time both the cartilagenous and bony fishes appeared plentifully. Immediately thereafter the crossopterygeans and amphibians appeared. The reptiles evolved in Carboniferous and flourished to a maximum with diversified branches during permian to cretaceous and occupied the major niches in land, ocean and lakes (fresh water). Some became gigantic in size - Brontosaurus, Dinosaurs, etc. But after cretaceous only four Orders could survive to date. Gradually the mammals in primitive forms came into existence in the Triassic and birds in the Jurassic. Most of the species existed in particular geological horizon and era, thus considered as ideal index fossils.

Through successive strata, well preserved representatives of closely related species render the scientists to depict the phylogeny of some present day species. Thus the ancestry of modern horse could be traced to the small dog-size extinct Eohippus of Lower Eocene in North America. Similarly, the extinct small Eocene Moeritherium, lacking the trunk and tusks, has been traced to be the ancestor of present day elephants (*Elephas, Loxodonta*).

In context to the study of vertebrate fossils in India mention should be made to the following pioneers : H. Falconer, & P. T. Cautley, R. Lydekker; W. D. Mathew; G. E. Pilgrim and E. H. Colbert, R. Owen; T. H. Huxley.

(1) *Bibliography of fossil fishes*

1. *Historical* : Fossil fish remains from different parts of India have been described by several scientists viz., McClelland (1844), Egerto (1845), Verneuil (1867), Bell (1853), Blanford (1878), Lydekker (1880), Miall (1878), Oldham (1859), Stoliczka (1873), and Waagen (1879), Wood-word (1889-1901), Hora (1937), Menon (1958), Prasad and Rao (1958) till a couple of decades back. Menon (1959) published a catalogue & bibliography of fossil fishes of India.

Since then the following workers have contributed to the subject. Tiwari (1959), Verma (1965), Trivedy (1966), Mohanti (1967), Gupta (1967), Misra & Sexena (1967), Chakraborti (1968), Gowda (1968), Tiwari, Chaturbedi & Singh (1968), Jain (1968, 1973), Gupta (1968) included a few records in his bibliography of fossil fauna of Rajasthan, Paul (1973) described a fossil shark tooth collected by Lakshminarayana from Trichinopoly cretaceous beds, Broker (1973), Dassarma & Sinha (1975) and Satsangi & Mukherjee (1975), Jain (1974), Gupta and Yazdani (1978), Mukherjee and Ghosh (1978) described a new fossil fish *Leiomens kapurdiensis* from Kapurdi, Rajasthan, India.

Reproduced from *State of Art Report : Zoology*, 1980, partly updated by M. Ghosh, Zoological Survey of India, Calcutta.

2. *No. of families, genera and species in the country so far reported*

39 families, 58 genera and 106 species (34 not determined).

3. *Areas covered*

(A) *Family wise* : Heterodontidae, Odontaspidae, Lamnidae, Carcharhinidae, Ptychodontidae, Myliobatidae, Cochliodontidae, Psammodontidae, Ptychodontidae, Edestidae, Ceratodidae, Amblypteridae, Saurichthyidae, Semionotidae, Aspidorhynchidae, Lepidosteridae Clupeidae, Osteoglossidae, Enchodontidae, Tachysuridae Siluridae, Bagridae, Sisordiae, Clariidae, Cyprinidae, Cyprinodontidae Ophicephalidae, Centropomidae, Serranidae, Anapantidae, Nandidae, Pristolepidae, Trichiuridae, Diodontidae, Sparidae, Amblypteridae, Coelacanthidae.

(B) Kashmir, Siwalik, Punjab, Rajasthan, Gujarat, Madhya Pradesh, Assam, Tripura, Orissa, Andhra Pradesh, Tamil Nadu, West Bengal, Meghalaya.

4. *Present work of the survey in relation to work done in other Institutes*

Geological Survey of India and Statistical Research Institute, Calcutta have reported fossil fishes.

5. *Areas to be explored*

(A) *Survey wise* : All the areas reported under item 3(B).

(B) *Family wise* : As under item 3(A).

