


Ecosystems of India


J.R.B. Alfred
A.K.Das
A.K.Sanyal


ENVIS Centre
Zoological Survey of India

Ecosystems of India

Edited by

J.R.B. Alfred
A.K. Das
A.K. Sanyal

ZOOLOGICAL SURVEY
OF INDIA
1916

ENVIS Centre
Zoological Survey of India
Kolkata

CITATION
Alfred, J.R.B., Das, A.K. and Sanyal, A.K. 2001 *Ecosystems of India,* ENVIS—*Zool. Surv. India,* Kolkata : 1-410

Published : March, 2001

ISBN : 81-85874-57-3

PRICE
Indian Rs. 2000.00
Foreign $ 125 £ 100

Published at the ENVIS Centre by the Director, Zoological Survey of India, M-Block, New Alipore, Kolkata-700 053 and funded by the Ministry of Environment & Forests, Govt. of India. Laser typesetting by Calcutta Repro Graphics, Kolkata-700 006 and printed at Krishna Printing Works, Kolkata-700 006.

PREFACE

India is blessed with a highly variable natural continuum from snow clad high mountain ranges of the Himalaya to sea coasts of sandy, muddy, rocky, shingle and coralline nature through forests, grasslands, deserts, wetlands, mangroves and coral reefs. Covering the terrestrial part of the Indian territory in the south and west, there is a marine water-spread of variea depth with islands and archipelagoes of various configuration. In ecology, each of these are classified as ecosystem which is defined as a dynamic complex of interactive and interdependent biotic communities and their abiotic environment, functioning as an unit within a definable boundary.

However, there is no satisfactory and universally accepted definition and classification of ecosystem since variations and gradations between ecological communities are yet to be adequately and properly understood. As such, there is no unanimity in identifying ecosystem boundary. In reality, there is no discrete discontinuous unit in natural environment. Therefore, an ecosystem may be as large as biogeographic regions or as small as natural habitats and ecosystem diversity is considered at three levels—biogeographic regions, biotic provinces and biomes.

Ecosystems are usually demarcated on the basis of natural habitat classification on the physical characteristics and general appearance like forests and grasslands. They are also classified on the basis of geographical and geological features like mountains, islands, etc. Considering all these, the present publication incorporates eighteen articles on selected Indian ecosystems and their diversity at three levels as stated above, written by the concerned experts. These articles cover all the major natural habitats of India, namely, forests, grasslands, deserts, wetlands (including estuaries), mangroves, coral reefs and marine as well as geographical and geological features like high mountain ranges and the islands. The articles also include two significant biogeographic regions—Western Ghats and Deccan Peninsula and several biotic provinces : Trans-Himalaya, North-West Himalaya, Western Himalaya and Eastern Himalaya including North-East India. One important ecoregion, the Eastern Ghats has also been dealt with. A few of the articles are abridged and edited for keeping uniformity of the book.

We would like to thank all the authors and co-authors of the articles for their timely contributions, to Shri Rati Ram, Publication Production Officer, ZSI, for his assistance in printing the document and to Shri Nikhil Bhowmik, ZSI for redrawing several text-figures. We would like to thank to Shri Biswajit Roy Chowdhury, Nature, Environment & Wildlife Society, Kolkata and Shri Amit Ray, Kolkata for providing their photographs for this publication.

The Focal Point of Environmental Information System (ENVIS) in the Ministry of Environment & Forests, Government of India has provided financial support for the publication of this book, for which we are extremely grateful.

We hope this publication will serve as a valuable source of information for all concerned as well as for preparing National Biodiversity Strategy and Action Plan of this country.

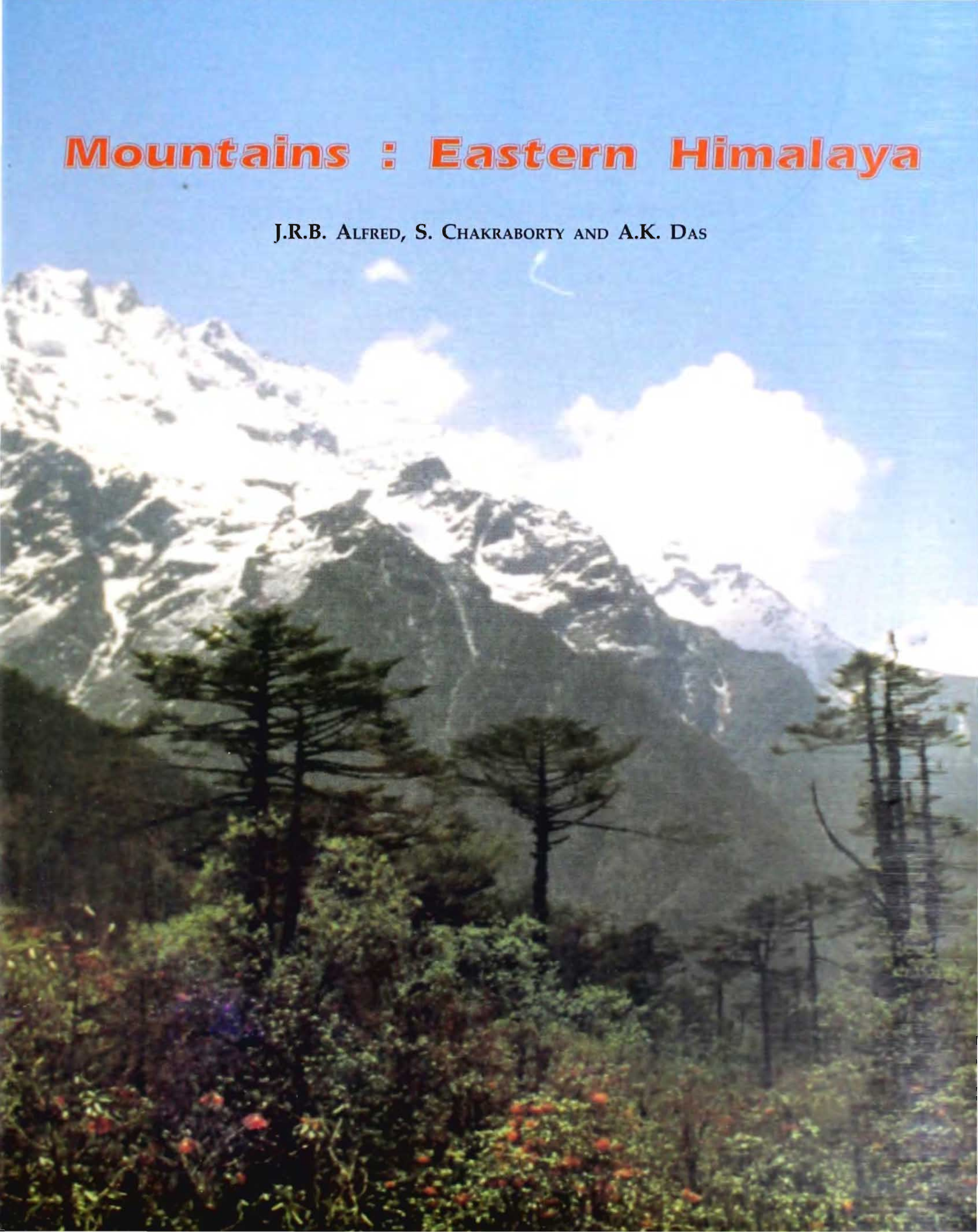
J.R.B. Alfred
A.K. Das
A.K. Sanyal

Kolkata
March, 2001

CONTENTS

Mountains : Eastern Himalaya

J.R.B. Alfred, S. Chakraborty and A.K. Das



ENVIS–*Zool. Surv. India*
Ecosystems of India : 1-33, 2001.

Mountains : Eastern Himalaya

J.R.B. ALFRED, S. CHAKRABORTY AND A.K. DAS

Zoological Survey of India
Kolkata-700 053

1. INTRODUCTION

The Himalaya is the great range of mountains that spreads over a west-northwest to east-southeast distance of about 2500 km, covering political administrative regions of Afghanistan, Pakistan, India Nepal, Bhutan and China. It extends from the Indus Trench below Nanga Parbat (8,125 m) in the west to Yarlungtsangpo—Brahmaputra george below Namche Barwa Peak (7,756 m) in the east, between 26°20′-35°40′ N latitudes and 74°50′-95°40′ E longitudes (Ives and Messerli, 1989). The Himalaya may be divided geographically into (1) the Eastern or the Assam Himalaya, (2) the Central or the Nepal Himalaya, (3) the Kumaon or the Western Himalaya and (4) the North-West or the Punjab Himalaya (Mani, 1974).

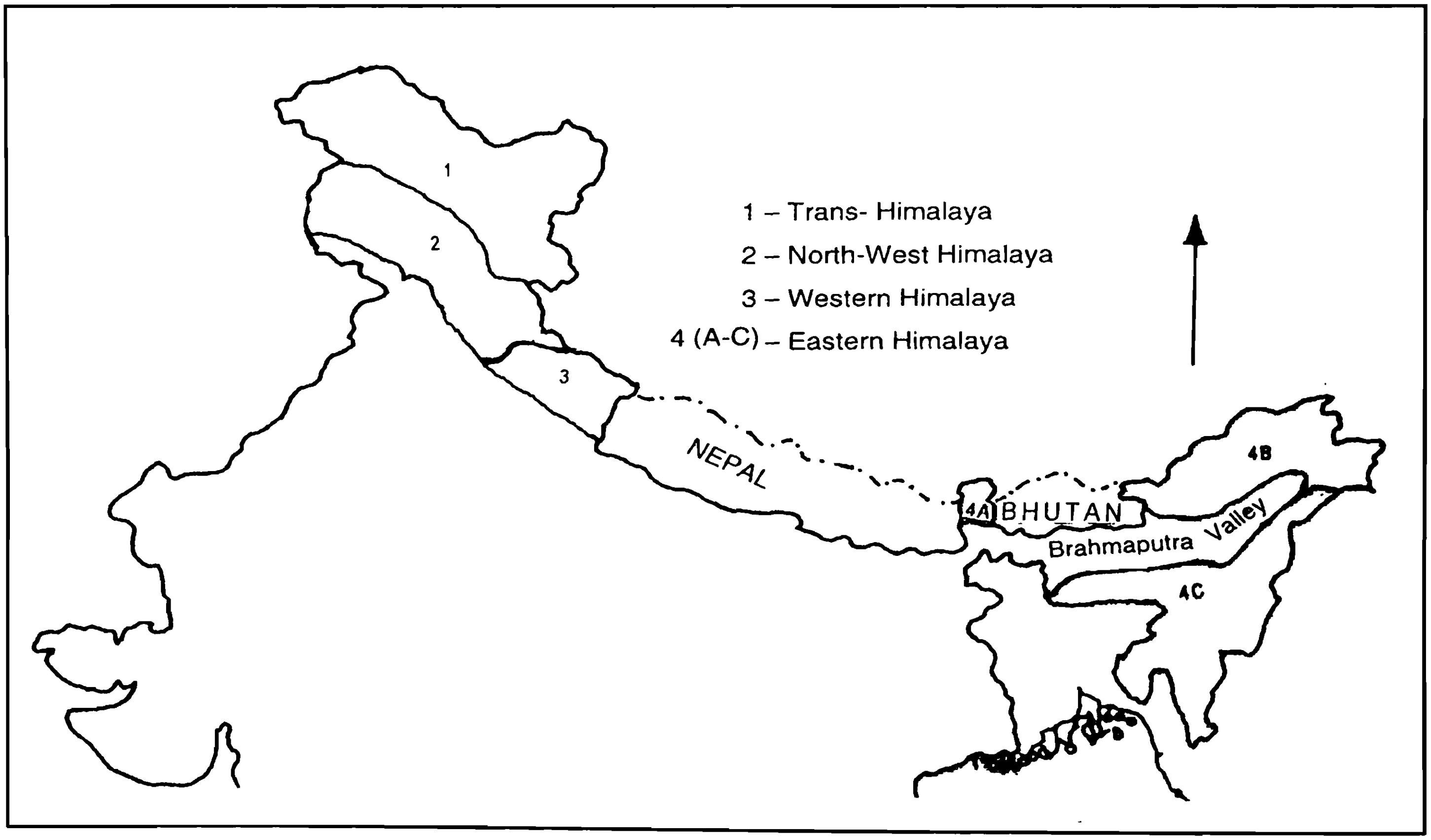


Fig. 1 : Biogeographic divisions of Indian Himalaya (only coloured area dealt with in the article)

The Himalaya, lying within the Indian territory has a width varying from 250 to 300 km and covers fully or partially 12 states of India, namely, Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, West Bengal, Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. It occupies 5,31,250 km^2 area, spreading between 21°57'-37°5'N latitudes and 72°40'-97°25' E longitudes, constituting about 16.6% of India's total geographical area (Nandi *et al.*, 2000).

Ahmad *et al.* (1990) divided Indian Himalaya into three main regions, namely, (1) Western Himalaya, which includes Jammu & Kashmir and Himachal Pradesh, (2) Central Himalaya which includes Garwal and Kumaon Division of Uttar Pradesh now known as Uttaranchal (8 hill districts) and (3) North-Eastern Himalaya which includes Assam (part), Meghalaya, Arunachal Pradesh, Sikkim, North Bengal, Manipur, Tripura, Nagaland and Mizoram. According to Rodgers and Panwar (1988), the Indian Himalaya as demarcated by Ahmad *et al.* comes under 3 biogeographic zones and 6 biotic provinces as presented in Table 1.

This is to mention here that, the biotic province, Brahmaputra valley which includes about 83% of Assam is excluded from the Indian Himalaya.

Recently the Indian Himalaya has been divided orographically into three "regional divisions" (Nandi *et al.* 2000) based on population features and vegetation elements. These are : (i) Western Himalaya, which includes Kashmir Himalaya and Himachal Himalaya (ii) Central Himalaya, which includes U.P. Himalaya, *i.e.*, Uttaranchal and (iii) Eastern Himalaya, which includes Sikkim and Darjeeling Hills and, "Purvanchal" (7 North-eastern States).

Considering both geographic and biogeographic divisions discussed above, the Indian Himalaya is divided into four zones as follows for the convenience of biodiversity analysis of the mountain ecosystems of India.

1. Trans-Himalaya which includes upper region of Jammu & Kashmir and Himachal Pradesh as in Table 1.

2. North-West Himalaya which includes Jammu & Kashmir and Himachal Pradesh excluding the Trans-Himalayan part.

Table 1. Biogeographic divisions of Indian Himalaya

Biogeographic zone	Biotic Provinces	State	% of State
1. Trans-Himalayan	Upper regions	Jammu & Kashmir	81
		Himachal Pradesh	11
2. Himalayan	North-West Himalaya	Jammu & Kashmir	18
		Himachal Pradesh	52
	West Himalaya	Himachal Pradesh	34
		Uttaranchal	100
	Central Himalaya	Sikkim	100
		West Bengal (Darjeeling district)	5.6
	East Himalaya	Arunachal Pradesh	100
3. North-East India	North-Eastern Hills	Assam	17
		Manipur	100
		Meghalaya	100
		Mizoram	100
		Nagaland	100
		Tripura	100

3. Western Himalaya includes Uttar Pradesh Himalaya (now known as Uttaranchal)

(= Central Himalaya, demarcated by Ahmad *et al.* 1990 and Nandi *et al.* 2000).

4. Eastern Himalaya, covering 3 biotic provinces, *viz.*, Central Himalaya, East Himalaya and North-Eastern Hills under 2 biogeographic zones, *viz.*, Himalayan (part) and North-East India (Table 1).

(= North-Eastern Himalaya, demarcated by Ahmad *et al.* 1990 and Eastern Himalaya, by Nandi *et al.* 2000).

In this context, the present article deals with biodiversity of the Eastern Himalaya as mentioned above. Geographically this region includes both "Assam Himalaya" (the portion between the Himalaya lying in Sikkim and Namcha Barwa Peak in Arunachal Pradesh) and North-Eastern Hills, *viz.*, Naga, Patkai, Khasi, Jaintia, Garo, Lusai and Mikir Hills. Moreover, for the sake of convenience biodiversity aspect of the Brahmaputra valley is also discussed under the present chapter.

Because of exceptional concentration of species with high level endemism and rapid rate of their depletion, Myers (1988) considered the Eastern Himalaya as one of the "Hotspots" of the world. In reality, this part of the Himalaya, with plains and hills of variable height, abundant rainfall, varied climatic features and lush vegetation provides wide gamut of habitats for numerous and diversified life forms. Richness in biodiversity is further enhanced as this region served as the biogeographic 'gateway' for much of the Indian flora and fauna. However, natural calamities, felling, hunting, shifting cultivation, refugee problem, developmental activities and others are altering the various habitats of the area and thereby depleting the biodiversity at a more and more faster rate.

2. DESCRIPTION AND PHYSIOGRAPHY

The Eastern Himalaya includes political boundaries of Sikkim (7096 km^2), Arunachal Pradesh (83743 km^2), Assam (part) (15322 km^2), Manipur (22,327 km^2), Meghalaya (22,423 km^2), Tripura (10,491 km^2), Mizoram (21081 km^2), Nagaland (16570 km^2) and Darjeeling district of West Bengal (3149 km^2). However, opinions differ regarding the limits of Eastern Himalaya as a biogeographic zone. While some workers include Sikkim, Darjeeling district of West Bengal and Arunachal Pradesh under Eastern Himalaya, yet others include only Arunachal under Eastern Himalaya and treat Sikkim-Darjeeling under Central Himalaya. In the present article, as accepted by a majority of biogeographers, Sikkim, Darjeeling (West Bengal) and Arunachal Pradesh are treated as a part of the Eastern Himalaya along with North-Eastern hills as discussed earlier.

The stretch of the Eastern Himalaya (covering the Central and Easter Himalayan biotic provinces) approximately runs to 850 km. Here the Himalaya rises rather abruptly from the plain and hence the sub-Himalayan zone is not distinct as compared to the Western Himalaya. This region is also more mesic. The high degree of precipitation is due to abruptly rising hills that directly confront the moisture laiden monsoon wind, blowing from the Bay of Bengal. The special horse-shoe shaped arrangement of the fold of the mountains ensure plenty of rains in most of the places. Alongwith the region of high rainfall, there are also regions with moderate to low rainfall, which account for a different vegetation types. The altitude ranges from 1500 m to the lofty ice-capped mountains of Kanchenjunga (8598 m).