(2) *Bibliography of Indian fossil Amphibia*

1. *Historical* : Owen (1854, 1857), Huxley (1865), Wynne (1869), Stoliczka (1869), Lydekker (1877, 1879, 1881, 1882, 1883, 1886, 1887, 1890), Feistmantel, (1877), Foote (1884) reported or described fossil amphibia from India during last century, Woodward (1905), Huenė (1920, 1940), Huene and Sahni (1958), Noble (1930), Chiplenkar (1940), Tiwari (1961, 1962), Roy (1961, 1962), Tripathi (1962), Tripathi and Puri (1962), Roy Choudhuri (1965), Tripathi (1969, 1980), Von Huene and Sahni (1981), Yadagiri and Prasad (1977), have added to our knowledge of Indian fossils of this group since then. Ghose (1968) published a catalogue of amphibian species, their distribution in India and a full bibliography, which will help all future workers on this group.

2. *No. of families, genera, and species in the country so far reported*

9 families, 14 genera and 26 species (9 not determined) and some undetermined Labyrinthodont remains.

3. *Areas covered*

(A) *Family wise* : Archegosauridae, Eryopsidae, Rhinesuchidae, Capitosauridae, Trematosauridae, Metaposauridae, Brachyopidae, Bufonidae, Ranidae.

(B) *Survey wise* : Kashmir, Punjab, Madhya Pradesh, West Bengal, Maharashtra, Andhra Pradesh.

4. *Present work of the survey in relation to work done in other Institutes*

Geological Survey of India mainly surveyed these fossil sites from India.

5. *Areas to be explored*

(A) *Survey wise* : Kashmir, Punjab, Madhya Pradesh, West Bengal, Maharashtra, Andhra Pradesh.

(B) *Family wise* : Archegosauridae, Eryopsidae, Rhinesuchidae, Capitosauridae, Trematosauridae, Metaposauridae, Brachyopidae, Bufonidae, Ranidae.

(3) *Bibliography on fossil Reptilia from India*

1. *Historical* : The first studies on fossil reptilia from India were carried by Falconer (1835) from Siwalik Hills. Since then a number of scientists like Cautley (1836); Falconer (1837, 1846, 1855, 1868); Falconer & Cautley (1840, 1844); Carter (1852, 1854); Theobald (1850, 1877, 1879); Huxley (1861, 1865, 1889), Blanford (1862), Hislop (1864); Mayer (1865); Stoliczka (1869); Grey (1871); Lydekker (1876, 1877, 1879, 1880, 1881, 1882, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890); Faistmantel (1880); Pilgrim (1908, 1912), Cotter (1918), Matley (1918, 1919, 1921, 1923, 1929, 1932); Dasgupta (1920, 1922, 1926, 1928); Rao & Seshachar (1927); Mook(1932, 1933); Rao (1932); Huene & Matley (1933); Chakraborti (1934, 1935); Aiyenger (1937); Huene (1940, 1942, 1956, 1960); Dubey & Narain (1946); Mukherjee (1949); Sukheswala (1949); Efrenov (1957); Robinson (1960, 1967); Tarlo & Robinson (1960). Colbart (1961); Ramaiha (1961); Sahni (1962); Tripathi & Puri (1962); Jain, Robinson & Chowdhury (1962, 1964); Tripathi & Satsangi (1963); Pascoe (1964; Satsangi (1964); Tripathi (1964, 1968); Prasad 1966, 1968, 1970, 1974); Trivedy (1966); Tewari & Badam (1969); Chatterjee, Jain, Kutty & Chowdhury (1969), Kutty (1972); Badam (1973, 1974); Mahabey (1984), Sen and Banerjee (1984), Yadagiri (1987), Mathur (1989), etc., described Indian reptilian fossils from time to time and also made observations of stratigraphic and evolutionery importance. Most of these fossils are from Siwalik hills; Panchet beds, Raniganj (West Bengal); Lameta beds, Jubbulpore (Madhya Pradesh); Tiki beds, South Rewah (Gujarat), Narmada valley; Kota Maleri beds around Maleri Yerrapalli formation in Pranhita Godavari valley, Kurnool caves (Andhra Pradesh) and from Ariyalur and Sayamalai area of Tamil Nadu.

2. *No. of families, genera and species in the country so far reported*

32 families, 47 genera, 92 species (19 not determined upto specific level).

3. *Areas covered*

(A) *Family wise* : Captorhinidae, Pelomedusidae, Cheloniidae, Emydidae, Testudinidae, Trionynhidae, Carettochelidae, Ichthyosauridae, Plesiosauridae, Rhynchosauridae, Varanidae, Pythonidae, Colubridae, Erythrosuchidae, Phytosauridae, Pholidosauridae, Crocodylidae, Gavialidae, Rhamphorhynchidae, Coeluridae, Compsognathidae, Ornithomimidae, Teratosauridae, Megalosauridae, Allosauridae, Thecodontosauridae, Cetiosauridae, Stegosauridae, Nodosauridae, Dicynodontidae, Lystrosauridae, Endothiodontidae, plus two families not specified.

(B) *Survey wise* : Siwalik Hills, Jammu & Kashmir, Gujarat, Rajasthan, Maharashtra, Madhya Pradesh, Tripura, Assam, West Bengal, Andhra Pradesh, Tamil Nadu.

4. *Present work of the survey in relation to work done in other Institutes*

Geological Survey of India, Indian Statistical Institute, Calcutta and Centre of Advanced Study in Geology, Punjab University, Chandigarh surveyed for these fossils from India.

5. *Areas to be explored*

(A) *Survey wise* : All the areas reported under item 3(B).

(B) *Family wise* : As under item 3(A).

(4) *Bibliography on fossil aves from the world*

1. *Historical* : Lydekker (1879) recorded the first avain fossil from India followed by Davies (1880), Foote (1884), Blanford (1885) and Harrison (1979); Howard (1963) discussed the avian evolution.

2. *No. of families, genera and species in the country so far reported*

11 families, 15 genera, 19 species (3 were not reported upto specific level).

3. *Areas covered*

(A) *Family wise* : Pelecanidae (Pelecaniformes); Anatidae (Anseriformes); Phasianidae (Galliformes); Ardeidae & Ciconiidae (Ciconiformes); Accipitridae (Falconiformes); Gruidae (Gruiformes); Strigidae (Strigiformes); Struthiidae (Struthiniformes); Dromiceidae (Casuariiformes) plus two families not reported.

(B) *Survey wise* : Reports are available from Kurnool Caves (Andhra Pradesh) and Siwalik Hills.

4. *Present work of the survey in relation to work done in other Institutes*

Geological Survey of India, Southern Region and Archaeological Department, Deccan College of Science, Pune, have surveyed the kurnool Caves.

5. *Areas to be explored*

(A) *Survey wise* : There is scope for further exploration in the two areas.

(B) *Family wise* : In India, getting the fossil aves is a problem because of the excessive disturbance of nature from a long time, except in Siwaliks caves. Since we have a rich modern Avifauna, it is quite possible to assume that some of their ancestral forms have definitely occurred in the bygone in India.

(5) *Bibliography of fossil Carnivora*

1. *Historical* : Falconer & Cautley (1835) first described fossil Carnivora from Siwalik Hills. In their series of papers Lydekker (1875-1887) and Pilgrim (1908-1941) have advanced our knowledge to a great extent chiefly based on the specimens collected from the Siwalik Hills. Since then a number of workers added their contribution to the subject. Bose (1879), Woodward (1915), Kaltzoi (1929), Mathew (1923), Lewis (1933), Colbert (1933), Rao (1934), Prasad (1963), Pascoe (1964), Gupta & Badam (1972), Dutta (1976), Dassarma (1982), Saha (1984), have discussed the relative statigraphy and evolution of Indian fossil Carnivora.

2. *No. of families, genera and species in the country so far reported*

10 families, 67 genera and 168 species (19 not determined).

3. *Areas covered*

(A) *Family wise* : Canidae, Felidae, Hyaenidae, Mustelidae, Procyonidae, Ursidae, Viverridae, Hyaenodontidae, Mesonychidae.

(B) *Survey wise* : Siwalik Hills, Punjab, Himachal Pradesh, Assam, Gujarat, Madhya Pradesh, Andhra Pradesh, Tamil Nadu.