The Eastern Himalaya, covering North-Eastern Hills biotic province represents the transition zone between Indian, Indo-Malayan and Indo-Chinese biogeographic regions as well as the meeting place of Himalayan mountains with that of Peninsular India. The region experiences heavy rainfall, frequent flood and landslides. The average rainfall in the sub-Himalayan ranges in Assam, Manipur and Tripura is 300 cm, but the rainfall pattern in the region highly varies from over 1100 cm at Cherrapunji and Mawsyangram (the world's raniest spots) to 230 cm at Shillong which is only 50 km north of Cherrapunji. Rainy season is characterised by humidity which favours rapid growth of vegetation. Summer (March-June) temperature over the hills varies from 5°-30°C and that in the foothills ranges from 12°-35°C. Winter months (December-March) are characterised by heavy dewfall and misty nights, and frost at higher elevations. The region is composed of two principal valleys-The Brahmaputra and Surma. The Surma valley is a level plain through which flows the river Surma, rising on the southern slopes on the mountains along the border of Naga Hills. The Brahmaputra valley, drained by river Brahmaputra, is 750 km long and roughly uniform 80 km wide alluvial plain bounded on the north by the Himalaya of Arunachal and Bhutan, on the east by Naga and Pakoi hills and on the south by Khasi, Jaintia and Garo Hills of Meghalaya. The valley is intensively cultivated and considerable areas of it is inundated during monsoon. In the north of Brahmaputra valley, the Himalaya is traversed from east to west by the rivers Luhit, Dibang, Siang and Subansiri. The eastern hill ranges are composed of the relatively narrow Patkoi Hills with a mean elevation of 1200 m. In the south, they are broaden out to form Naga Hills. Doiang is the main river of the area. The Manipur Plateau drained by the river Manipur, is situated south of Naga Hills. The Lushai Hills extending southwards from Manipur are disposed at a north south direction with Tlong, Sonai, Tuivol, Karnaphuli and others as the main rivers. In the south of Brahmaputra valley, from west to east are the Garo, Khasi and Jaintia Hills of Meghalaya. The southern and central parts of Meghalaya comprise the Shillong Plateau. On the east, Mikir Hills project into the Brahmaputra valley from the Hill ranges of Meghalaya.

Fig. 2 : Where glacier is melting

3. BIOLOGICAL DIVERSITY

3.1 Ecosystem/Habitat Diversity

The Eastern Himalaya is adorned with diverse ecosystems like forests, grasslands and wetlands including marshes, swamps, beels and lakes, streams and rivers, each of which comprises of a great variety of habitats.

3.1.1. Forests : The Eastern Himalaya abounds in forests. The forests in the region are of 4 major types, *viz.*, the tropical, the temperate, the subalpine and the alpine, each with numerous subtypes. Distribution of different types of forest in different states of the Eastern Himalaya is shown in Table 2. However, regardless of type, forests possess large above-ground biomass and provide numerous niches.

Tropical vegetation typically occurs up to 900 m and includes evergreen, semievergreen and deciduous forests, grasslands and swamps. Tropical evergreen forests may extend up to 1000 m and are found in the Assam valley, in the foothills of Himalaya and in the lower parts of Naga Hills and Manipur where rainfall and humidity are very high. Tropical evergreen forests exhibit distinct stratification with top storey consisting of tall trees of *Dipterocarpus retusus, Artocarpus chama, etc.* Trees are heavily plastered with lichens and festooned with climbers and epiphytes. Depending upon location and precipitation, these forests also harbour a number of semievergreen trees. Tropical evergreen and semievergreen forests represent one of the major ecological types in the zone with a rich floristic diversity. The vegetation seems to be of a climatic climax type. The middle storey is characterised by the preponderance of *Mesua ferrea, Endospermum diadenum, Ficus* spp., *etc.* The third storey wherever evident, consists of trees of 5 to 10 m high and the main components in this category are *Premna bengalensis, Carallia brachiata, Hibiscus macrophyllus, etc.* In moist areas particularly in valleys, these forests are often interspersed with various bamboo species. Ferns and orchids are quite conspicuous epiphytic species in these forests.

The tropical deciduous forests occur in areas like Goalpara, Kamrup, Nowgang, Darrang and northern lower slopes of Garo and Khasi Hills, where rainfall is less than 150 cm. Important tree species are *Shorea robusta, Tectona grandis, Sterculia villosa, etc. Albizia* spp. are also in abundance but in scattered form. A distinct second storey of *Aporusa octandra, Careya arborea, Rhus semilata* are also not uncommon. Shrubby layer is often gregarious and forms impenetrable thickets

Table 2. Distribution of major forest types in the different States of the Eastern Himalaya

Forest types	Assam	Arunachal Pradesh	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura	West Bengal (Darjeeling)
Tropical Wet Evergreen	+	+	+	-	+	+	+	-	+
Tropical Semi-Evergreen	+	-	-	-	-	+	-	-	+
Tropical Moist Deciduous	+	-	+	+	+	-	-	+	+
Sub Tropical Broadleaved Hill	+	-	-	-	-	-	-	-	+
Sub Tropical Pine	-	+	+	+	-	+	+	-	+
Montane Wet Temperate	-	+	-	-	-	+	-	-	+
Sub Alpine	-	+	+	-	-	+	+	-	+
Dry Alpine Scrub	-	+	-	-	-	-	+	-	-
Moist Alpine Scrub	-	+	-	-	-	-	+	-	-

during rainy season. The lianas and ephiphytic flora is extremely low. Introduced weedy species of the genera *Eupatorium, Mikania, Galinsoga, Lantana* can be seen during dry season. Most of the deciduous forests in this part are not the typical natural deciduous forests but are only subclimax, man-made forests. Tropical bamboo forests form pure stand in many localities of Eartern Himalaya, but these are also not natural and appear in Jhum fallows of 25-50 years.

Subtropical forest typically covers the elevation from 900-2000 m with an average rainfall of 150-500 cm. Subtropical evergreen and semievergreen forests are climatic climax forests and seen in scattered valleys, banks of rivers and in pockets on hills. Trees are generally short and bushy in appearance. The stratification is not well marked. Undergrowth is almost impenetrable. Common tree species are *Callicarpa* spp., *Castanopsis tribuloides, Ficus elastica, Schima wallichi, Magnolia insignis, Michelia* spp., *etc.* Subtropical pine forests are found at higher elevation (1200-2000 m) along the hill slopes of Arunachal, Sikkim, Darjeeling, Manipur, Nagaland and Meghalaya. These are climax forests of secondary nature. *Pinus kesiya* is the principal species occurring in almost pure stands. Occasionally broad-leaved species like *Rhododendron arboreum, Schima wallichi, Engelhardtia spicata, etc.,* are associated. The forest floor, covered by thick mat of pine

Fig 3 : Alpine malow in bloom

leaves which supports the growth of shrubby and herbaceous species.

Temperate forests chiefly occupy the areas between 1800-3500 m with high rainfall (200-500 cm) in Sikkim, Darjeeling, Arunachal, Shillong plateau, Nagaland, Lushai and Mikir Hills. In comparatively lower region, mixed forest of *Acer, Betula, Jugulans, Magnolia, Michelia, Rhododendron* and others characterised the hill tops and valleys. At higher region, the temperate forests are dominated by the genera, *Pinus, Tsuga, Abies, Cupressus, etc*. These coniferous belts are also associated with broad-leaved plants like *Rhododendron, Pyrus, Acer* and others. Epiphytic flora is exceptionally rich as almost all the trees are heavily covered with a layer of epiphytes. Fern flora dominates over flowering plants.

The temperate vegetation in Khasi and Jaintia Hills in the form of "Sacred forests" at Shillong peak, Mawpholong and Mowsmai are most significant from the point of conservation. These forests are relict types and are left in small pockets untouched due to religious belief and myths. "Sacred forests" are rich storehouses of vegetal wealth. Many rare and endangered species of the region are also now finding a refuge in these sacred forests. Dominant species of "Sacred forests" belong to the genera *Castanopsis, Photinia, Eriobotrya, Pyrus, Prunus* and *Sorbus*. Primitive flowering plants, *viz., Coryloposis himalayana, Exbucklandia populnea, etc.*, are common. The forest floor has a thick mat of litter.

Fig 4 : Alpine zone with Rhododendrons, Silver in foreground and nival snowcapped mountain peaks behind

Subalpine forests usually range between 3500-4200 m altitude of Sikkim, Darjeeling, Arunachal, and also in Nagaland and Manipur. Tree species are very poor and mostly represented by *Abies*, *Betula* and rarely *Juniperus*. Bushy and herbaceous species belonging to the genera *Berberis*, *Cotoneaster*, *Ribes*, *Rhododendron* and *Salix* are conspicuous. Aerial portion of many of these plants die off during severe winter and heavy snowfall.

Alpine vegetation occurs between 4200-5500 m in Arunachal and Sikkim. The vegetation is strikingly composed of low shrubs and herb; trees are wanting and the region resembles a moorland. *Rhododendron anthopogon*, *R. campanulatum*, *R. nivale*, *R. pumilum*, *Primula sikkimensis*, *P. glabra*, *Sedum spp.*, *Bergenia* spp., *etc.*, are common. The Nathula region of Sikkim is more humid and characterised by gregarious patches of ornamental *Primula calderiana* and *Rheum nobile*, while southwest Sikkim shows a strong admixture of western Himalaya and Tibetan species, particularly belonging to the families Arecaceae, Primulaceae, Asteraceae, Rosaceae, *etc.*

3.1.2. Grasslands : Tropical grasslands occur in ripararian flats inundated by flood water of river Brahmaputra. Grasses are tall and belong to the species of *Saccharum*, *Anthisteria*, *Erianthus*, *Setaria*, *Arundinella* and a few others reaching as high as 5 m. These grasslands are also not climax type but resulted from the removal of original forest cover by the combined effect of frequent heavy floods, fire, tree-felling, and grazing. The grassland area of the Kaziranga represents a combination of grasslands, swamp forests and marsh, which form the ideal habitat of one-horned rhino. The tropical grasslands are different from those in the higher elevation of Shillong plateau and lower parts of North Cachar and Mikkir Hills, where the rolling grasslands are composed of much shorter grasses at the ground level.

3.1.3. Cultivated Fields and Human Habitations : These are diffused throughout the area, either continuous for long stretches in the plains or are isolated patches in the mountaneous regions. Of these, Jhum fields deserve special mention. Shifting cultivation (*Jhum*) in hill section is a common landuse. The process involves cutting of tropical and subtropical forests, burning, growing mixed crops and fallowing to regenerate the productivity of soil. The traditional 20-30 years or more of *Jhum* cycle has now been reduced to 4-5 years or even less in many areas, thereby reducing crop productivity and regenerating capacity of soils. Along with these, changes are also brought about in the biota of the soils. Total area affected by the shifting cultivation in some states of Eastern Himalaya is shown in Table 3.

Fig 5 : Ridges with pristine forest tract and jhum field in Mizoram

3.1.4. Wetlands : The swamp or marsh vegetation is a typical feature in the warm, humid Assam valley. There are innumerable stagnant ponds in the region specially in Goalpara, Kamrup and North Lakhimpur.

Fig 6 : Temporary bog as splashed by melted snow in Sikkim

These ponds or 'beels' support a rich diversity of aquatic angiosperms mainly belonging to the families Nymphaeaceae, Lemnaceae, Araceae, Poaceae, *etc*. *Euryale ferox* with large orbicular leaves covering the water surface is very common in Kamrup. In fact, entire Eastern Himalaya is dotted with numerous wetlands. The details of some major wetlands in different states of Eastern Himalaya are summarised in Table 4 along with their ecological category.

3.1.5. Streams and rivers : Entire Eastern Himalaya is ornamented with numerous streams. Upland headwaters streams are small, shallow, usually swift and cold. Production, although high, is dependent upon the

Table 3. Cumulative area (in million hactre) affected by the shifting cultivation in 7 States of the Eastern Himalaya (Anon. 1999).

States	Cumulative area (1987 to 1997)
Arunachal Pradesh	0.23
Assam	0.13
Manipur	0.36
Meghalaya	0.18
Mizoram	0.38
Nagaland	0.39
Tripura	0.06
Total	1.73

Table 4. Distribution of major wetlands (over 100 ha) in the different States of the Eastern Himalaya (Adopted from MoEF, 1990)

State	Sl. No.	Name of District	Name of Wetland	Name of nearest Town/Village	Lat.	Long.	Area (ha)	Ecological Category
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Arunachal	1.	Kameng	Pakhui (N)	Tejpur	26°50'	92°00'	20,000	Freshwater
Pradesh	2.	Subansiri	Talley Valley (N)	Hapoli	28°30'	94°00'	200	Freshwater
Assam	3.	Dibrugarh	Ladkhowa Ghats (N)	Saikhowa	26°27'	92°35'	2,800	Freshwater
	4.	Goalpara	Dalani Beel (N)	Calanta Para	26°15'	90°35'	200	Freshwater
	5.	Goalpara	Dhir Beel (N)	Chapper	26°15'	90°25'	450	Freshwater
	6.	Goalpara	Chandakhal Beel (N)	Dhubri	26°00'	89°55'	250	Freshwater
	7.	Goalpara	Hahilia Beel (N)	Goalpara	26°10'	90°35'	400	Freshwater
	8.	Goalpara	Kanar Beel (N)	Haripani	26°17'	90°40'	450	Freshwater
	9.	Goalpara	Medo Beel (N)	Majadar Hat	26°00'	90°05'	300	Freshwater
	10.	Goalpara	Sareswar Beel (N)	Gouripur	25°55'	90°05'	350	Freshwater
	11.	Goalpara	Tamaranga Beel (N)	Haripur	26°17'	90°40'	500	Freshwater
	12.	Goalpara	Urpad Beel (N)	Solmari	26°15'	90°40'	1000	Freshwater
	13.	Kamrup	Andheri Beel (N)	Chatgano	26°00'	91°40'	200	Freshwater
	14.	Kamrup	Chand Dubi Beel (N)	Pabsabari	26°25'	91°25'	1500	Freshwater
	15.	Kamrup	Dipor Beel (N)	Guwahati	26°07'	91°40'	1000	Freshwater
	16.	Kamrup	Laothari Swamps (N)	Mukalana	26°20'	92°25'	260	Freshwater
	17.	Karbi Anglong	Amreng Beel (N)	Diphu	25°50'	93°25'	150	Brackish water

Table 4. (contd.).

State	Sl. No.	Name of District	Name of Wetland	Name of nearest Town/Village	Lat.	Long.	Area (ha)	Ecological Category
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	18.	Karbi Anglong	Daldali Swamps (N)	Diphu	25°50'	93°25'	150	Brackish water
	19.	Karbi Anglong	Disama Beel (N)	Diphu			150	Brackish water
	20.	Naogaon	Joysagar (N)	Silghat	26°35'	92°55'	173	Freshwater
	21.	Naogaon	Kaziranga Swamps (N)	Jorhat	26°30'	93°05'	28,500	Freshwater
	22.	Sibsagar	Arimora (N)	Kohara	26°40'	93°25'	168	Freshwater
	23.	Sibsagar	Baguri Bor (N)	Baguri	26°30'	93°15'	110	Freshwater
Manipur	24.	Bishnupur	Loktak Lake (N)	Moirang	24°26'	93°49'	26,600	Freshwater
	25.	Bishnupur	Takmu (N)	Thanga			13,000	Freshwater
	26.	Bishnupur	Kharungpat (N)	Sekmaijin			500	Freshwater
	27.	Bishnupur	Pumlenpat (N)	Ithai			200	Freshwater
	28.	Bishnupur	Naorempat (N)	Hambal			120	Freshwater
Meghalaya	29.	East Khasi	Umian (N)		25°05'	91°09'	400	Freshwater
Nagaland	30.	Kohima	Pirnla & Dhaneari (N)	Dimapur			110	Freshwater
Sikkim	31.	North Sikkim	Gurudengman Tso (N)	Yumchho			135	Freshwater
Tripura	32.	South Tripura	Harijala (N)	Kakmaban	23°28'	91°25'	180	Freshwater
	33.	North Tripura	Khaurabil (N)	Kailashahar	24°22'	92°00'	145	Freshwater
	34.	West Tripura	Rudrasaga (N)	Sonamura	23°30'	91°19'	250	Freshwater
	35.	South Tripura	Gomti Reservoir (A)	Jatanbari	23°25'	91°52'	4,833	Freshwater

watershed they drain for nutrients which do not remain confined in one place. They are also removed and carried downstream by the current. Here, organisms are usually streamlined or flattened so that they can escape the current in crevices and underneath rocks or they may attach to the substratum. In downstream the volume of flow, width and depth of stream increase, while current becomes slow. Bottom turns soft with silt and mud. Here biota of swiftwater is replaced mostly by aquatic plants and animals which are usually characteristics of ponds and lakes. Some of the major rivers of Eastern Himalaya are : Brahmaputra, Teesta, Dibang, Dihang, Dibru, Dihing, Bhogdai, Disang, Dikho, Jhanji, Subansiri, Manas, Sankash, *etc.* The above and many other rivers form an intricate network of flowing waters in the entire Eastern Himalaya. These rivers in their different courses support a rich and diverse aquatic plants and animals, both invertebrates and vertebrates.

3.1.6. Special Habitats : The entire region, particularly the hill section is marked with numerous caves, cliffs, overhangs, crevices, *etc.* These are geomorphic in nature and serve as unique wildlife habitats of special function. These are not included within plant communities and successional stages. Many of these habitats supports a characteristic faunal composition. Excavation of Siju Cave in west Garo hills during 1922 revealed more than 100 species, both vertebrates and invertebrates. Many of those animal species though common in the cave were rare in the outside. Further, some of the species particularly molluscan and crustacean ones exhibit cavernicolous adaptation. Lamsial, Pukjing, Lakadong, Milu, *etc.* are some of the other important caves of the area.

3.2 Species Diversity

3.2.1 Flora : As already stated, the area harbours tropical, temperate, subalpine and alpine vegetation, with their characteristic species composition. Moreover the location of Eastern Himalaya is such that this region is not only able to capture maximum precipitation and high humidity, which is condusive for flora, but also comes in direct contact with many other floristic regions. All these factors have rendered this region as the richest botanical diversity centre in the entire subcontinent. Considering the richness as well as uniqueness, it is not possible to describe the diversity in all the groups of plants. As such, some selected groups are discussed below.

Orchid diversity : The Orchidaceae is the second largest family of flowering plants in India. Jain and Mehrotra (1984) listed 144 genera and 925 species of Orchids in India. Considering the recent additions to the Orchid flora one can put the number of Orchids at 1000, of which about 700 species are represented in the Eastern Himalaya alone. During one field trip, 18 species of Orchids were counted in a single tree in Khasi hills (Rao, 1994). Among the genera with highest diversity *Dendrobium*, *Bulbophyllum*, *Liparis*, *Ceologyne*, *Habenaria* and *Paphiopedilum* are important (Table 5).

Table 5. Diversity in some major groups of Orchids of the Eastern Himalaya (After Rao 1994)

Name of the genus	No. of species	
	India	Eastern Himalaya
Dendrobium	75	65
Bulbophyllum	50	35
Liparis	45	35
Ceologyne	35	30
Habenaria	100	45
Paphiopedilum	5	4

Rhododendron diversity : The *Rhododendron* belonging to the family Ericaceae has about 90 species in India, of which 80 species are exclusively confined to the present region. Arunachal alone has about 70 species. Sikkim is another region rich in *Rhododendron*. Some common species are *R. baileyi*, *R. bulu*, *R.*

hookeri, R. johnstoneanum, R. rex, R. anthopogon, R. arboreum, etc. Apart from just the number of species, *Rhododendron* has life form diversity like herbs, shrubs and trees.

Hedychium Diversity: Genus *Hedychium* under the family Zingiberaceae includes ornamental plants that can be directly introduced into our gardens. There are about 40 species in India, of which 35 occur in the Eastern Himalaya alone. From Arunachal itself 18 species are reported (Haridasan and Hegde, 1991). Some of the common species are *H. aurantiacum*, and *H. villosum*; rare ones are *H. luteum, H. greenii, H. aureum, H. wardii, etc.*

Diversity in Bamboos : Out of 18 genera and 130 species so far known in India, 15 genera and 82 species are represented in this part of Himalaya (Table 6).

The genetic resource is getting eroded in some of the bamboo species as their populations have become highly fragmented mainly due to practice of shifting agriculture and selective removal. Some of these species are *Arundinaria clarkei, A. mannii, Bambusa mastersii, Phyllostachys assamica, P. mannii, etc.*

Table 6. Genera and number of species of Bamboos reported from the Eastern Himalaya

Name of the Genera	No. of species
Teinostachyum	1
Arundinaria	10
Bambusa	22
Cephalostachyum	7
Chimanobambusa	9
Dendrocalamus	15
Oxytenanthera	2
Thamnocalamus	4
Dinochloa	2
Gigantochloa	2
Melocalamus	1
Melocanna	2
Neohouzeaua	2
Phyllostachys	2
Pseudostachyum	1

Diversity in timber species: A large number of commercial timber species come from the Eastern Himalaya. Rao (1994) made a list of 37 species belonging to 35 genera from the region. These species are in the market under the trade names Black Siris, Bahera, Champa, Chaplash, Gokul, Hollock, Kadam, Kumbi, Sal, Harra, Neem, Sheesham, Toon, Walnut, *etc.*

Medicinal plant diversity: The Himalaya in general, since ages has served as a storehouse of numerous life saving drugs. Recent ethnobotanical studies (Rao 1981, Rao and Jamir 1982, Rao and Haridasan 1991) in

Table 7. Medicinal plant diversity in the different forest zones of the Eastern Himalaya (Adopted from Rao 1984).

Forest Types	Species Names
Tropical and Subtropical	*Abrus precatorius, Acorus calamus, Adhatoda zeylanica, Atrops acuminata, Centella asiatica, Costus speciosus, Dioscorea deltoidea, Hydnocarpus kurzii, Hyoscyamus niger, Gloriosa superba, Mucuna prurita, Ocimus sanctum, Paederia foetida, Plumbago zeylanica, Rauvolfia serpentina, Veteveria zizanioides.*
Temperate	*Artemisia nilagirica, Berberis asiatica, Taxus wallichiana, Bergenia ciliata, Ephedra gerardiana, Habenaria commelinifolia, Hoya globulosa, Gaultheria fragrantissima, Gentiana kurroo, Illicium griffithi, Mahonia nepalensis, Myrica esculenta, Panax pseudoginseng, Sarcandra glabra, Saussurea lappa.*
Subalpine and Alpine	*Aconitum chasmanthum, A. deinorrhizum, A ferox, A hetero-phyllum Coptis teeta, Swertia chirayita, S. hookeri, S. ciliata, Nardostachys grandiflora, Picrorhiza kurrooa, Podophyllum hexandrum, Rheum australe, R. nobile, Veleriana hardwickii, V. jatamansi.*

Eastern Himalaya have shown enormous diversity in them. Table 7 lists some important medicinal plants from the different forest zones of the Eastern Himalaya. While some of these, *e.g., Taxus wallichiana, Coptis teeta, Podophyllum hexandrum* have been extensively exploited and others have become rare due to destruction of habitat.

Diversity in primitive flowering plants : Eastern Himalaya has been considered as a sanctuary of ancient angisosperms. There are a number of such species, *viz., Magnolia griffithi, M. gustavi, M. pterocarpa, Euptelea* spp., *Pycnarrhena, pleniflora, Parvatia brunoniana, Decaisnea insignis, etc.,* which grow in this part of Himalaya and further eastwards but do not occur in any other parts of India.

Nonflowering plant diversity : The ferns and fern-allies form a striking features of vegetation of the Eastern Himalaya. Out of about 1000 species of ferns occurring in India 50% are represented in this region. Some of the rare and interesting ferns of this region are *Dipteris wallichii, Osmunda cinnamomea, O. regalis, Botrychium languginosum* and few others. The diversity of fern allies like *Selaginella* and *Lycopodium* is best expressed in this region. There are 12 species of *Lycopodium* in this part of the Himalaya against only three in West Himalaya.

Fig 7 : Bracketed fern along damp hill slope

3.2.2 Fauna : Geographical location, rich and diverse foliage cover, vast stretches of grasslands with an wide array of floral species, numerous and varied types of wetlands, special habitats, climatic and altitudinal variations offer a host of microclimatic condition and niches to support a great assemblege of faunal components. As vast areas of the Eastern Himalaya are yet to be explored with special reference to many of the groups, following descriptions only provide a glimpse of the actual faunal richness existing in the region.

Protista (Protozoa) : Protozoa are underexplored throughout the Indian Himalaya including the Eastern Himalaya. Even then, 256 species of Protozoa have been recorded from this region, out of which 100 species are freeliving, 121 species parasitic and 35 species symbiotic. Freeliving protozoa were collected from soil, mossess and freshwater, while parasitic protozoa were recovered from gut contents, blood, coelomic fluid and smears of different organs like lungs, livers, kidney, *etc.,* of different vertebrate and invertebrate hosts. The symbiotic protozoa were collected from the gut contents of wood-eating termites, belonging to the families Kalotermitidae and Rhinotermitidae. Statewise record of Protozoan species in the Eastern Himalaya is presented in the Table 8. From the table it is quite evident that the Assam region is unexplored for this group.

Invertebrates

Porifera : Out of 31 species of Indian freshwater sponges (Family : Spongillidae),

Table 8. Species diversity of Protozoa in the Eastern Himalaya

State	Number of species of Protozoa :			
	Freeliving	Parasitic	Symbiotic	Total
Arunachal Pradesh	43	20	9	72
Manipur	77	8	—	85
Meghalaya	58	58	12	128
Mizoram	31	—	—	—
Nagaland	22	3	34	59
Sikkim	55	2	23	80
Tripura	45	37	20	102
West Bengal (Darjeeling dist.)	11	72	—	83

only six (Arunachal-2; Assam-3; Meghalaya-1) are so far known from the region.

Platyhelminthes : Nine species belonging to equal number of genera of Trematoda have been reported from the vertebrate hosts from Darjeeling district, while from Meghalaya 53 species under 38 genera have been recorded. As regard Cestoda, 30 species belonging to 18 genera are known from Meghalaya. Out of 47 Indian Turbellarian species only five belonging to two genera, *viz.*, *Bipalium* and *Palmatoplana* are so far known from the region.

Nematoda : Soil samples associated with citrus trees in Sikkim revealed a high degree of abundance and dominance of Nematode fauna consisting of 61 species under four orders, *viz.*, Tylenchida, Aphelenchida, Dorylaimida and Monochida (Baqri 1991). Further, 28 species belonging 14 genera have been reported from the different plant species of Meghalaya. An index of species to genus (34 spp., 26 genera in Arunachal; 47 spp., 35 genera in Meghalaya) of Nematode parasites from vertebrate host indicates an assemblege of high diversity.

Rotifera : Rotifers comprise an integral link in aquatic food chain by virtue of their rapid turn over rate and thus becoming significant constituents of fresh water ecosystem. In all 132 species belonging to 32 genera and 19 families are so far represented from the region, which represent 46.6% and 50.8% of the total species and genera respectively know from the country. Further, Rotifer fauna of the Eastern Himalaya is characterised by more qualitative diversity of *Lecane* spp. and relative paucity of *Brachionus* spp.—a feature well in conformity with acidic nature of waters and fewer permanent lentic biotopes (Sharma 1998). Among the endemic species *Lecane jaintiensis*, *Lepadella nartiangensis*, *L. patella* may be mentioned.

Gastrotricha : A total of five species belonging to two genera, *viz.*, *Chaetinotus* and *Lepidodermella* are known from Meghalaya, of which two are discontinuously distributed in Andhra Pradesh.

Annelida : At least 52 species of oligochaete worms are known from the region of which *Plutellus bahli*, *P. dominensis*, *P. richikensis*, *Tonoscolex kabakensis*, *etc.*, are endemic in the Eastern Himalaya. Not much study has been made as regard the Hirudinean species. However, 9 species belonging to 8 genera and 5 species belonging to 3 genera have been recorded from Meghalaya and Arunachal Pradesh respectively.

Arthopoda

Onychophora : These are considered as connecting link between Annelida and Arthopoda and species belonging to this class are known as 'living fossils' Out of about

100 species of the world, only one, *viz.*, *Typhloperipatus williamsoni* occurs in the Indian limit and that too is confined to the Abor Hills. The Indian species exhibits alliances with the species occurring in Sumatra and Malay Peninsula.

Crustacea : Crustaceans play an indirect role in the trophic dynamics of aquatic ecosystems, particularly the Cladocerans which are considered to be the most important group converting more than 75% of the absorbed energy for reproduction (Venkataraman and Krishnamoorthy 1998). Survey of water bodies in Meghalaya revealed that zooplankton numerically constitutes at an average 24.6% Copepods and 22.1% Cladoceran individuals. However, detail species list of Crustacean fauna of the Eastern Himalaya is not available except for Meghalaya which harbours 60 species belonging to 39 genera (Alfred 1995). Chopra (1924) reported four species of Isopoda from Sizu cave, in one of which, *viz.*, *Philoscia dobakholi* colour is almost totally bleached and eyes considerably reduced. Ghosh (1987) reported 2 species under two genera under Isopoda and 11 species under four genera belonging to Decapoda from Namdhapha. Kemp (1924) reported three species of Decapoda from the Siju cave, of which *Palaemon cavernicola* is the only true cave dwelling form of the oriental region showing some adaptations for cavernicolous existence. As regard Cladocerans, following number of species have been reported from the different states of the Eastern Himalaya: Assam-13; Meghalaya-41; Manipur-6; Tripura-7.

Arachnida : Of the 1270 species of Indian spiders (Araneae), 92 species are known from the Eastern Himalaya, of which 15 are endemic. Waterbodies of the region also harbour a good number species particularly of those belonging to the genera *Lycosa*, *Hippasa*, *Perdosa etc.*

As compared to the country's figure of 2186 Acarine species, relatively fewer number of species are known from the Eastern Himalaya (Table 9). However, of the recorded species, nearly 45% are endemic to the region. Further, Darlong and Alfred (1993) found that Acarine species are the most dominant among the microarthopods occurring in the soils of the Eastern Himalaya. They also revealed that species diversity is less in 'Jhum' fields as compared to that in forest soils. Some Acarine species of the region are discontinuously distributed, such as, *Agistemns industani* (Nagaland and Kerala), *A. garrulus* (Meghalaya and Pakistan). Except for a few tick species so far no mite species has been recorded from Mizoram.

Of the 167 Indian Opiliones, only two have been recorded from Siju cave (Roewar 1924).

Table 9. Number of Acarine species in the different States of Eastern Himalaya (Adopted from Sanyal 1998)

States	Prostigmata	Astigmata	Mesostigmata	Cryptostigmata	Metastigmata
Arunachal Pradesh	—	—	4	—	12
Assam	20	2	26	11	10
Manipur	33	—	5	5	4
Meghalaya	11	—	25	—	5
Mizoram	—	—	—	—	4
Nagaland	2	—	—	5	4
Sikkim	—	—	—	21	2
Tripura	—	—	10	90	6
Darjeeling, W.B.	72	14	30	104	16

Insecta : Very little information regarding Apterygote insects of the region is available. So far only 5 species of Thysanura and 37 species of Collembota have been listed. One species of Thysanura (*Ctenolepisma nigra*) is endemic to Manipur, while Collembolan species *Salina tricolor* and *Callyntrura vestita* are discontinuously distributed in Peninsular India (Mitra 1973, 74; Hazra *et al.* 1999). It is interesting to note that although not much species diversity of Collembola has been recorded, next to Acarina, this animal groups is most dominant and abundant in soils.

Termite fauna hold a vital status as a primary consumer and contribute in many ways in the tropical ecosystem. They are involved in increasing soil fertility by disintegrating wood in its various forms and thereby enhance the plant growth. Termites in the Eastern Himalaya are represented by five families (Kalotermitidae, Rhinotermitidae, Stylotermitidae, Indotermitidae and Termitidae), 27 genera, 76 species (Bose 1999). Kalotermitid genera *Neotermes* and *Glyptotermes* have wide distribution in the tropics, but the species represented in the Eastern Himalaya are endemic. Rhinotermitid genera *Reticulitermes* (5 spp.) and *Parrhinotermes* (2 spp.) are also endemic while the genus *Stylotermes* though widely distributed, is represented in the region by a single endemic species. In all 36 species out 76 are endemic. Occurrence of *Nasutitermes* in the Eastern Himalaya is an indicator of rich biodiversity in rain forest and grassland ecosystems. Likewise, presence of *Reticulotermes* indicates temperate climatic conditions (Maiti and Saha 1998).

Srivastava (1976) estimated 125 species of Dermaptera from the Eastern Himalaya, which is nearly half of the total Indian fauna. As many as 58 species and two genera, *viz.*, *Aborolabis* and *Prasadiya* are endemic. Fifty species are derivatives of Indochinese and Indomalayan elements, while species belonging the genera *Anechura, Aliodahlia* and *Forficula* have Palaearctic affinities.

Blattariae insects are adapted to diverse habitats. Some are semiaquatic, while others are found among the fallen leaves on soil surface, under stone and bark, in grasses, debris, caves, houses and godowns. As such, great species diversity is expected in the region. However, due to lack of exploration only a few species are reported. Ghosh (1987) reported 34 species of eight genera from Namdhapha, while Alfred (1995) estimated 26 species belonging to 20 genera from Meghalaya. Quite blind, cavernicolous species *Diestrammena brevifroms frieli* from Lekadong cave exhibits parallel evolution with the Europeans species of the genera *Dolichopoda* and *Troglophilus* (Chopard 1924). Several domestic pest species, e.g., *Blatta orientalis, Periplaneta* spp., *Blattella germanica, B. humbertiana* are found to be well established in the region.

Mitra (1994) reported 315 species of Odonates from Eastern India which includes those from Bihar, Orissa and whole of West Bengal in addition to Eastern Himalaya. Prasad (Pers. Comm.) provided the following break up of number of Odonate species and genera (given in parentheses) from different states under Eastern Himalaya : Mizoram-64 (41); Meghalaya 151 (79); Nagaland-48 (32); Arunachal 91 (41); Assam 24 (15); Tripura 35 (21); Sikkim 24 (16). Majority of these species are confined to Eastern Himalaya, Indo-Chinese and Indo-Malayan regions, but a few, *e.g., Agriocnemis pygmaea* ranges up to Australia.

Orthopteran fauna exhibits a complex admixture of endemic, Indo-Chinese, Malayan, Palaearctic, Ethiopian and a few Neotropical forms. A total of 77 species belonging 24 genera of Tetrigidae and 81 species under 39 genera of Gryllidae are known from Eastern Himalaya (Shishodia 1991, Vasanth 1993), while Hazra *et al.* (1995) reported 55 species under 38 genera belonging to Acridoidea from Meghalaya. Maximum diversity of Orthopteran species has been observed in the typical rain forest areas. However, distribution pattern of grasshoppers is changing rapidly due to encroachment of grasslands and forests for agricultural and Industrial purposes.

Hazra and Mukherjee (1998) recorded following number of species and genera of Praying Mantis (Mantodea) from some states of the region : Arunachal-20 (12); Assam-29(22); Manipur-10(7); Meghalaya-25(17); Sikkim-16(12); Tripura-7(2).

In the Hemipteran fauna of the Eastern Himalaya, Palaearctic, Chinese and Malayan elements are well represented. Statewise species list, is not available but richness is obvious from the fact that Meghalaya alone harbours 516 species under 318 genera. Species diversity and abundance in Aphididae is more marked in hilly terrain which meets with the subtropical to warm temperate climate and represents the transition zone between the realms of Oriental and Palaearctic. Out of 212 total Indian genera of this family, Eastern Himalaya alone represents 160 genera against 130, 60 and 35 genera represented by Peninsular India, Gangetic plains and Indus plains respectively. Further, temperate climate and forests of Oak, Pine, *etc.*, provide shelter to a number of little known and rare Hemipteran species. The necton fauna of the region is also dominated by the Hemipteran species mainly belonging to the families Gerridae, Corixidae, Notonectidae, Nepidae, and Belostomidae.

Nearly 600 species of Diptera are known from the region, but actual number will be much more as large areas are yet to be explored. Specific studies on medically important family Culicidae only in certain pockets have revealed as many as 88 species (Rajput and Singh 1991, 93, Pal and Dutta 1993). Maximum species diversity is exhibited by the suborder Nematocera having at least 270 species under 68 genera, but so far number of genera is concerned, suborder Cyclorrhapha surpasses the others with 209 species and 132 genera.

The Eastern Himalaya along the border of Myanmar may be considered as the most significant area for Lepidopteran fauna both in species diversity as well as from the zoogeographical point of view. Out of about 1500 species of Indian butterfly more than 50%, and of 13000 species of moth about 4000 occur in the Eastern Himalaya (Gupta, pers. Comm.). Nymphalidae, Lycaenidae and Papilionidae are predominant butterfly families, while Geometridae, Noctuidae, Pyralidae and Arctidae are predominant moth families. Owing to habitat destruction and commercial exploitation, Lepidopteran species specially the butterflies are becoming scarcer to an approximate estimate of 30 to 40% (Mondal 1998). A good number of species, *viz., Colias berylla, C. dubia, Neptis nycteus, Polydorus polla, Neozephyrus paona, N. intermedius, N. tytteri, N. khasia, N. suroria, Papilio elephenor* and many others are endemic to this region.

Table 10. Species richness in the Eastern Himalaya for some groups of insects (Adopted from Alfred *et al.* 1998).