4. *Present work of the survey in relation to work done in other Institutes*

Geological Survey of India and Deccan School of Archaeology, Pune, conducted surveys earlier in these areas.

5. *Areas to be explored*

(A) *Survey wise* : There is a scope for further exploration.

(B) *Family wise* : As under item 3(A).

6. *Studies on fossil Bovidae and other artiodactyls and perissodactyls of India*

1. *Historical* : Prinsep (1834) was first to record a fossil ruminant from the Siwalik of India

and this work was followed by Caurley and Falconer (1836), Falconer (1845), Lydekker (1876, 1877, 1878, 1884, 1885, 1886, 1887) Brown (1926); Colbert (1933, 1935); Pilgrim (1915, 1937, 1939); Azzaroli (1954); Prasad and Satsangi (1963, 1968, 1969); Prasad (1936); Pascoe (1964); Tripathi (1965); Trivedy (1966); Sahni and Khan (1968); Badam (1969); Hooijer (1950), Banerjee *et al.* (1987), Tobien (1988), Dassarma *et al.* (1982) and Jayakaran (1980). Pilgrim's (1939) work on fossil Bovidae is a monographic work. Most of these fossil records are from Siwalik, a few are from Kutch and Kurnool caves (A.P.). Only two species of *Bubalus* and three species of *Bos* have been reported from India and adjacent (Falconer, 1859, 1868; Lydekker, 1877, 1878, 1898). Pilgrim (1939) listed the known species from India, basing on Falconer and Lydekker. Mamgain and Sastry (1967) also obtained broken fragments of *Bos* sp., from Trichinopoly Cretaceous beds in South India. During a survey tour conducted by Lakshminarayana, a large fossil right humerus was obtained on Marudaiyar River beds in Tamil Nadu. This large fragment was studied in the Section and on comparison with the available extant and extinct material of *Bubalus* or *Bos* available in the Geological and Zoological Survey on India respectively was found to belong to yet another new species of *Bubalus* and described it as *Bubalus maruvattoorensis* sp. nov. (Ghosh, Paul and Saha 1973).

Dental fragments and lower jaws of bovids have been reported earlier by Mamgain and Sastry (1967) and those of equines by Rao (1927) and Rao and Seshachar (1927) respectively. Lakshminarayana has also collected lower right 3rd premolar (possibly near to that of *Equus namadicus* Falc. & Caut.) and the upper left second molar of *Bos* sp. (the first upper tooth reported so far from India). A note on these teeth have been published by Saha (1976).

2. *No. of families, genera and species estimated in the country*

7 families; 58 genera and 119 species.

3. *Areas covered*

(A) *Family wise* : Tragulidae, Cervidae, Giraffidae and Bovidae.

(B) *Survey wise* : Kashmir, Siwaliks, Tripura, Madhya Pradesh, Andhra Pradesh, Tamil Nadu.

4. *Present work of the Survey in relation to work done in other Institutes in India*

A large number of contribution on these families are based on G.S.I. collections. Dept. of Geology and Zoology, Central College of Bangalore and Deccan College of Archaeology, Pune have also conducted surveys in Tamil Nadu.

5. *Areas to be explored*

(A) *Survey wise* : There is a scope for further exploration in Kashmir, Siwalik, Tripura, Madhya Pradesh, Andhra Pradesh, and Tamil Nadu.

(B) *Family wise* : Tragulidae, Cervidae, Giraffidae and Bovidae.

(7) *Bibliography on fossil Primates*

1. *Historical* : Falconer & Cautley (1837) first described the fossil primates from Siwalik Hills. Since then a number of scientists contributed to the subject. Lydekker (1879), Pilgrim (1910), Wadia & Aiyengar (1937), Hooijer (1951), Pascoe (1964), Gupta (1970) and Prasad (1972) discussed the relative statigraphy and evolution of Indian fossil Primates.

Primatological studies are now receiving greater attention from different parts of the world including India. Therefore, it was felt desirable to have a fossil bibliography on this subject so that the workers on the extinct primates will have an easy access for the fossil literature and thereby the evolutionary significance and importance of primates in time and space can be better understood.