Orders	Species in India	Species in Eastern Himalaya
Mecoptera	15	13
Thysanoptera	693	105
Psocoptera	90	43
Phasmida	146	82
Neuroptera	335	128

Coleopteran insects are found from subterranean situation in plains to the snows at hills and usually exhibit greatest species diversity in all the terrestrial ecosystems. Sample survey of Namdhapha Biosphere Reserve revealed as many as 188 species belonging to 105 genera and 12 families. This provides an indication of the probable richness of the Coleopteran species in the Eastern Himalaya. Pal (Pers. comm.) estimated that out of 15,500 Indian species about 4800 species occur in the region and opined that the actual number will be many times more as vast areas are yet to be explored.

Species richness in some other groups of insects are summarised in Table 10.

Mollusca : The Eastern Himalaya and the Western Ghats have been identified as the greatest concentration areas for land and freshwater molluscan species. Apparently, the subtrophic climatic conditions, dense tropical evergreen forests producing a deep leaf and foliage litter, higher rainfall and less rigorous temperature extremes of the Eastern Himalaya provide the most suitable and favourable conditions for the molluscan species to thrive and flourish. Out of 92 species of freshwater molluscs reported so far from the entire Indian Himalaya, 66 are known from Eastern Himalaya (Dey and Mitra, 2000). While tiny Gastropod genera, *viz.*, *Tricula*, *Erhaia*, and *Ferrissia* are lotic in habit, rest are essentially stagnant water dwellers. Of the 597 species of Himalayan land molluscs, 439 are represented in the Eastern Himalaya and around 379 (86.33%) species are endemic. Molluscan fauna of the Eastern Himalaya includes some Indo-Chinese and Malayan derivatives and few of them extended their range to Northwest Himalaya up to Kashmir, *e.g. Lymnaea andersonia*. Distributional range of some land molluscs lies between Myanmer to Northwest Himalaya through this region, *e.g. Indoplanorbis exustus*, *Hippeautis umbilicalis*, while that of a few extend up to Andamans *e.g.*, *Macrochlamys pungi*. Among the prominent genera *Cyclophorus*, *Alycaeus*, *Diplommatina*, *Cryptaustenia*, *Glessula*, *Kaliella*, *Oxytesta*, *Phaedusa*, *Sitala* are represented by large number of species in the Eastern Himalaya. But, these are either totally absent or just represented by 1 or 2 species each in the Northwest Himalaya. Genus *Phaedusa* is represented by one endemic species in the Northwest Himalaya as against four in the East Himalaya. The pulmonate snails of the genera like, *Macrochlamys*, *Sitala*, *Kaliella*, *Girasia*, *Durgella*, *etc.*, have a number of endemic species confined to tropical rainforest ecosystem of the Eastern Himalaya and the Western Ghats.

Vertebrate

Pisces : Fishes, the most important components of aquatic ecosystem, are represented in almost all the water bodies from plains to high mountains and even in the total darkness of caves in the Eastern Himalaya. As many as 187 species belonging to 86 genera. 28 families and 9 orders have been recorded from the region by Sen (1985). Out of these, 118 species are riverine, 69 species may be stated as torrential and 43 species are considered as endemic. The list was further enriched by addition of 18 species from Namadhapha and Tripura. (Ghosh 1987, Barman 1998). Pisciculture is one of the most important professions for the people of the region. This has resulted many hybrid varieties and exotic species in the water bodies under culture.

Amphibia : Next to the Western Ghats, highest concentration of amphibian species is found in the Eastern Himalaya. It is worthwhile to mention that though Western Ghats harbours maximum species diversity, but the Eastern Himalaya is the only region of the country where all the three living orders of Amphibia *viz.*, Gymnophiona (limbless amphibia), Caudata (tailed amphibia) and Anura (tailless amphibia) are represented. A total of 80 species of amphibia are so far known from the Eastern Himalaya excluding Sikkim (Deuti 2001), of which 75 species under 22 genera belong to the order Anura, one species under one genus belong to the order Caudata and 4 species under 2 genera belong to order Gymnophiona. This is to mention here that from Sikkim at least another four species of anuran are known. Among these amphibian species 29 are endemic to the Eastern Himalaya. Further, the only species of Salamander *viz.*, *Pleurodeles verrucosus*, that occurs within the Indian limit is confined to the hills of Darjeeling, Sikkim, Manipur, Arunachal and Meghalaya.

Reptilia : All the major groups of aquatic raptiles are found in the plains as well as hills but by a limited number of species. Gharial, *Gavialis gangeticus* occurs in Brahmaputra River system, while Muggar, *Crocodylus palustris* has been recorded from the water bodies of Arunachal. Further, at least 10 species of turtle and tortoise, three species of monitar lizard and several species of snakes particularly belonging to the genus *Natrix* are occurring in the water bodies. Forests, graslands and even the residential areas at different altitudes harbour a great diversity of reptilian species, which include of at least two species of Testudines, 38 species of lizards and 63 species of snakes. These along with the aquatic ones constitute about 30% of the total reptilian fauna of the country.

Two genera and 35 species of lizard are endemic to the Eastern Himalaya. It is interesting to note that Reticulated Python, *Python reticulatus* is discontinuously distributed in the Eastern Himalaya and Nicobar Islands.

Aves : Rivers, lakes, swamps and other water bodies at plains as well as hills support a very rich and diverse resident and migratory avifauna. At least 80 species belonging to 46 genera and 12 families have been recorded from the different water bodies of this region. These water bodies often serve as the last refuge of a number of threatened species of birds, *viz.*, Giant Heron-*Ardea goliath*, Great white-bellied Heron-*A. insignis*, Adjutant Slork *Leptoptilos dubius*, Eastern white Slork—*Ciconia ciconia boyciana*, Large Whistling Teal—*Dendrocygna bicolor*, White-winged Wood Duck—*Cairina scutulala*, Marked Finfoot—*Heliopais personata* and others. Forest ecosystems also exhibit an extraordinary richness of avian species particularly Tropical and Oriental elements. About 60% of the Indian Avifauna may be observed here. Among the different families highest diversity lies in Muscicapidae having nearly 200 species. Endemicity is not much evident and only three species, *viz.*, *Psittacula intermedia*, *Stachyris oglei*, and *Pardicula manipurensis* are endemic to the region. However, quite a number of species belonging to the genera *Liothrix*, *Cutia*, *Peruthius*, *Mesia*, *etc.*, are confined to the Eastern Himalaya and Myanmor.

Mammals : Forests and mountains in the Eastern Himalayan amphitheatre present an impressive array of the mammalian species. Of the 13 orders of Indian mammals, except Sirenia all are found here. Nearly 45% of the Indian mammal fauna comprising of 172 species under 97 genera and 32 families are represened in this region. The Gangetic Dolphin, *Platanista gangetica* (Cetacea : platanistidae) is the only aquatic mammalian species of Eastern Himalaya and confined to Brahmaputra River System. However, there are few species of Carnivores, *viz.*, Fishing Cat—*Felis viverrinus*, Clawless Otter—*Amblonyx cinereus*, Common Otter—*Lutra lutra*, Insectivores, *viz.*, Himalayan Water Shrew—

Fig 8 : Hoolock Gibbon-*Hylobates hoolocks* in Eastern Arunachal

Fig 9 : Red Panda–*Ailurus fulgens* in Sikkim Himalaya

confined to the forests, grasslands and swamps of the Eastern Himalaya so far India is concerned. Some of these species are Hispid Hare-*Caprolagus hispidus*, Pygmy Hog-*Sus salvanius*, Great one-horned Rhinoceros—*Rhinoceros unicornis*, Hoolock Gibbon—*Hylobates hoolock*, Phayre's Leaf Monkey—*Presbytis phayrei*, Malayan Sun Bear—*Helarctos malayanus*, Red Panda—*Ailurus fulgens*, Takin—*Budorcas taxicolor*, *etc*. All these species are extended to further east countries like Myanmar, Malaysia, *etc*. but not to the west.

Chimmarogale platycephala and Szechuan Water Shrew—*Nectogale elegans* are closely associated with aquatic ecosystems as predators. One of the critical species of Indian mammals, *viz*., Manipur Brow antlered Deer—*Cervus eldi eldi* finds shelter in the floating swamps *(Phumdis)* of Loktak Lake in Manipur. As regard the number of species, order Rodentia comes first having 53 species and represented in all the habitats from snows to plains. From the taxonomic point of view, mammalian species of the world are most well-worked out, still during the last few decades one new genus and species of flying squirrel *(Biswamoyopterus biswasi)* and a langur *(Presbytis geei)* have been discovered from the region. Out of 46 monotypic genera of Indian land mammals, 26 are found in the Eastern Himalaya. However, endemicity is not much evident except for three species. Quite a number of threatened species are solely or mainly

4. SPECIAL FEATURES

4.1 Flora

The total number of flowering plants in India is expected around 17000, of which about 50% (8000 species) hail from the Eastern Himalaya. Out of about 315 flowering plant families in India, more than 200 families are represented in this region. There are a number of primitive flowering plant species *viz*., *Magnolia griffithi*, *M. gustavii*, *Altingia excelsa*, *Betula alnoides*, *etc*., which grow in Eastern Himalaya and further eastwards but do not occur in other parts of India. Based on the analysis of distribution of primitive angiosperms Takhtajan (1969) treated East Himalaya-Fiji region as the 'Cradle of flowering plants', where angiosperms have diversified.

Many plant families, represented in India by a solitary genus with 1 or 2 species are found in this region, *e.g*., Coriariaceae, Nepenthaceae, Turneraceae, Illiciaceae, and a few others. Similarly, this part of Himalaya also contributes significantly to the conservation of the world's genetic resources by way of harbouring a number of monotypic genera, such as, *Alcimandra, Aspidocarya, Circaester* and *Hemsleya.* As there are no closely related genomes of these genera anywhere in the world, their conservation is of special significance.

Maximum number of endemic plant species of the country are shared by this part of Himalaya. Some such endemic species are: *Uvaria lurida, Magnolia gustavi, M. griffithi, Coptis teeta, Pachylarnax pleiocarpa, Distylium indicum, Nepenthes khasiana, Merrilliopanax cordifolia, Gastrodia exilis, etc.* This region also harbours many rare plants showing discontinuous distribution, such as, *Nymphaea pygmaea* (Siberia, N. China), *Michelia velutina* (Nepal, Tibet, Myanmar), *Illicium cambodiana* (Southern Indo-China), *Homalium schleichii* (Myanmar), *Cotylanthera tenuis* (Java), *Epipogium roseum* (W. Africa, Java, Australia), *Aphyllorchis montana* (Sri Lanka) and many others. Nepenthaceae with the single endemic species *Nepenthes khasiana* represents the northernmost limits of this family, with a general range of distribution from Madagascar to Malaysia. Similarly, genus *Zeylanidium* of the family Podostemaceae, found in Kameng district of Arunachal Pradesh also represents the northernmost distribution of this family in India. *Munronia pinnata* occurs in Sikkim and Khasi Hills and also in the Western Ghats.

Some plants of the Eastern Himalaya have created interest among the botanists on account of their special modifications and adaptations. *Sapria himalayana,* the largest root parasite, has attractive crimson flowers measuring 35 cm across. Another root parasite, *viz., Mitrastemon yamamotoi* from Mawsami forest is polyendemic (Rao, 1994). Among insectivorous plants *Nepenthes khasiana* with leaf tips modified into pitchers measuring up to 12 cm, and two species or *Drosera* are important.

On the other end of the spectrum there are some plants with unusual forms in the high alpine areas. These may be 'cushion forming' or 'snow ball' plants or the 'hot house' plants. Several hundred plants aggregate together to form dense, spherical globose cushions as an adaptation against severe cold and heavy snow fall during winter.

Ammal (1952) observed the high polyploidy in the species of the genera *Magnolia, Camellia, Lonicera, Rhododendron, Viburnum, etc.,* in region close to the glaciers of the Eastern Himalaya. She considered this region as a region of active speciation today. According to her these groups have adopted to hardy mountain life on high altitudes by polyploidy.

According to Vavilov (1926, 1951) this region of India, forming the 'Hindustani Centre of Origin of Cultivated Plants' is very significant for tropical and subtropical fruits, cereals, *etc.* The area forms the richest reservoir of genetic variability of many groups of crop plants. Over 50 species of economic plants have their genetic diversity in this Hindustani Centre (Zeven and Zhukovsky, 1975). The Eastern Himalaya is considered as the centre of origin of coconut, *Musa, Citrus,* Cucurbits and various temperate fruits particularly of the family Rosaceae and each of them exhibits a very rich speices diversity in the region. Diversity in legume crops and their wild relatives is also of a very high order. Maximum variability can be observed in *Cajanus cajan, Vigna umbellata, V. mungo, V. aconitifolia, Glycine max* and *Lathyrus sativus.* In addition, there are about 200 non-conventional legumes of which about 50 are used as vegetables by the various ethnic groups in the region. The region is also unique in having many wild food plants which form the subsidiary food of the local people. Many land races of jute and mesta have been found in Tripura, Meghalaya and Garo Hills. Tea, *Camellia sinensis,* was in cultivation in this region for last 4000 years and many allied wild species used as substitute of tea are found growing here (Maheshwari and Singh 1964). One of the world's most comprehensive collections of primitive rice cultivars was made by I.A.R.I. from 1800-2700 m altitudes of Meghalaya and Arunachal. Out of 6730 collections of different types of these cultivars, nearly about 5000 come from the hills. Some wild relatives of cultivated plants from the Eastern Himalaya are shown in Table 11.

4.2 Fauna

The Eastern Himalaya holds a pivotal place in the historic process of progressive evolution of the present day fauna of India by serving as an effective gateway to faunal influx. Its tropical and subtropical moist evergreen forest ensured the survival of species and enhanced the space of their speciation by affording more ecological niches than was possible in the dry deciduous forests and plains of the rest of India, excepting the Western Ghats. Though the detailed study on the faunal composition of the Eastern Himalaya is far from the complete, still richness and diversity of faunal species may be guessed from the results of Abor Hills expedition in 1911-12. A four months long expedition revealed the following diversity in some major groups : Porifera (2 spp.), Planaria (9 spp.), Oligochaeta (21 spp.), Collembola (9 spp.), Thysanoptera (1 spp.), Hymenoptera (118 spp.), Lepidoptera (111 spp.) Coleoptera (84 spp.), Diptera (81 spp.), Dermaptera (31 spp.), Orthoptera (22 spp.), Odonata (50 spp.), Isoptera (8 spp.), Arachnida (25 spp.), Onychophora (1 spp.), Mollusca (14 spp.), Fish (43 spp.), Amphibia (25 spp.), Reptilia (48 spp.), Birds (111 spp.), Mammale (26 spp.) and many others.

4.3 Distribution Pattern

The fauna of forested tract of the region differs markedly from that of Indian Peninsula stretching away from the base of the hills. It does not contain much of the so-called Aryan element of mammals, birds and reptiles which are related to Ethiopian and Holarctic genera, and to the Pliocene Siwalik fauna, nor does

Table 11. Some wild relatives of cultivated plants in the Eastern Himalaya (Adopted from Arora *et al.* 1983).

Category of Plants	Name of species
1. CEREALS AND MILLETS	*Hordeum agricrithon, Digitaria cruciata, Coix lacryma jobi, C. giganttea, C. aquatica, Oryza rufipogon, Polytoca wallichiana.*
2. LEGUMES	*Moghania vestita, M. bracteata, Vigna capensis, V. umbellata, V. pilosa, Atylosia barbata, A. scarabaeoides, A. villosa, Canavalia ensiformis, Mucuna bracteata.*
3. FRUITS	*Abelmoschus manihot, Duchesnea indica, Myrica esculenta, Prunus acuminata, P. cerasoides, P. cornuta, P. jenkinsii, P. nepalensis, Pyrus pashia, Ribes graciale, Rubus lineatus, R. ellipticus, R. lasiocarpus, R. moluccanus, R. reticulatus, Citrus assamensis, C. ichangensis, C. indica, C. jambiri, C. latipes, C. macroptera, C. medica, C. aurantium, Docynia indica, D. hookeriana, Eriobotrya angustifolia, Mangifera sylvatica, Musa acuminata, M. balbisiana, M. manii, M. nagensium, M. sikkimensis, M. superba, M. velutina.*
4 VEGETABLES	*Cucamis trigonus, C. hystrix, Luffa graveolens, Neoluffa sikkimensis, Alocasia macrorhiza, Amorphophallus bulbifer, Calocasia esculenta, Dioscorea alata, Moghania vestita, Momordica dioica, M. cochinchinensis, M. macrophylla, Trichosanthes cucumerina, T. dioica, T. dicaelosperma, T. khasiana, T. ovata, T. truncata, Solanum indicum.*
5. OIL SEED	*Brassica trilocularis*
6. FIBRES	*Corchorus capsularis, Gossypium arboreum*
7. SPICES AND CONDIMENTS	*Allium tuberosum, Amomum subulatum, Curcuma zedoaria, Alpinia galanga, A. speciosa, curcuma amada, Piper longum, P. peepuloides*
8. MISCELLANEOUS	*Saccharum longisetosum, S. sikkimensis, S. ravennae, S. procerum, S. rufipilum, Miscanthus nudipus, M. taylorii, M. nepalensis, M. wardii, Erianthus* sp., *Camellia* sp.

it include Dravidian elements of reptiles or amphibians. On the other hand, it includes the following animals which do not occur in the Peninsula - Mammals; the families Hylobatidae, Talpidae, Procyonidae, Rhizomyidae, and the subfamily Gymnurinae, besides numerous genera, such as, *Prionodon, Arctonyx, Arctictis, Arctogalida, Nycticebus, Rhinoceros, Budorcas, Nemorhedus, Atherurus, Dacnomys, etc.*; Birds : the families Eurylaemidae, Indicatoridae, Heliornithidae, and the subfamily Paradoxornithinae; Reptiles : the families Platysternidae and Anguidae; Amphibians : Dyscophidae, Hylidae, Pelobatidae and Salamandridae. The region also contains some genera of several groups, e.g., *Papilio* and *Pieris* (Lepidoptera), *Moschus, Ovis, Nemorhedus, Eupetaurus, Marmota* (Mammals), which have Holarctic or Palaearctic affinities. However, Oriental elements are most predominantly represented in the fauna of Eastern Himalaya, which gradually diminishes to the westward, until in Kashmir and further westward it ceases to be the principal constituent. This fact is in conformity with the theory that the Oriental element of the Himalayan fauna, or the greater portion of it have migrated into the Himalaya from the east at a comparatively recent period.

Many of the genera and species occurring in the east exhibit extreme discontinuity in distribution. They occur in Peninsular south or even in Sri Lanka with an extensive intervening areas totally without them. Some examples are already cited in connection with description of faunal diversity and few more are mentioned in Table 12. There are many more examples of discontinuous distribution of faunal components, of which most interesting is that of a lizard belonging to a monotypic genus *Teratolepis* which occurs in Sind and Khasi hills widely varying in climate and are separated by a wide gap.

The marked discontinuous distribution of the Indo-Chinese and Malayyan faunal derivatives was interpreted by Kurup (1966) with special reference to mammals. He opined that present day discontinuity is essentially a relict of former continuous distribution. The extensive and continuous ranges of a number of the humid-tropical forest forms have recently come to be broken up into a series of isolated patches, partly because of topographical or partly because of climatic changes and partly by the gradual retraction and regression, leaving behind more or less large areas of the isolates.

Table 12. Showing some discontinuously distributed faunal element in the Eastern Himalaya and southern Peninsula.

Group	Family/Genera/Species
Oligochaeta	*Megascolides, Plutellus, Notoscolex, Drawida*
Diptera	*Phytomyza, Blepharocera, Agromyza, Apistomyia*
Lepidoptera	*Graphium nomius*
Pisces	Homalopteridae, *Gagata, Balitora brucei, Batasio, Silurus*
Amphibia	*Ichthyophis, Philautus, Nectophryne*
Reptilia	*Rhabdos, Draco*
Aves	*Garrulax, Irena puella, Buceros bicornis*
Mammalia	Lorisidae, *Ratufa, Hemitragus, Harpiocephalus harpia*

A large number of species, considered as threatened are found in, the Eastern Himalaya (Table-13), and a few of them such as *Caprolagus hispidus, Sus salvanius, Rhinoceros unicornis, Cervus eldi eldi, Prionodon pardicolor, Helarctos malayanus, Hylobates hoolock, Bambusicola fytchii, Tragopan blythii, Lophophorus sclateri, etc.*, are mainly confined to this territory so far India is concerned.

Economically important honey bee, *Apis cerana himalayana* in the east has further evolved into three ecotypes that correspond to geographic distribution in (1) Naga and Mizo Hills, (2) Brahmaputra valley and Khasi Hills, and (3) the foot hills. The partially domesticated *Mithan* is another interesting component of the fauna which is resulted from the hybridization of Gaur *(Bos frontalis)* with the domestic cattle.

5. THREATS

Enormous massiveness, the great elevations of the mountain ranges, their trendlines, their location in the middle of a vast continental mass, their tertiary orogeny, the pleistocene glaciations and continued post-pleistocene uplift provided outstanding pecularities of the ecology of Himalayas. For centuries, highlanders have lived in partnership and equilibrium with nature in the Himalayas which created some of the planet's most harmonious landscapes. However, at the moment, pressure of population growth and movement, coupled with new demands of development, are placing this equilibrium in jeopardy. Mountain ecosystems, especially the tropical high mountains, are usually sensitive to quite small disturbances and consequent of that disturbances are often irreversible. Damage to natural ecosystems and ecological diversities of the Himalayas for one or other reasons are the burning problems for very rich as well as unique biodiversity of the region and also of the land, rivers, people and economy.

Threats and conservation aspects of the Himalayan ecosystem has been nicely discussed by Ahmad *et al.* (1990). Anthropogenic impact on Himalayan mountain ecosystems is producing critical situations at a faster rate than on most other types of ecosystem. Man-induced activities in the Himalayas, such as unplanned landuse, cultivation on steep slopes, overgrazing, major developmental activities, such as mining and construction of dams, roads, over-exploitation of village or community forests as well as faunal resources and shifting cultivation are some of the factors which have accelerated ecological degradation and threatened the equilibrium of the mountain ecosystem in the Eastern Himalaya. Resulting enviornmental problems may be categorised under three subheads, viz., socio-economic, biological and physical environments.

A. Physical Environment Components :

(a) **Soil impoverishment and losses** Vast land areas of the entire Himalaya may be considered environmentally 'derelict land' due to poor land maintenance practices, altered agricultural practices, over-intensive landuse. Besides this 'derelict land', many other landmasses are highly susceptible to soil erosion and landslides. Soil properties are also deteriorated due to short cycle shifting cultivation, monoculture in place of mixed forests, ruthless destruction of native plant species and overgrazing. The soils in many areas are becoming nutrient deficient mainly owing to traditional pasturalism. Nutrient deficiency of soil leads to desert like conditions having low biological productivity. Dams, reservoirs and mining have also caused soil losses and impoverishment.

(b) **Atmospheric pollution and micro-climatic changes** Till today atmospheric pollution in this region is not much of serious concern, but setting up of industries in these environmentally sensitive areas without environment management plan is gradually increasing the pollution. Micro-climatic changes due to clear felling of native plant species and construction of dams and reservoirs in the fragile areas are of common occurrence in the entire Himalaya.

(c) **Landscape transformation and landslides** These are natural phenomenon in the Himalaya, but the rate is enhanced by large-scale developmental activities as stated earlier, deforestation and continuing use of mountain slopes.

(d) **Impact on water resources** Shrinking water bodies and their eutrophication have been noticed in Loktak lake in Manipur, Khichipur Lake in Sikkim and in many others. Changes in the river course and flash floods due to poor infiltration rates and poor vegetation cover, modify perennial water resources and change surface and groundwater

Table 13. Distribution of some threatened vertebrate species in the diferent States of Eastern Himalaya									
MAMMAL									
Species	W. B. (Darjeeling)	Assam	Meghalaya	Manipur	Mizoram	Tripura	Nagaland	Arunachal	Sikkim
Nycticebus coucang	–	+	+	+	+	+	+	+	–
Macaca arctoides	–	+	+	+	+	+	+	–	–
M. nemestrina	–	+	+	+	+	+	+	+	–
Presbytis geei	–	–	–	–	–	–	–	–	–
P. phayrei	–	+	–	–	–	+	–	–	–
P. pileatus	–	+	+	+	+	+	+	+	–
Hylobates hoolock	–	+	+	–	+	+	–	+	–
Helarctos malayanus	–	+	–	–	+	–	–	+	+
Ailurus fulgens	+	–	–	–	–	–	–	+	+
Amblonyx cinereus	+	+	+	–	–	–	–	+	+
Arctonyx collaris	+	+	–	+	+	+	+	+	–
Arctictis binturong	+	–	–	–	–	–	+	+	+
Prionodon pardicolor	–	–	–	–	–	–	–	+	+
Felis marmorata	+	+	+	–	–	–	–	+	+
Felis temmincki	+	+	+	–	–	–	–	+	+
Felis viverrina	–	+	–	+	+	+	+	+	–
Neofelis nebulosa	+	+	+	–	–	–	–	+	+
Panthera pardus	+	+	+	+	+	+	+	+	+
P. tigris	+	+	+	–	+	–	+	+	+
P. uncia	+	–	–	–	–	–	–	+	+
Platanista gangetica	–	+	–	–	–	–	–	–	–
Elephas maximus	+	+	+	+	+	+	+	+	–
Rhinoceros unicornis	–	+	–	–	–	–	–	–	–
Sus salvanius	–	+	–	–	–	–	–	–	–
Cervus duvauceli	–	+	–	–	–	–	–	–	–
Cervus eldi	–	–	–	+	–	–	–	–	–
Moschus chrysogaster	–	–	–	–	–	–	–	+	+
Bos gauras	+	+	+	–	–	–	–	+	–
Bubalus bubalis	–	+	–	–	–	–	–	+	–
Capricornis sumatraensis	+	–	+	–	+	+	–	+	+
Hemitragus jemlahicus	+	–	–	–	–	–	–	–	+
Equus kiang	–	–	–	–	–	–	–	–	+
Manis pentadactyla	+	+	+	+	+	+	+	+	+
Caprolagus hispidus	–	+	–	–	–	+	–	–	+

Table 13. (contd.)

Species	W. B. (Darjeeling)	Assam	Meghalaya	Manipur	Mizoram	Tripura	Nagaland	Arunachal	Sikkim
AVES									
Bambusiola fytchii	–	+	–	+	+	+	+	+	–
Aviceda jerdoni	+	+	+	+	+	+	+	+	+
A. leuphotes	+	+	+	+	+	+	+	+	+
Eupodotis bengalensis	–	+	–	+	–	–	–	–	–
Grus nigricollis	–	–	–	–	–	–	–	+	–
Ithaginis cruentus	+	–	–	–	–	–	–	+	+
Ciconia ciconia	–	+	–	–	–	–	–	–	–
Batrachostomas hodgsoni	+	+	+?	+?	+?	+?	+	+	+
Buceros bicornis	+	+	+	+	+	+	+	+	–
Rhyticeros undulatus	–	+	–	+	+	+	+	+	–
Aceros nipalensis	+	+	+	+	+	+	+	+	+
Ptilolaemus tickelli	–	+	+	+	+	+	+	+	–
Anthracoceros malabaricus	+	+	+	+	+	+	+	+	+
Syrmaticus humei	–	–	–	–	+	–	–	–	–
Gypaetus barbatus	+	–	–	–	–	–	–	+	+
Falco peregrinus	+	+	+	+	+	+	+	+	+
Dendrocygna bicolor	–	+	–	+	–	–	–	–	–
Lophophorus sclateri	–	–	–	+	+	–	+	+	–
Pandion haliaetus	+	+	–	+	–	–	–	+	+
Polyplectron bicalcaratum	+	+	+	+	+	+	+	+	+
Tragopan blythi	–	–	+	+	+	+	+	+	–
T. temminckii	–	–	–	–	–	–	–	+	–
Crossoptilion crossoptilion	+	–	–	–	–	–	–	+	+
Cairina scutulata	–	+	–	–	–	–	–	+	–
REPTLIA									
Gavialis gangetics	–	+	–	–	–	–	–	–	–
Crocodylus palustris	–	–	–	–	–	–	–	+	–
Trionyx gangeticus	–	+	–	–	–	–	–	–	–
T. hurum	–	+	+	–	–	–	–	–	–
Python molurus	+	+	+	+	+	+	+	+	+
P. reticulatus	–	+	+	+	+	+	+	+	–
AMPHIBIA									
Pleurodeles verrucosus	+	–	+	+	–	–	–	+	+

hydrology to create problem. Indiscriminate lopping of broad leaved tree species leads to the drying up natural springs.

B. Biological components :

(a) **Impact on vegetation** : The Eastern Himalaya, with high biological diversity and rich genetic resources are very fragile, because of its low intrinsic resilience. Continued human interference has resulted in the partial collapse of this ecosystem. Clear felling has resulted in poor recycling of nutrients, and the forest, often fails to recover the original state. This may results in the desertification as happened in the entire West Khasi hills district of Meghalaya. The settled agriculture, the shifting cultivation, expansion of agricultural land due to population pressures, forest exploitation for fuel, fodder and timber, selective collection of medicinal/ornamental plants and major developmental activities are responsible for the decline of forest cover and fragmentation of habitats. The Eastern Himalaya which had forest cover of about 76% as per assessment of 1997, has lost 783 km^2 of forest cover as per assessment of 1995. Considerable number of Orchid, Rhododendron, Bamboo and medicinal plant species have also become threatened. It has been estimated that at least 300 species of orchids are threatened in the region. The genetic variability *vis-a-vis* genetic resources are getting erroded in *Arundinaria clarkei*, *A. mannii*, *Bambusa mastersii*, and some other species of bamboo. Medicinal plants, *e.g.*, *Coptis teeta*, *Podophyllum hexandrum*, *Taxus wallichiana*, *etc.* have become threatned for extensive exploitation and habitat destruction. Genetic resources in cultivated plants have also been lost to a great extent due to introduction of high yielding variety.

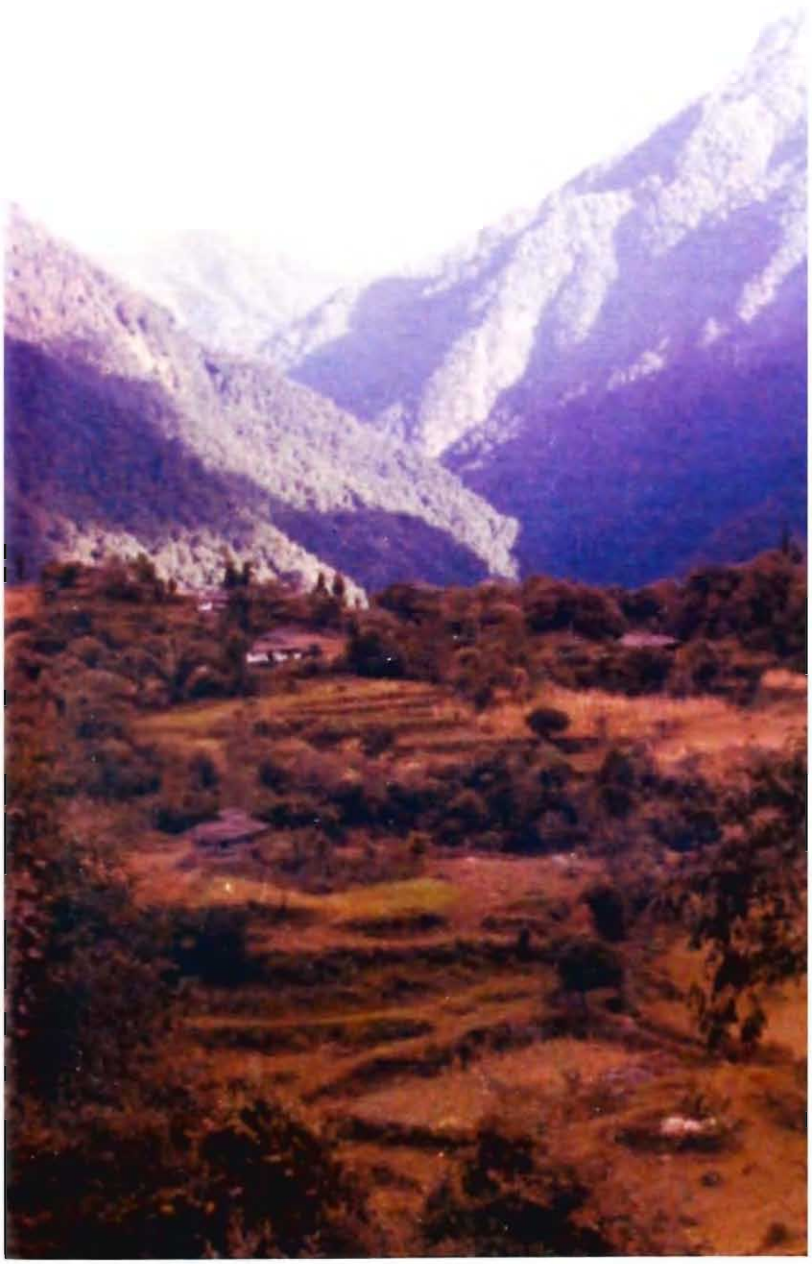


Fig 10 : Slope cultivation in Eastern Himalaya

(b) **Impact of fauna :** Population of almost all the faunal species of the region have been adversely affected owing to combined effect of habitat destruction/fragmentation, hunting, poaching, illegal trade, hybridization, random use of pesticides, landslides, flood and others. Some of the species of threatened category have already been shown in Table 13. It has been found that Brown Trout *(Salmo trutta ferio)*, Mahaseer *(Tor* spp.) and other stream fishes are reduced in numbers mainly due to construction of dams and reservoirs which has caused obstruction in their migratory routes and changes in their breeding places. Reduction in forest cover and disturbances within the forest have forced many of the species like Elephant, Wild boar, Deer, Leopard, Tiger, *etc.*, to invade human habitat resulting damage of crops and other properties, death of human beings, road kills and severe man-animal conflict.

C. Socio-Economic Components

(a) **Population and poverty** : The population of both human and their livestock are increasing alarmingly over the entire area. Such rise in population is now gradually exceeding the carrying capacity of available land. This had lead to overstocking of grazing land and need for new agricultural land and pastures. Consequently, the forested upper slopes, which hitherto protected the slopes from excessive erosion, are being cleared for cultivation, fodder and grazing. Emigration of the young and physically fit members of the population, leaving behind the old and least fit, tends to result in inadequate land maintenance practices. The emigration plays a major role in the environmental degradation, especially the further extension of 'derelict land'.

(b) **Tourism and recreation** : Tourism and adhoc planning of tourist activities in environmentally sensitive areas has affected the environment as well as wildlife to a great extent. The use firewood for heating and food preparation with inherent fire danger in the ecologically sensitive areas is intricately associated with the unrestricted tourist movements. Camps, noise, and movement through forests are disturbing the normal

Fig 11 : Alpine medow a favourite pastur for yak in Sikkim

Fig 12 : Domistic Yak grazing in Rhododendron forest in Sikkim

activities of the wildlife as well as their feeding and breeding grounds. The unused materials, like plastic containers, glass bottles, *etc.*, are converting the hill stations into 'slums'.

6. CONSERVATION

Above description is only a fraction of what actually taking a huge toll of natural ecosystems and wildlife of the Eastern Himalaya. Several species specific as well as habitat specific programmes have been adopted for the management and conservation of habitats and wildlife through Indian Wildlife (Protection) Act, 1972, Forest Conservation Act, 1980, Environment Protection Act, 1986, several Conventions and other measures. These include survey and inventorisation, *in situ* conservation through protected area network, and *ex situ* conservation. In addition, Government is also providing technical and financial supports to biodiversity-related research in the area either directly or through non-government agencies.

The Botanical Survey of India and the Zoological Survey of India are engaged mainly in the floral and faunal exploration respectively in the region. In order to understand ecosystem functioning and to scientifically manage protected areas, a number of research projects are being carried out in the region by the Wildlife Institute of India ICAR, WWF, diferent universities and many

Table 14. Number of National Parks and Wildlife Sanctuaries in the different States of Eastern Himalayas. (Source : Anon, 2000).

States	National Parks		Wildlife Sanctuaries	
	Number	Area (km²)	Number	Area (km²)
Arunachal Pradesh	2	2468.23	10	7114.45
Assam	5	1590.511	12	530.38
Manipur	1	40.00	1	184.00
Meghalaya	2	267.48	3	34.20
Mizoram	2	250.00	4	634.00
Nagaland	1	202.00	3	24.41
Sikkim	1	1784.00	5	265.10
Tripura	—	—	4	603.62
Darjeeling, W.B.	4	362.45	6	697.03
Total	**16**	**6647.89**	**49**	**10497.49**

other organisation. GB Pant Institute of Himalayan Environment and Development with a regional centre at Gangtok has undertaken action oriented research for development of technologies and demonstration packages towards sustainable development of Himalayan regions suited to local specifications.