2. *No. of families, genera and species in the country so far reported*

7 families, 24 genera, 44 species (3 not determined).

3. *Areas covered*

(A) *Family wise* : Cercopithecidae, Pongidae, Lemuridae, Simiidae, Plesiadapidae, Adapidae, Hominidae.

(B) *Survey wise* : Siwalik, Punjab, Himachal Pradesh, and Andhra Pradesh.

4. *Present work of the survey in relation to work done in other Institutes*

Geological Survey of India and Deccan School of Archaeology, Pune, conducted surveys earlier in these areas.

5. *Areas to be explored*

(A) *Survey wise* : There are several unexplored caves in Kurnool District and Siwalik Hills the survey of which can be taken up.

(B) *Family wise* : As under item 3(A).

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PREHISTORIC ZOOLOGY

Introduction

The study on the prehistoric and ancient zoological remains collected from the excavated sites of India is of recent origin and commenced from about 1930 onwards. The Prehistoric Zoology Section is really the custodian of the prehistoric animal remains excavated by the Archaeological Survey of India, Directorate of State Archaeology, universities and individuals (chance findings) and other institutions from different prehistoric sites of the Indian subcontinent. The collections are of great scientific value. No duplicates are available in any other organisation in India. The collection comprise both of higher chordate and lower chordate groups of animals, as well as some invertebrate groups. Many renowned scientists of India worked out the collections housed in Z.S.I., such as D. B. Prasad, Col. R. B. S. Sewell, H. C. Ray, B. Nath, S. Banerjee, H. D. Sankalia, B. S. Guha, J. Espen, etc. At present M. Ghosh, U. Saha, K. D. Saha, S. Roy, etc., are carrying out researches on prehistoric animal remains.

The animal remains found in the excavation also help us to know the geographical, geo-ecological condition of the bygone. The actual remains combined with the paintings and engravings of the prehistoric man reflects the animal life of the past.

Furthermore, study on the prehistoric animal remains excavated from the various strata of the different sites where civilization flourished during the ancient days helps us in understanding the relations between animals, both domesticated and wild, and man in various cultural sequences, thus providing us with the chronological history of our cultural heritage.

India has been divided into eight broad cultural divisions : 1. Early Stone Age or Palaeolithic culture; 2. Mesolithic culture; 3. Neolithic culture; 4. Indus culture; 5. Chalcolithic cum Neolithic culture; 6. Grey ware and North Black Polish ware culture; 7. Megalithic culture; 8. Early historic culture.

The oldest of the sites are Mohenjodaro and Harappa (both *ca* 2500-1500 B.C.) of Indus Valley Civilization. Another older site is Burzahom, which has Neolithic culture (*ca* 2300 B.C.) and a "Pit dwelling" site of India. The Kitchen midden culture is not very old, in India it is found at the Andaman Islands. In 1974-75 a team of the Zoological Survey of India collected a number of animal shells and bones for study. The latest is the early Historic cultural site from Sarnath (12th century A.D.).

The Prehistoric Zoology Section was established in the Zoological Survey of India, sometimes in 1960. All the collections from the different prehistoric sites were transferred from other departments to this section of the Survey.

Historical Resumé

A brief account of the animal remains of a few important prehistoric sites in India and Pakistan are given below :

1. Mohenjodaro (2500-1500 B.C.)—The first report on the animal remains of the Indus civilization was from Mohenjodaro (Larkana District, Sind, Pakistan). The collection was studied by Sewel and Guha (1931). It represented about 37 species of animals which were ***Bos indicus*** Linn. (Cattle); ***Bubalus bubalis*** (Linn.) (Buffalo); ***Ovis*** sp. (Sheep); ***Canis familiaris*** Linn. (Dog); ***Sus scrofa*** Linn. (Pig); ***Camelus dromedarius*** Linn. (Camel); ***Elephas maximus*** Linn. (Elephant); ***Gallus*** sp. (Fowl); ***Equus caballus*** (Horse); these were probably domesticated animals. ***Herpestes***