For *in situ* conservation a network of 16 National Parks and 49 Sanctuaries covering about 17045.38 km^2 area has been set up in the region (Table 14). Further, five Biosphere Reserves have been notified in the Eastern Himalaya. These are Nokrek in Meghalaya, Manas and Dibru Saikowa in Assam, Khangchendzonga in Sikkim and Dehang Dibang in Arunachal. To ensure the maintenance of viable population of tigers and to preserve areas of biological importance, four Tiger Reserves have been created in the region. The Tura region in Garo Hills has been demarcated as a gene sanctuary for preserving the rich native diversity of wild *Citrus* and *Musa* spp. Sanctuaries for Rhododendron and Orchids have also been established in Sikkim. Five botanic gardens in this region have been established for *ex situ* conservation.

7. FUTRE DIRECTION

No doubt, Government as well as NGOs are working in a coordinated manner for the conservation and sustainable development of the region. But it is still a fact that the Eastern Himalaya, home of unique ecosystems, plants, animals and other organisms, is undergoing extensive changes in a negative direction. The magnitude and rate of losses of biodiversity at all levels are obvious but poorly documented in this region. A Geographical Information System based upon past and present inventories of habitats, forests, and species could supply some of necessary information, but follow-up projects to obtain and supply more accurate and detailed data are also important. Specifically, the conservation status of existing biodiversity should be assessed and efforts to restore degraded ecosystems to be accelerated. However, the most critical aspect of preservation of ecosystems in the eastern Himalaya is the formulation of programmes and development of institutions to catalogue and change the present usage of biological resources. If human factors causing biodiversity loss are not addressed, the losses will continue inspite of conservation efforts. The public must be informed about the real costs of loss in biodiversity. An effective conservation policy based on a better understanding of biological resources and human use of biodiversity would require new mechanisms of co-operation among local communities, government agencies and non-government organisations. To be really effective, all conservation programmes for the Eastern Himalaya must first address human use of bioresources; if human needs are not met, depletion of biological diversity will inevitably continue.

8. SELECTED REFERENCES

Ahmad, A., Rajput, J.S. and Rai, S.C. 1990. An analysis of the Himalayan environment and guidelines for its management and ecologically sustainable development. *Environmentalist*, **10**(4) : 281-298.

Alfred, J.R.B. 1995. The State of Meghalaya : An overview. *Zool. Surv. India State Fauna Series* **4 :** *Fauna of Meghalaya*, Part-I : 1-22.

Alfred, J.R.B., Das, A.K. and Sanyal, A.K. (Eds.). 1998. *Faunal Diversity in India*, ENVIS Centre, Zoological Survey of India, Calcutta.

Ammal, J.E.K. 1952. Chromosomes relationships in cultivated species of *Camellia. Amer. Cammellia Yearb.*, 1952 : 106-114.

Anon. 1990. *Wetlands of India A Directory.* Government of India, MOEF, New Delhi.

Anon. 1999. State of Forest Report, 1999. Summary. Forest Survey of India, Dehra Dun.

Anon, 2000. Wildlife and Protected area. *ENVIS Bulletin*, **3** (1), Wildlife Institute of India, Dehra Dun.

Arora, R.K., Mehra, K.L. and Nayar, E.R. 1983. Conservation of wild relatives of crop plants in India. *N.B.P.G.R. Science Monograph*, **6** : 14. New Delhi.

Bagri, Q.H. 1991. Contribution to the fauna of Sikkim nematodes associated with Citrus from Sikkim, India. *Rec. zool. Surv. India Occ. Paper*, No. **128** : 1-103.

Ghosh, A.K. 1987. *Qualitative analysis of faunal resources of proposed Namdhapha Biosphere Reserve, Arunachal Pradesh.* pp. 1-129. Zoological Survey of India, Calcutta.

Haridasan, K. and Hegde, S.N. 1991. The genus *Hedychium* Koen. in Arunachal Pradesh, its distribution and ecology. *Arunachal For. News.*, **9**(1) : 1-4.

Ives, J. D. and Messerli, B. 1989. *The Himalayan Dilemma-Reconciling Development and Conservation.* Routledge, London.

Jain, S.K. and Mehrotra, A. 1984. *A Preliminary Inventory of Orchidaceae in India*. Botanical Survey of India, Howrah.

Kemp, S. 1924. Crustacea Decapoda of the Siju Cave. *Rec. Indian Mus.*, **26** : 41-48.

Kurup, G.U. 1966. Mammals of Assam and adjoining areas. 1. Analytical Study. *Proc. zool. Soc. Calcutta*, **19** : 1-21.

Maheshwari, P. and Singh, U. 1964. Dictionary of Economic Plants of India. ICAR, New Delhi.

Mani, M.S. 1974. Biogeography of the Himalaya. In *Ecology and Bio-geography in India*. Ed. M.S. Mani. pp. 664-681. Dr. W. Junk b.v. Publishers, the Hague.

Myers, N. 1988. Threatened Biotas : 'Hot Spots' in Tropical Forests. *Environmentalist*, **8** : 187-208.

Nandi, S.N., Pant, R. and Rao, K.S. 2000. *Indian Himalaya a demographic database. ENVIS Monograph 2*, G.B. Pant Institute of Himalayan Environment and Development, Almora, India. 75 pp.

Rao, R.R. 1981. Ethnobotany of Meghalaya : Medicinal plants used by Khasi and Garo tribes. *Econ. Bot.*, **35** : 4-9.

Rao, R.R. 1994. *Biodiversity in India (Floristic Aspects).* Bishen Singh Mahendra Pal Singh, Dehradun.

Rao, R.R. and Haridasan, K. 1991. An ethnobotanical survey of medicinal and other useful plants of Northeast India. *J. Econ. Taxon. Bot.*, **15**(2) : 423-435.

Rao, R.R. and Jamir, N.S. 1982. Ethnobotanical studies in Nagaland 1. Medicinal plants. *Econ Bot.*, **36** : 176-181.

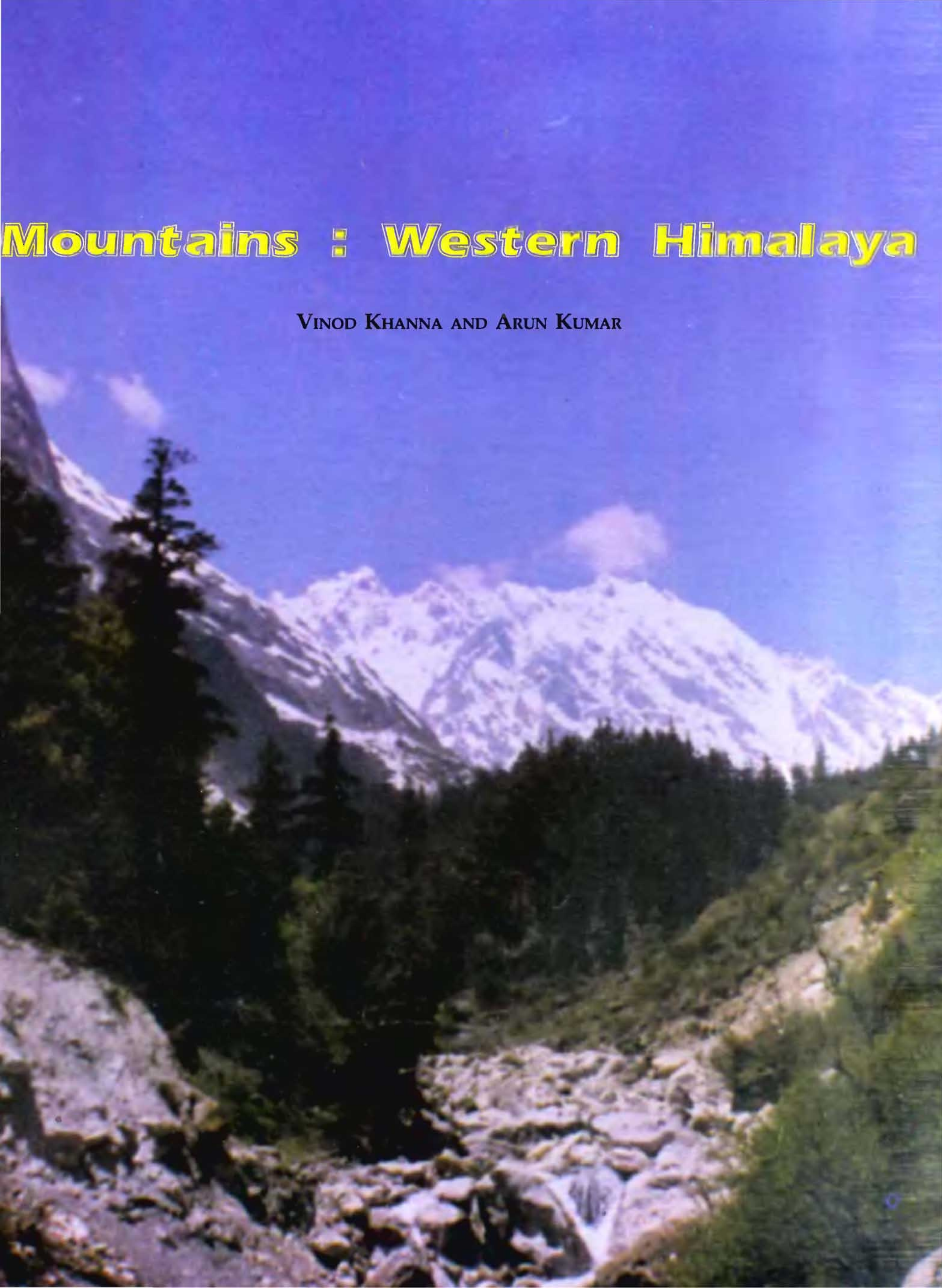
Rodgers, W.A. and Panwar, H.S. 1988. *Planning A Wildlife Protected Area Network in India.* 2 vols. Wildlife Institute of India, Dehradun.

Takhtajan, A. 1969. Flowering plants, origin and dispersal. (Tr. Jeffery) Edinburg.

Zeven, A.C. & Zhukovasky, P.H. 1975. *Dictionary of Cultivated Plants and Their Centres of Diversity.* Washington.

Mountains : Western Himalaya

VINOD KHANNA AND ARUN KUMAR



ENVIS–*Zool. Surv. India*
Ecosystems of India : 35-50, 2001.

Mountains : Western Himalaya

VINOD KHANNA AND ARUN KUMAR

Northern Regional Station
Zoological Survey of India, Dehra Dun 248 195

1. INTRODUCTION

The Himalaya or the mountainous zone is the loftiest range of the world, extending between 26° 20′ and 35° 40′ N longitudes and 74° 50′ and 95° 40′ E latitudes, with a total area of 100 million hectares. It extends uninterrupted from Pamir Knot in the extreme northwest to Arunachal Pradesh in the east. The width of these mountains decreases gradually from about 400 km in the west to about 150 km in the east. The traditional limits being the Indus valley in the west, to Brahmputra in the east. It literally forms a "gigantic arch" which separates the Indian plains from north Tibet and central Asia.

The Himalaya is divided into two biogeographic zones—the Trans Himalaya and the Himalaya.

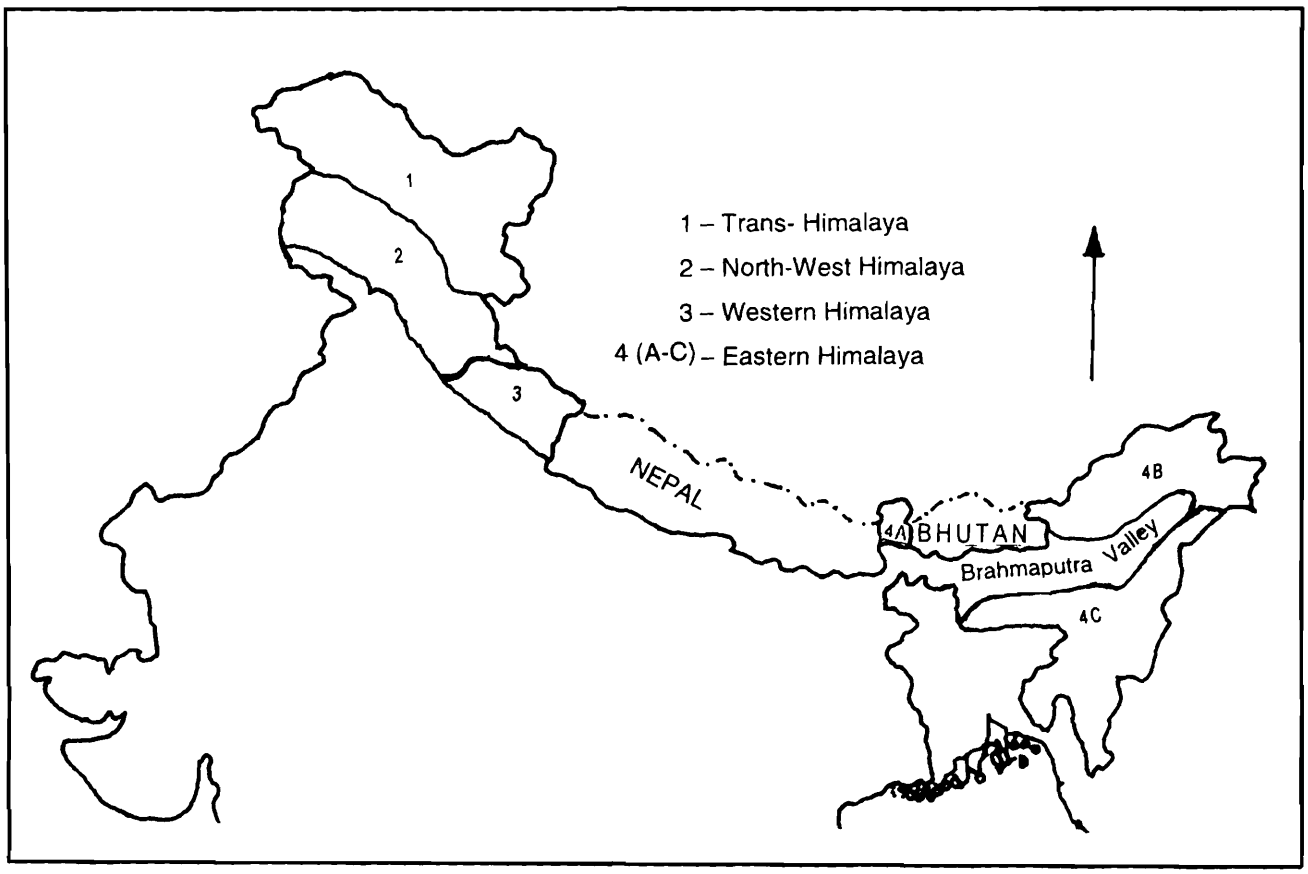


Fig. 1 : Biogeographic divisions of Indian Himalaya (only coloured area dealt with in the article)

Fig 2 : A view of mountain ecosystem in Western Himalaya

Geographically the Himalaya is divided into:

(i) The Eastern Himalaya,

(ii) The Central or Nepal Himalaya

(iii) The Western Himalaya and

(iv) The North-West Himalaya

It is quite evident that the Himalaya lying within the Indian territory excludes central Himalaya. Considering both geographic and biogeographic divisions of Indian Himalaya (Rodgers and Panwar, 1988; Ahmad *et al.* 1990; Nandi, *et al.* 2000) and for the convenience of biodiversity analysis, Alfred *et al.* (2001) have divided it into four zones, *viz.*, (i) Trans-Himalaya, (ii) North-West Himalaya, (iii) Western Himalaya and (iv) Eastern Himalaya. Out these, the present article reviews the status of ecosystems and biotic diversity of the Western Himalaya which includes 8 hilly districts of earstwhile Uttar Pradesh (now known as Uttaranchal). This is the smallest division (length approx. 30 km) amongst the four referred earlier. It lies between River Kali and the great defile of River Sutlej and comprises Garhwal and Kumaon hills. It is located between 29°5′-31°25′N latitudes and 77°45′-81°E longitudes covering an area of 51,124 km² and comprises 9.62% of the Himalayan region (Nandi, *et al.* 2000).

2. BIOLOGICAL DIVERSITY

2.1 Ecosystem/Habitat diversity

2.1.1 Forest Cover: The forest vegetation diversity of the Western Himalaya is influenced by the topography, soil, climate and geographical location. The altitudinal variation and rainfall pattern has also contributed to the vegetation diversity. The vegetation diversity of this region, may be divided into:

Tropical Forest (500 m - 1000 m) : Terai and Bhabar belt of sub-Himalayan tract sub-divided into: a) Scrub Forest; b) Deciduous Forest; c) Savannah Forest.

Sub-tropical Forest (1000 m - 2000 m) : Subdivided into : a) Broad-leaved Forest; b) Pine Forest (1500 m - 1800 m); c) Subtropical evergreen Forest (1800m - 2000 m).

The dominant species are *Shorea, Terminalia, Albizzia, Cedrela, Bischofia, Salmalia, Arctocarpus* and *Michelia*.

Fig. 4 : Alpine Meadows in Western Himalaya (*Courtsey* : B.P. Uniyal, WII, Dehra Dun)

Temperate Forest (2000 m - 3000 m) : a) Broad-leaved Forest; b) Conifer Forest.

The dominant species are *Quercus, Acer, Betula, Ulmus, Prunnus, Populus, Fraxinus, Pinus, Cedrus, Picea* and *Rhododendron*.

Fig. 3 : A lush green temperate forest in Western Himalaya (*Courtsey* : B.P. Uniyal, WII, Dehra Dun)

Sub-alpine Forest (3400 m - 4000 m) : This forest appears above the timberline having only scattered stunted bushes, mainly of *Juniperus communis, J. wallichiana, Rhododendron campanulatum, etc.*

Alpine forest (4000 m - 5000 m) : This forest type in Western Himalaya exhibits an enormous floristic and vegetation diversity and marks the upper limit of vegetation in the Western Himalaya. There are a variety of orchids, medicinal plants, horticultural plants, economic plants, bamboo, wild germ plasm of some cultivated species and even plants of botanical curiosities. The common species are *Albies, Betula, Juniperus* and *Rhododendron*.

2.1.2 Wetlands : By virtue of its extensive geographical stretch, varied terrain and climate, the Himalayan mountain ranges are bestowed with a series of wetland habitats. The entire Himalayan region being a cradle of a large number of streams and mighty rivers ensures the availability of water for the whole subcontinent. The most important being the Rivers Ganga, Yamuna, Bhagirithi, Ramganga, Kosi, Sharda, Suryu and their tributaries and the largest water body in the form of Mansarover Lake, adorns the wetland ecosystem of the region. These wetlands exhibit tremendous faunal diversity from Protozoa to Mammalia.

2.2 Species diversity

2.2.1. Floral: The Western Himalaya embodies one of the most important and fascinating vegetation zone of Himalaya with diverse and peculiar biotic forms and diverse topographical and climate zones. The deterioration of habitats and exploitation of economic plants coupled with other developmental factors are creating a great stress to these biotic forms.

The distribution and composition of timberline change with latitude. The timberline stretches between 3000-3500 m ASL and contains three diverse physiognomic types, *i.e.*, evergreen broad-leaved, evergreen middle-leaved and deciduous broad-leaved.

The economic plant wealth of this region is outlined with reference to wild edible plants, medicinal plants, aromatic plants, oil yielding plants, dyes, gum, resins, ornamental plants, fodder and fuel resources, fibers and cordage plants and plants of botanical curiosities.

Owing to a great variety of physiographic and phytoclimatic conditions the Himalaya fosters almost all types of vegetation from humid tropical evergreen to moist mixed deciduous sal forest, marshes, swamps, mixed deciduous forest, subtropical pine forest, broad-leaved temperate forest, moist temperate broad-leaved forest, temperate conifer forest, subalpine and alpine vegetation, alpine meadows and alpine scrub.

The vegetation of the Western Himalaya region is characterised by drought resistant and cold-loving plants belonging mostly to Coniferae, Leguminosae, Asteraceae, Poaceae, Rosaceae, etc. In the cold dry valleys at high altitudes the landscape is dominated by *Abies, Cedrus, Picea, Pinus, Quercus, Rhododendron* forests, with *Betula utilis- Abies spectabilis* association around 3600 m marking the tree limit in this region. However, in the cold arid regions of Ladakh, Lahaul-Spiti, Melam, Malavi and Nelang, the vegetation is conspicuous by the absence of tree species, except *Juniperus macropoda* in Lahaul valley. The flora here is represented by alpine scrubs and is characterised by highly specialised cold desert elements, like *Arenaria seryillifolia, Nepeta*

Table 1. Plant diversity in the Himalaya (aproximate)

Taxa	Total number of species			
	Himalayan Region		India	
Angiosperms	8000	(3200)	17000	(5400)
Gymnosperms	44	(7)	54	(8)
Pteridophytes	600	(150)	1022	(200)
Bryophytes				
Liverworts	500	(115)	843	(166)
Mosses	1237	(450)	2000	(820)
Lichens	1159	(130)	1948	(423)
Fungi	69000	(1890)	13000	(3000)

Source : Singh, D.K. & P.K. Hazra (1996)

Note: Figures in the parenthesis represent the number of taxa considered endemic to Himalayan/Indian region.

tibetica, Lancea tibetica, Draba lanceophylla, Allardia tomentosa, Thermopsis inflata, Pagaeophyton scapiflorum, Trigochline maritima, Hippophae rhamnoides, etc., which variously modify themselves to ward off extreme climatic conditions because of almost negligible precipitation and excessive dryness. As a part of their survival strategy these plants acquire bushy and diminutive cushion, clump or mat forming habit ranging from just a few centimeters to about 50 cm.

The Himalayan ranges are the richest in the floristic diversity in the country. Out of about 17000 flowering plant species (belonging to about 315 families) estimated to be occurring within the present political boundary of India, about 8,000 species (of which 3169 are endemic), belonging to over two hundred families are present in this region.

The richness of this great diversity is well appreciated considering the fact that the Himalaya represents just 12% and 0.3% of the total landmass of India and the world respectively. In the present state of our knowledge the Western Himalaya alone harbours 5,000 taxa. The flora of western Himalaya is comparatively best understood than that of Eastern Himalaya, a considerable portion of which is botanically still *terra incognita.*

Orchidaceae with over 750 taxa represents the largest flowering plant family in the Himalaya, followed by Asteraceae (734), Poaceae (517) and Leguminosae (507). The different flanks of Himalaya have, however, their own floristic composition.

On the other hand a number of families, such as, Biebersteiniaceae, Basellaceae, Coriariaceae, Daphniphyllaceae, Datiscaceae, Dorascaceae, Droseraceae, Phrymaceae, Pyrolaceae, Plantaceae, Hamamelidaceae, etc., are represented by just a single species in the Himalaya. Even a number of monotypic families, like Podophyllaceae, Moringaceae, Hippuridaceae, Myricaceae, Ceratophyllaceae, Circeasteraceae, Butomaceae, Tetracentraceae, Stachyuraceae, etc., have also been reported to be occurring in this region.

Similarly, *Primula, Impatiens* and *Carex*, each with more than hundred species and intraspecific categories, are amongst the largest genera in the Himalaya. Yet the different sectors of the Himalaya exhibit individual pattern of generic dominance.

Apart from the high endemism in the Himalayan flora, the floristic elements from neighbouring territories, such as, Afghanistan, Tibet, Turkistan, Siberia, Europe, USSR, China and Myanmar have also contributed significantly towards its richness because of contiguous geographical nature of the territory and other phyto-geographical phenomenon. The region is also far richer in the number of legume species as compared to that in the Eastern Himalaya, as also in the number of timber species, such as, *Acacia, Albizzia* and *Delbergia* species.

2.2.2. Fauna : The Himalayan ecosystem is unique, and perhaps no other single geographical feature had greater influence on the life, culture and history of the people of the Indian subcontinent than these mountains. In fact the Himalaya is the richest representative of the natural resources and biological needs. An annotated list of 2672 species, including 1837 invertebrates and 835 vertebrate species has been reported, as below, from Western Himalaya (ZSI, 1995).

Invertebrates : Cnidaria (01 species), Mollusca (56 species), Annelida (57 species), Crustacea (07 species), Arachnida (105 species), Chilopoda (21 species), Odonata (140 species), Plecoptera (20 species), Orthoptera (97 species), Dermaptera (43 species), Isoptera (44 species), Hemiptera (250 species), Trichoptera (60 species), Lepidoptera (230 species), Hymenoptera (600 species) and Coleoptera (106 species).

Vertebrates : Pisces (124 species), Amphibia (19 species), Reptilia (69 species), Aves (521 species) and Mammalia (102 species).

Comprehensive inventories on the faunal diversity of protected areas in the region, such as, Corbett National Park (1987), Rajaji National Park (1995) and Nanda Devi Biosphere Reserve (1989, 1997) have also been made. A brief account of the faunal components and their biodiversity in various faunistic groups in the Western Himalaya ecosystem have been given below.

Invertebrates

Cnidaria : Freshwater medusae have been found to be present in low altitude lakes in Kumaon hills. *Hydra vulgaris*, a hydroid, inhabits Bhim Tal lake.

Mollusca : 56 species (28 genera and 17 families) have been reported from the area, of which six species of land molluscs are endemic to Western Himalaya. *Anadenus*, a genus of slug, is confined to altitudes between 2000-3000 m while the species of *Macrochlamys*, *Syama* and *Bensonia*, etc., are found well above 3000 m. Globe trotting species like *Achantina fulica* introduced nearly a century back at Mussoorie failed to survive there. However, the molluscs seem to be thriving very well in the foothills and Siwaliks. Thus, out of 56 species, 35 have been found to occur in Dehra Dun district.

Annelida : While 20 species of leeches have been recorded from the forest zone, as many as 37 Oligochaete species occur both in terrestrial and aquatic habitats. Four species of earthworms are found in the lakes of Kumaon hills. Having been widely distributed in the ecosystem the earthworms form a dominant component of the fauna in some of the niches but with a little less endemicity as compared to that of Eastern Himalaya. The animals are of economic importance due to their role in vermi-composting and vermiculture.

Crustacea : It comprises Crabs, Shrimps, Isopods and various kinds of zooplanktons. The group constitutes a major food component for aquatic insects and fishes. Only 7 species of the group have been identified so far and recorded from Garhwal and Kumaon hills.

Arachnida : A total of 105 species of Arachnids comprising of scorpions and spiders are known from the ecosystem.

Scolopendromorpha : 21 species of the centipedes, belonging to seven genera and one family, are known to occur. This includes some new species and subspecies, *viz.*, *Rhysida corbetti*, *Rhysida monalii*, *Rhysida longicarinulata* and *Otostigmus poonamae* from the ecosystem.

Insecta

Odonata : 140 species out of a total of 499 known Indian species of dragonflies, have been reported from the Western Himalayan region alone, including a considerable number of new species and a large number of new records from the ecosystem.

Plecoptera : About 20 species including a small number of endemic forms are known to represent the ecosystem. The dominant genera being *Amphinemoura* and *Indonemoura*, while *Rhadiopteryx lunata* has been recorded to be very common above timber line up to an elevation of 4800 m in the West Himalaya.

Orthoptera : 97 species of orthopterans belonging to Acridoidea, Grylloidea, Tetrigoidea and Tridactyloidea have been chronicled from Garhwal and Kumaon hills.

Dermaptera : About 43 species of earwigs mostly belonging to the genera *Allodahia, Anecura, Forficula* and *Isolaboides,* exhibiting strong Palaearctic affinities, occur in the region.

Isoptera : These are economically very important group of insects that damages timber. 44 species belonging to Kalotermitidae, Stylotermitidae, Rhinotermitidae and Termitidae are known from the region. The general distribution pattern is Oriental. Interestingly, the relict termite, *Archotermopsis wroughtoni* is found to occur up to an altitude of 3655 m in Western Himalaya. A number of endemic forms and new species have also been reported from the region.

Hemiptera : The group comprising bugs, aphids, scale insects, etc., is known to be represented by as many as 250 species.

Trichoptera : Caddisflies also constitute another major group of amphibiotic insects in the ecosystem. About 60 species are known from Western Himalaya, 60% of which belongs to the family Rhyacophilidae. The cosmopolitan and the most dominant genus is *Rhyacophila*. The caddisflies play an important role in the food chain within the freshwater ecosystem and are of great importance in nutrition and management of fisheries.

Lepidoptera : Butterflies and moths constitute one of the largest group of insects in Western Himalaya and have assumed tremendous importance on account of economic considerations since most of their larval stages are herbivorous and, as such, cause extensive damage to their hosts including plants of economic importance. About 230 species of butterflies from Garhwal and Kumaon region are known. Several of these species are under the threat of extinction.

Hymenoptera : Out of about 1200 species of the family Ichneumoniidae known from India, 25% of the species are known from the Western Himalaya alone. About 200 species represent Vespoidea, Apoidea, Chalcidoidea and Proctotrupopidea. These are the insects of economic importance since most of them parasitise the eggs and larvae of the pest of crops and can be effectively used as agents for biological control of insect pests. A total of about 600 species of hymenoptera are known from this region.

Coleoptera : Beetles are of great economic importance so far as their role in damaging timbers, foliage, horticulture, agricultural crops, being borers of soft wood, hardwood and felled trees, defoliators, seed borers and stored grain pests, etc., during their various stages of growth. More that 690 species are reported from the Northwest Himalaya. However, 106 species of beetles have so far been identified from the Western Himalaya.

Vertebrates

Pisces : 124 species, including new species, new records and introduced species are known from this region, the most important being Mahaseer (*Tor putitora)* and Snow Trout *(Schizothorax richardsonii)*, which are widely distributed in lesser Himalaya among all the major rivers and their tributaries. Both the species are highly endangered due to interference in their migratory routes and breeding grounds by the construction of hydroelectric dams, which obstruct their migration to spawning grounds and back. Serious conservation measures need to be undertaken for the conservation of these species.

Amphibia : 19 species of frogs and toads, including three new species have been reported from the region.

Reptilia : The fascinating snakes, lizards, testudines and crocodiles constitute this group, represented by 69 species from Western Himalaya.

Fig. 5 : Western Tragopan (*Tragapan melanocephalus)* (Female) (*Courtsey* Rames, K., WII, Dehra Dun)

Aves : As many as 521 species of birds have been reported from the Himalayan ecosystem, which includes pheasants, hill stream birds, forest birds and a large number of water birds. A number of migratory waterfowl from temperate region visit the natural lakes and man made wetlands in this region in lakhs during winters.

Mammalia : Mammalian fauna of the ecosystem is most fascinating and diverse because of varied ecological conditions at different altitudes. Little over 100 species of mammals are known to occur presently, some of which are already threatened and listed in Schedule I of Wildlife (Protection) Act, 1972. The mammals are represented by five insectivore species, 27 species of bats and

Fig. 6 : Himalalyan Tahr (*Hemitragus jemlahicus*) (*Courtsey* : Otto Fisher, WII, Dehra Dun)

flying fox; Rhesus Macaque and Langoor; Pangolin; Indian elephant; 26 species of carnivores, important of them being Snow Leopard, Leopard, Leopard Cat, Tiger, Caracal, Lynx, Jungle Cat, Civet, Hyaena Weasel, Martin, Brown/Black/Sloth Bears, Jackal and Foxes; five species of Deer besides Giant Flying Squirrel, Palm Squirrel, Himalayan Marmot, Porcupine and several species of rats and mice.

3. SPECIAL FEATURES

The diversity of faunal components in the Himalaya clearly indicates the extent of fauna restricted to the forest zone and above the timberline, including a remarkably high percentage and predominance of Indo-Malayan elements. Besides the endemism, the Western Himalaya shows central Asian and Palaearctic affinities. The richness of fauna is distinctly higher in forest zone especially in the broad-leaved wet forest area than in nival zone. The Palaearctic forms generally increase towards the west; the endemic forms in the forest zones are poor and the fauna generally comprises tropical elements derived from Oriental region. The oriental faunal elements disappear gradually towards the west but some of them may still be found in parts of Kashmir. There is more complete intermingling of Oriental and Palaearctic elements among vertebrates than invertebrates. Then gorge of the River Sutlej forms the biogeographical transition between the eastern humid tropical and western largely steppe fauna in the Himalayan forest zones. Thus the Oriental element is generally restricted to the east of this river while the Ethiopian and Mediterranean elements are found west to the river though infiltration of these elements on either side is not uncommon. The fauna above the timberline is strikingly different from that of forest zones, relatively sparse, characteristically lacking in tropical Indian, south Chinese and Malayan derivatives, and comprises almost exclusively of endemic cold adapted Palaearctic elements. Among the vertebrates,

Fig. 7 : Typical Himalayan tahr habitat (*Courtsey* : Vinod, T.R. WII, Dehra Dun)

the fishes and the amphibians are almost totally absent, reptiles are present in poor numbers while the birds and mammals are moderately abundant.

3.1 Endemic species

Broadly endemics are of two types : those who are the relict as the last remnant of old taxa and whose distribution has shrunk and, those that are of recent origin which did not have the time to extend their range. It appears that in Western Himalaya the endemic of the second category is found. The endemism in the Himalayan biota is further related to a number of physical and biological factors. There is a considerable diversity in geology, geography, soil and climate giving rise to many 'micro' and 'macro' habitats. The diversity in the flora is particularly apparent in vegetation types. The three major factors operating simultaneously are longitude, latitude and altitude. Additionally, the Himalayan biota is under different biogeographic influences, *viz.*, Palaearctic, Mediterranean, Sino-Japanese, Indo-Malayan and Peninsular India. Still there is a considerable degree of endemism.

4. INTRODUCED BIODIVERSITY

With the continual degradation and depletion of forest floor, the areas which were earlier inaccessible are now being cultivated with the fast growing forest and fruit tree species of temperate region up to high altitudes. Such cultures have brought with them introduced variety of fauna specially pests of crops, fruit trees and forests, as also the viruses. With the growing tendency of social forestry and ornamental plants, the advent of soil microarthropods, annelids, centipedes, millipedes, etc., has increased, which may establish and may also be threatening to the local population of species. For instance exotic fishes like Brown Trout (*Salmo trutafario)* and Rainbow Trout (*Salmo gairdnerii)* were introduced by the British administrators for sports in the cold water streams of Himalaya. Realizing their potential as a food fish, these trouts are now being cultured in large scale in the parts of Kashmir, Himachal Pradesh, Garhwal and Kumaon hills. Since these trouts are carnivorous they adversely affect the natural population of endemic Mahaseer (*Tor* sp.) wherever cultured. Similarly the weeds like *Lantana* sp. and *Parthenium* sp. introduced for some other purpose have now become menace and their erradication has become a problem in the cultivated and semi-cultivated lands.

5. VALUE

Since the Himalaya literally forms a gigantic arch, which separates Indian plains from north Tibet and central Asia, any degradation of Himalaya will have a profound effect on the environment of Indian plains and central Asia. Therefore, it is of utmost importance to conserve this rather fast deteriorating and fragile ecosystem as a number of endemic species are present in this ecosystem. These are adapted to the characteristic environmental conditions prevalent there specially in the nival zone. In addition, there are a number of species, which are threatened due to large-scale destruction of their habitats. Considering the ecosystem as a gene bank, if the populations of these species are reduced, there may be genetic drift and gene loss, which is an important loss.

6. THREATS

There are manifold causes for the loss of biodiversity. Some of these are the rapid expansion of industries and agriculture, urbanization and large-scale development projects like dams, highways, mining and increased intensification of human activities. These activities have led to destruction of the habitats, pollution and over utilization of biological resources, which have resulted in the rapid erosion of India's biodiversity.

Fig. 8 : Himalayan Musk deer *(Moschus chrysogaster)* (*Courtsey* : S. Sathyakumar, WII, Dehra Dun)

Trade in wildlife and its derivatives is a phenomenon seriously affecting global biodiversity. Despite stringent protection it continues unabated illegally for want of serious punitive measures and penalties. The Himalayan region is considered as a hotspot for global biodiversity and as such the trade and utilization from this region constitute a serious threat to its ecology. As expected, plants and plant produce are among the heavily traded species. Among fauna, musk from the Himalayan Musk Deer *(Moschus chrysogaster)*, bile from Himalayan black bear *(Ursus arctos)*, mammalian furs, wool and butterfly form the 'backbone of the himalayan species in trade'

Due to ever increasing human activities in the hills especially since about last century or so there has been lot of biotic pressure on the Himalayan ecosystem. Local communities for subsistence needs used the forests of the hills till 19th century. Traditional societies depended more upon the utilization of non-timber forest products while utilization of timber resource was kept minimum. However, intensive depletion of forests due to logging started by the beginning of 20th century so as to meet the national and global timber demands.

The Himalayan Black bear, the Brown bear and Musk deer are the most threatened species, poaching of which for trade in musk and bile, etc., continues unabated into astronomical values, although the flora Ladies-slipper Orchids *(Paphiopedilum species)* remains the leader in quantum of illegal trade.

About 20 species are categorized as "possibly extinct" as these species have not been sighted in India during the last 6-10 decades, while the Indian Cheetah, the Pink-headed duck and Mountain quail have become

Table 2. Faunal Diversity and Endemism in Himalaya

Taxa	No. of species				
	Western Himalaya (314-3322 m)	Central Himalaya (618-2005 m)	Eastern Himalaya (1871-5000 m)	NE Himalaya (395-2500 m)	Total from Himalaya/ Endemic/ typical to Himalaya
Reptilia	32	30	60	90	149/29/nil
Amphibia	17	16	26	54	74/5/25
Pisces	80	130	44	159	218/56/35

Source : Ghosh, A.K., 1996

Fig. 9 : Typical Himalayan Musk deer habitat (*Courtsey* : Vinod, T.R., WII, Dehra Dun)

extinct. 81 species of mammals, 47 birds, 15 reptiles, 3 amphibians and equally large number of butterflies, moths and beetles, besides 1500 species of plants are considered vulnerable and endangered. Unfortunately illegal trade still continues in ivory, Rhinoceros horns, musk, Peacock feathers, snake skins and certain threatened plants species including orchids. The Tables 3 and 4 indicate the list of threatened and endangered fauna.