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auropunctatus (Hodg.) (Indian Mongoose); *Suncus stoliczkanus* (And.), (Anderson's shrew); *Rattus rattus* Linn. (Rat) lived in the vicinity of human habitations. *Gavialis gangeticus* (Gmelin), (Gharial), several species of turtles and tortoises and fishes of the species *Rita rita* (Ham. Buch), *Wallaga* sp., *Arius* sp., were probably caught and utilised as food. The remains of shells imported for ornaments consist of species of both freshwater and marine molluscs. Remains of *Cervus elaphus hanglu* (Wag.) (Kashmir Stag), *Cervus unicolor* Kerr (Sambar), *Axis axis* (Erxl.), (Chital), *Axis porcinus* (Zimm.), (Hog deer) etc., were probably imported for medicinal purposes. The people of Mohenjodaro practiced a high grade of domestication of animals and utilized them as food, medicine and ornamentation.

2. Harappa (2500-1500 B.C.)—The next important site of Indus Civilization, situated at Montgomery District, Punjab, now in Pakistan, is Harappa. The animal remains were studied by Prasad (1936). He described 30 species of animals along with their probable ancestries. Several species are the same as in Mohenjodaro.

The occurrence of *Rhinoceros unicornis* Linn., which lives in marshy and humid forests, indicates that the ecological condition of Punjab in those days were different than that of now. *Rhinoceros* is not found in that region now a days. Its presence in those days is very interesting. Prasad also described a new dog from Harappa, known as *Canis tenggeranus* race *harappensis*, resembling the original ancestral type of dog found in the Orient in diluvial times which was of the Greyhound type. Nath (1962) also reported the remains of horse (*Equus caballus* Linn.) and Indian elephant (*Elephas maximus* Linn.) from Harappa. Ghosh and Saha, have reported two more species, *Helichoerus grypus* Fabricius (Grey seal) and *Gazella subgutturosa* Guldenstaedt (Persian gazelle) from the remains of Harappa. The remains earlier considered to be of domestic cat by Prasad (1936) are redefined by Ghosh (1982) as of Caracal (*Felis caracal* Schreiber) and Bengal Fox (*Vulpes bengalensis* Shaw).

3. Rupar (2000-900 B.C.)—Rupar (Ambala District, Haryana) is another site of Harappan culture. Nath, has found 18 species of animals from this remains, all the them are similar to those of Harappa and Mohenjodaro except the occurrence of *Francolinus francolinus* (Linn.) (Black Partridge) and *Bandicota bengalensis* Gray & Hardw.

4. Rangpur (2000-800 B.C.)—Rangpur (Ahmedabad District, Gujarat) is also a Harappan cultural site. Nath has described 10 species from these remains. The occurrence of domestic ass (*Equus asinus* Linn.) is noteworthy.

5. Lothal (2000-1200 B.C.)—Lothal (Ahmedabad District, Gujarat) is a Harappan cultural site. Nath has recorded 23 species of animals from the remains. The presence of *Rhinoceros unicornis* Linn., *Elephas maximus* Linn. and *Equus cabellus* Linn., from the late period of Harappan culture is interesting.

6. Nevasa (1500-1000 B.C.)—Eapen has worked out the collection from Nevasa (Ahmednagar District, Maharashtra) and found 13 species of animals. The bony remains of the Chalcolithic period of Navasa are mainly domestic cattle and Barasingha (*Cervus devauceli* Cuv.). There are no remains of pig.

7. Hastinapura (1100 B.C. to 3rd Century A.D.) (Meerut District, U.P.) is also mentioned in the oldest Indian epic, the Mahabharata. Nath has studied and described 13 species of animal remains from this site. The majority of the remains are of domesticated animals. In this period people seem to have been fond of hunting deer, the bones of which were used for style and other decorative objects.

8. Nagarjuna Konda (Neolithic—1200 A.D.)—Nagarjuna Konda (Guntur District, A.P.) has three different cultures, Neolithic, Megalithic and historic. In these three cultures about 30 different species were found. *Bos gaurus* H. Smith was found from this site. The remains of a sacrified pony from the 'Aswamedh' site of Nagarjuna konda is of a special significance as it throws light on the ritual and cultural practices of descendents of the Ikshuvaku kings who ruled there at that time.

9. Kalibangan—(2000-1500 B.C.)—Kalibangan (Ganganagar District, Rajashthan) is another site of Indus Valley Civilization. Banerjee and Mukherjee identified 29 species of animal remains. Most interesting are the remains of *Rhinoceros unicornis* Linn., *Muntiacus muntjak* Zimm. and *Axis axis* Erxl. The occurrence of these remains from Rajasthan support the idea of their extensive distribution in the earlier days. These animals inhabit swampy land mixed with forest, so their occurrence in Rajasthan strengthens the geological evidence that the desert conditions of this area is of recent origin.

10. Burzahom (2000—B.C. to 400 A.D.) Burzahom (Kashmir) has different cultural phases from Neolithic to Early Historic. This is a pit dwelling site in India. From this collection, Banerjee and Ghosh described 12 species of animals. There were two different types of dogs. The remains of *Bos gaurus* H. smith is noteworthy as this is a new record form Kashmir from where they are extinct now. Huge remains of *Cervus elaphus hanglu* Wagner suggest that the site was once a favourite place of large population of this species, which is becoming rare now-a-days. This is the only site from where a large number of Neolithic Bone Tools have been recovered. Banerjee and Ghosh identified the species and topographic portion of the bones from which these tools were prepared.

11. Bharatpur (1000 B.C.—900 A.D.)—Bharatpur is in Burdwan District of West Bengal. The animal remains have been found from Chalcolithic and Iron Age cultures. Banerjee has described 16 species of different groups of animals from the remains. Most interesting is the remains of *Bos namadicus* Falconer, which probably is the first record from a prehistoric site excavated by the Archaeological Survey of India.

12. Pandu Rajar Dhibi (1012 - 1120 B.C.) is a Chalocolithic site situated near the confluence of Ajoy and Kunoor rivers in Burdwan. The site was explored and excavated by the State Archaeology Department, Government of West Bengal, in 1985. Species of fishes, turtles, fowls, foxes, Hog deer and farm animals like the cattle and buffalo have been identified by Ghosh (1991).

Banerjee (1976) described from the prehistoric animal remains from Mochpal and Susunia both in West Bengal the remains of *Bos nomadicus* Falconer which is an extinct species; this is considered to be a new record from eastern India. Banerjee and Ghosh (1976) also described the remains of *Giraffa cf. camelopardalis* Brisson from Susunia, West Bengal which is believed to be about 20,000 years old. A new subspecies of extinct cattle, *Bos namadicus bengalensis* has been described by Ghosh (1977) from Mochpal, North 24-Parganas, West Bengal.

Area Covered

The survey for the prehistoric animal remains are carried out by the Archaeological Survey of India. So far collections from about 41 sites have been worked out. They are as follows :

1. Adamgarh; 2. Alamgirpur; 3. Arikamedu; 4. Aurangabad; 5. Bharatpur; 6. Brahmagiri; 7. Burzahom; 8. Harappa; 9. Hastinapur; 10. Jaugada; 11. Jorwe; 12. Kalibangan; 13. Kausambi; 14. Kaveripattanam; 15. Kesavapalli; 16. Kunnattur; 17. Lothal; 18. Mahisadal; 19. Maski; 20. Mohenjodaro; 21. Nagarjunakonda; 22. Nagda; 23. Nevasa; 24. Nasil; 25. Probhas; 26. Rajghat; 27. Rangpur; 28. Rupar; 29. Sanur; 30. Sarnath; 31. Taxilla; 32. Tilorkotkodam; 33. Ujjain. 34. Manglakot; 35. Pandu Rajar Dhibi; 36. Dhulian; 37. Boral; 38. Katasur; 39. Hatikra; 40. Bahiri; 41. Susunia.

The identification and research work on prehistoric animal remains are done in proper systematic and methodical way in this survey. Almost all the excavated material of animal remains of the Archaeological Survey of India have been worked out mostly by the scientists of this department. Some work is also being done by the Deccan College, Pune.

Areas to be explored

The excavation of the prehistoric sites in India is exclusively being carried out by the

Archaeological Survey of India (A.S.I.). The departmental scientists are sometimes attached with A.S.I. for field observations.

Expertise

INDIA

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ABROAD

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