Most of the world's biodiversity is present in the developing countries. The tropical zones are particularly rich. Although essentially falling in the temperate region, the climate of Himalaya varies from near sub-tropical to tropical, temperate, alpine to other extremes of arctic conditions, with permanent snow at high altitudes. The region is vulnerable to various pressures related to natural, economic, developmental and the population causes. Estimates may vary but it is certain that the biodiversity in the Himalaya is now being lost at an alarming rate, giving rise to wide spread concern. This is evidenced in the substantial increase in the interest accorded to the biodiversity conservation programme in the Himalaya.

The percentage of the threatened taxa in this fragile ecosystem is comparatively much higher with a break up, Mammals 38%, Birds 21%, Reptiles 20%, Butterflies 13% and Beetles 2% of the respective groups. Freshwater and soil fauna is under tremendous stress due to organic and chemical pollution of ponds, streams and wetlands.

In light of the developmental needs of the area, various case studies reviewing specific conservation problems have been undertaken and are also in process. Yet the threat to the traditional practices and cultural beliefs of the people of the Himalaya region is always on the rise, besides the remarkable change in the status of biodiversity over the past few years. Coupled with this, there has also been a significant change in the people's perception of the biodiversity. We have literally moved from the era of sports hunting to game preservation followed through a phase of wildlife protection, to that of the current approach of conserving the habitat and biodiversity as a whole. Being a part of the developing nation, in Himalaya too we are loosing biodiversity due to habitat alteration, over-exploitation, urbanization and increased anthropogenic pressures.

The wetland biodiversity in the Himalayan Region is also subjected to a lot of anthropogenic pressures. Major upstream changes have resulted in the hydrological changes and increased output of nutrients and sediments. The man made barricades and construction of hydroelectric projects, drainage and flood control have added to the gravity of the problem and greatly affected the hydrological regime of the region. Massive deforestation has reduced residual cover and altered plant succession to the disadvantage of wildlife.

7. CONSERVATION

India is actively involved in biodiversity conservation and is cooperating with other nations in this regard. India is a contracting party to a number of International treaties/ conventions relevant to biodiversity. The total obligation in existing treaties falls short of the demands of an adequately comprehensive system. The Convention on Biological Diversity attempts to meet any of these demands and CBD is the first treaty to concentrate specifically on the conservation and sustainale use of biodiversity.

India, alongwith 166 other countries signed the CBD during UNCED Earth Summit held at Rio De Janeiro, Brazil in July 1992. The

Table 3. Some threatened fauna of Northwest and Western Himalaya

Common Name	Scientific name
Mammals :	
Barking deer	*Muntiacus muntjak*
Bharal	*Pseudois nayaur*
Caracal	*Felis caracal*
Chital	*Cervus axis*
Indian fox	*Vulpes bengalensis*
Common langur	*Semnopithecus entellus*
Fourhorned antelope	*Tetracerus quadricornis*
Goral	*Nemorhaedus goral*
Himalayan tahr	*Hemitragus jemlahicus*
Himalayan brown bear	*Ursus arctos*
Himalayan crestless porcupine	*Hystrix hodgsoni*
Himalayan ibex	*Capra ibex*
Himalayan palm civet	*Paguma larvata*
Himalayan black bear	*Selenarctos thibetanus*
Hog deer	*Axis porcinus*
Striped Hyaena	*Hyaena hyaena*
Small Indian civet	*Viverricula indica*
Indian elephant	*Elephas maximus*
Indian wolf	*Canis lupus pallipes*
Jungle cat	*Felis chaus*
Kashmir stag (Hangul)	*Cervus elaphus hanglu*
Leopard	*Panthera pardus*
Leopard cat	*Felis bengalensis*
Lynx	*Felis lynx isabellinus*
Markhor	*Capra falconeri*
Common Mongoose	*Herpestes edwardsi*
Musk deer	*Moschus chrysogaster*
Nayan	*Ovis ammon hodgsoni*
Nilgai or Blue Bull	*Boselaphus tragocamelus*
Pallas's cat	*Felis manul*
Pangolin	*Manis crassicaudata*
Red fox	*Vulpes vulpes*
Rhesus Macaque	*Macaca mulatta*

Table 3. (contd.)

Common Name	Scientific name
Sambar	*Cervus unicolor*
Serow	*Capricornis sumatraensis*
Sloth bear	*Melursus ursinus*
Snow leopard	*Panthera uncia*
Tibetan antelope	*Pantholops hodgsoni*
Tibetan gazelle	*Procapra picticaudata*
Tibetan Wild ass or Kiang	*Equus kiang*
Tiger	*Panthera tigris*
Urial (shapu)	*Ovis vignei*
Wild dog	*Cuon alpinus*
Wild yak	*Bos mutus*
Yellow-throat marten	*Martes falvigula*
Birds :	
Blacknecked crane	*Grus nigricollis*
Cheer pheasant	*Catrius wallichii*
Lemmergeier	*Gypaetus harbatus*
Himalayan monal	*Lophophorus impejanus*
Mountain quail	*Ophrysia superciliosa*
Pea fowl	*Pavo cristatus*
Tibetan snow-cock	*Tetraogallus tibetanus*
Western tragopan	*Tragopan melanocephalus*
Satyr tragopan	*Tragopan satyra*
Reptiles :	
Common Indian monitor	*Varanus bengalensis*
Dhaman (rat snake)	*Ptyas mucosus*
Indian cobra	*Naja naja*
King cobra	*Ophiophagus hannah*
Russel's viper	*Vipera russelli*
Insects :	
Carabid beetle	*Amara brucei*
Fritillary butterflies	*Argynnis altissima*
Fritillary butterflies	*Argynnis clara clara*
The Vanessas	*Vanessa c-album*
Apollo butterfly	*Parnassius stoliczkanus*
Regal Apollo butterfly	*Parnassius charltonius charltonius*
Keeled Apollo butterfly	*Parnassius jacquemontii jacquemontii*
Clouded yellows	*Colias eogenen*
Clouded yellows	*Colias ladakensis*
Argus butterfly	*Erebia mani mani*
Dusky labyrinth	*Lethe yamabutterfly*
Dark wall butterfly	*Parange menave meroides*

Source : Faunal resources in the Himalaya (1996).

convention has come into force w.e.f. 29th December, 1993.

The extent of protected areas in Himalaya is only 5% of its total surface, which is too little for such a unique and fragile ecosystem under sustained anthropogenic pressures. The protected areas should be revised to at least 10% of the ecosystem.

Within the eight hills districts of Western Himalaya (Garhwal & Kumaon), the following protected areas are very significant for the wildlife values and their faunal diversity.

1. Corbett National Park (Distt. Nainital),
2. Rajaji National Park (Distt. Dehra Dun and Pauri),

Table 4. Endangered Mammals in the Himalaya

Common Name	*Scientific name*
Slow Loris	*Nycticebus coucang*
Hoolock Gibbon	*Hylobates hoolock*
Brown Bear	*Ursus arcots*
Asiatic Black Bear	*Selenarctos thibetianus*
Spotted Linsang	*Prionodon pardicolor*
Binturong	*Arctictis binturong*
Marble Cat	*Felis marmorata*
Golden Cat	*Felis temmincki*
Himalayan Lynx	*Felix lynx*
Clouded Leopard	*Neofelis nebulosa*
Snow Leopard	*Panthera uncia*
Great one-horned Rhinoceros	*Rhinoceros unicornis*
Kiang	*Equus kiang*
Pygmy Hog	*Sus salvanius*
Musk Deer	*Moschus chrysogaster*
Kashmir Stag	*Cervus elaphus*
Indian Buffalo	*Bubalus bubalis*
Himalayan Tahr	*Hemitragus jemlahicus*
Ibex	*Capra ibex*
Markhor	*Capra falconeri*
Urial (Shapu)	*Ovis vignei*
Yak	*Bos mutus*
Hispid Hare	*Caprolagus hispidus*

Source: **Red Data Book I, ZSI (1994)**

3. Nanda Devi Biosphere Reserve—A World Heritage Site (Dist. Chamoli, Almora and Pithoragarh),
4. Valley of Flowers National Park (Dist. Chamoli).
5. Kedarnath wildlife sanctuary (Distt. Chamoli), and
6. Gobind Pashu Vihar (Dist. Uttarkashi)

In the above protected areas in this region, despite tremendous anthropogenic pressures, tourism, grazing, etc, the status of space, forest cover and wildlife still seems to be satisfactory, although some new protected areas to bridge the gap between high and low altitudes are yet to be identified. Management of existing forests needs improvement as is evident from the faulty ratio between seedlings, immature, mature and very old trees; pruning, especially conifers reduces cover for protection of soil, overgrazing and trampling. There is hardly any decline in illegal felling of forest trees and killing of wild animals. Population of live stock and human beings is on the increase. So is the case with the construction of hydroelectric projects. The situation is becoming alarming day by day.

8. FUTURE DIRECTIONS

The mountains in general, and the Himalaya in particular comprise one of the world's remaining intact wilderness, and were relatively better protected than most other biomes till very recently. The rich biodiversity is, however, severely threatened by various human dimensions.

The information available on different aspects of biodiversity in the Himalaya is still grossly inadequate. It is imperative to identify gaps in our knowledge, including the importance of maintaining biodiversity but the message has not percolated to the grassroots. It requires an effective tool of dissemination.

The issues related to Himalayan biodiversity conservation are location specific in their real perspective and mostly relate to the scarcity and inefficient management of necessities of sustenance. It is also important to develop action oriented strategies at different levels, including scientific inputs, people's participation, etc., as effective tools.

Planning for conservation of biodivesity can be approached in two ways: (i) ecosystem or habitat based and (ii) species based.

While the ecosystem based approach attempts to conserve the representative habitat types or ecosystem through designation of network of protected areas or through control on the use of land, the species based approach implies review of taxa identifying new species considered to be of high priority for conservation.

In order to control losses in biodiversity and restore degraded ecosystems, we need to have a full assesment of the magnitude of such losses that stem from the utilization of biodiversity, and the factors that promote the unsustainable use of biotic resources. An important aspect is to strengthen the measuring, monitoring and management of biodiversity and evaluate our conservation strategies in the light of human needs for biomass with coordinated approach to sustain protection of both areas and diversity as seen in totality.

9. SELECTED REFERENCES

Ahmad, A., Rajput, J.S. and Rai, S.C. 1990. An analysis of the Himalayan environment and guidelines for its management and ecologically sstainable development. *Environmentalists*, **10**(4) : 281-298.

Ahuja, Amber, 1996. Loss of biodiversity and need for conservation. In : *Changing perspectives of Biodiversity Status in Himalaya*. British Council Division, British High Commission, : 131-138.

Alfred, J.R.B., Chakraborty, S. and Das, A. K. 2001. Mountains : Eastern Himalaya. In : *Ecosystems of India* ENVIS–Centre, Zool. Surv. India, Kolkata : 1-33.

Arora, G.S. and Kumar, A. (Coordinators) 1995. Fauna of Western Himalaya (U.P.).
Himalayan Ecosystem Series, Part-I, Zool. Surv. India, : 1-223.

Arora, G.S. and Kumar, A. 1996. Faunal resources in the Western Himalay. In : *Conservation and Management of Biological Resources in Himalaya*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, : 209-232.

Bhat, J.L. and Desh Bandhu, 1994. Biodiversity for sustainable Development. *Indian Env. Soc.,* : 1-100.

Chandola, A. *et al.,* 1993. Status survey of 'endangered' Himalayan Mahseer. In : *Himalayan Biodiversity Conservation Strageties*. Himavikas Publication No. **3** : 303-309.

Dhar, U. 1996. Overview of Himalayan Biodiversity. In : *Changing perspectives of Biodiversity Status in the Himalaya.* British Council Division, British High Commission, : 3-20.

Ghosh, A.K. 1996. Faunal Diversity. In : *Changing perspectives of Biodiversity Status in the Himalaya.* British Council Division, British High Commission. : 43-51.

Jairajpuri, M.S. 1993. Faunal Diversity in Himalaya: Need for inventorisation and constraints. In : *Himalayan Biodiversity Conservation Strategies*. Himavikas Publication No. **3** : 57-64.

Khoshoo, T.N. 1993. Himalayan Biodiversity Conservation: An Overview. In : *Himalayan Biodiversity Conservation Strategies*. Himavikas Publication No. **3** : 7-35.

Kumar, A., Tak, P.C. and Arora, G.S. (Coordinators) 1997. Fauna of Nanda Devi. Biosphere Reserve-A World Heritage Site. *Fauna of Conservation areas* **9**, *Zool. Surv. India,* : 1-166.

Mani, M.S. 1974. *Ecology and Biogegraphy in India*. Dr. W. Junk b.v., Publishers, The Hague, : 1-772.

Nandi, S.N. Pant, R and Rao, K.S. 2000, *Indian Himalaya a demographic data base. ENVIS Monograph* 2. G.B. Pant Institute of Himalaya Environment and Development, Almora, India. 75 pp.

Rodgers, W.A. and Panwar, H.S. 1998. *Planning a wildlife Protected Area Network in India.* Wildlife Institute of India, Dehra Dun.

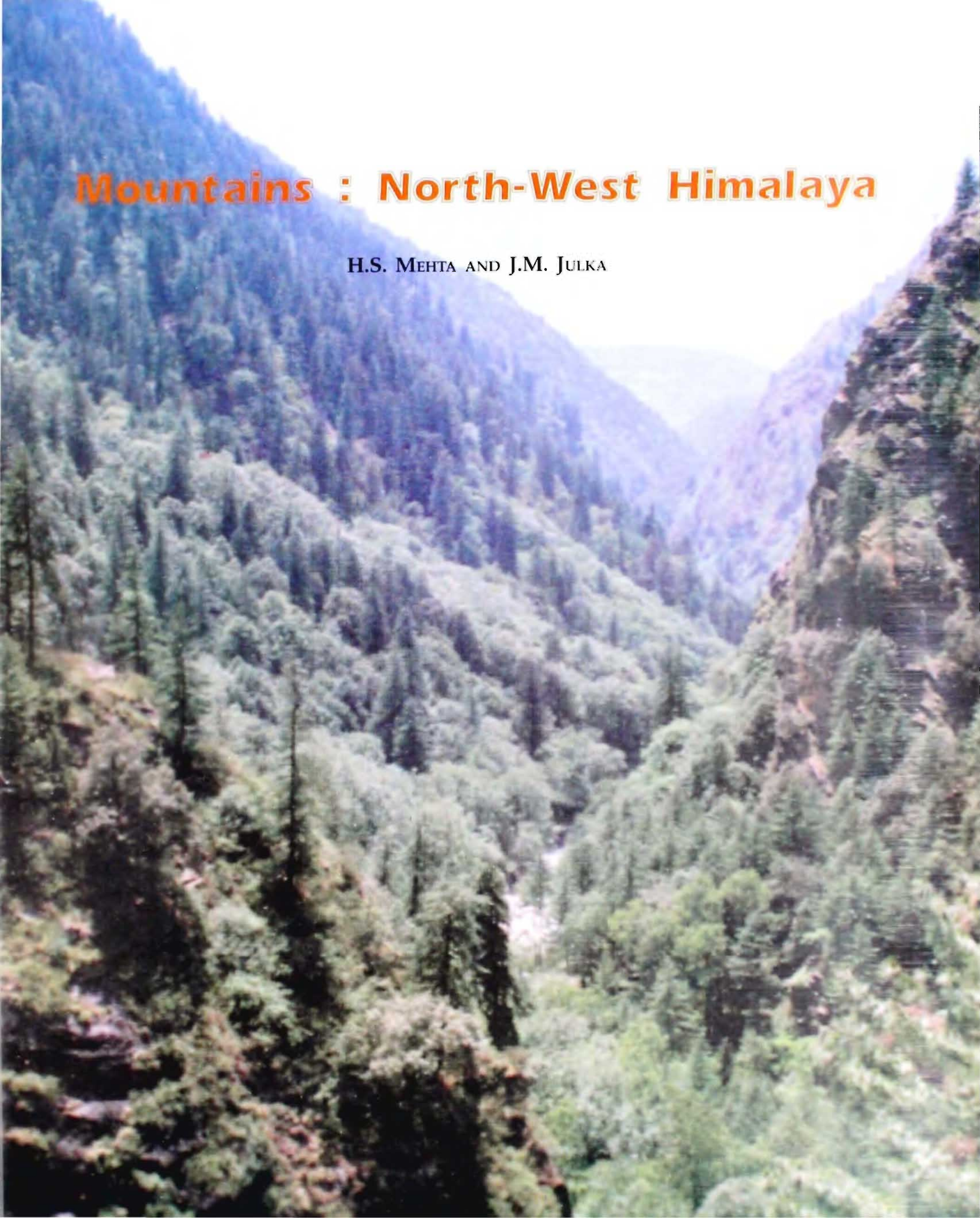
Singh, D.K. and Hazra, P.K. 1996. Floristic Diversity, In : *Changing perspectives of Biodiversity Status in the Himalaya.* British Council Division, British High Commission, : 23-28.

Shiva, Vandana, 1996. Case study of Western Himalaya. In : *Changing perspectives of Biodiversity Status in the Himalaya.* British Council Division, British High Commission, : 111-124.

Trishal, C.L. 1996. Wetland diversity in Himalayan Region. In : *Changing perspectives of Biodiversity Status in the Himalaya.* British Council Division, British High Commission, : 63-71.

Mountains : North-West Himalaya

H.S. Mehta and J.M. Julka



ENVIS–*Zool. Surv. India*
Ecosystems of India : 51-72, 2001.

Mountains : North-West Himalaya

H.S. Mehta and J.M. Julka

High Altitude Zoology Field Station
Zoological Survey of India, Solan, Himachal Pradesh

1. INTRODUCTION

The Himalaya constitutes one of the youngest mountain systems in the world and froms a gigantic physical barrier between the high plateaus of Tibet and Central Asia, and the Indian plains. They are about 2500 km long, extending from the River Indus in the west to the River Brahmaputra in the east. Geographically, the Himalayan ranges are subdivided into four major zones: East or Assam Himalaya, Central or Nepal Himalaya, West or Kumaon-Garhwal Himalaya and North-West or Himachal-Kashmir Himalaya. Each zone is characterised by distinct climatic conditions and biota.

This article reviews the status of ecosystem and biotic diversity in the North-West

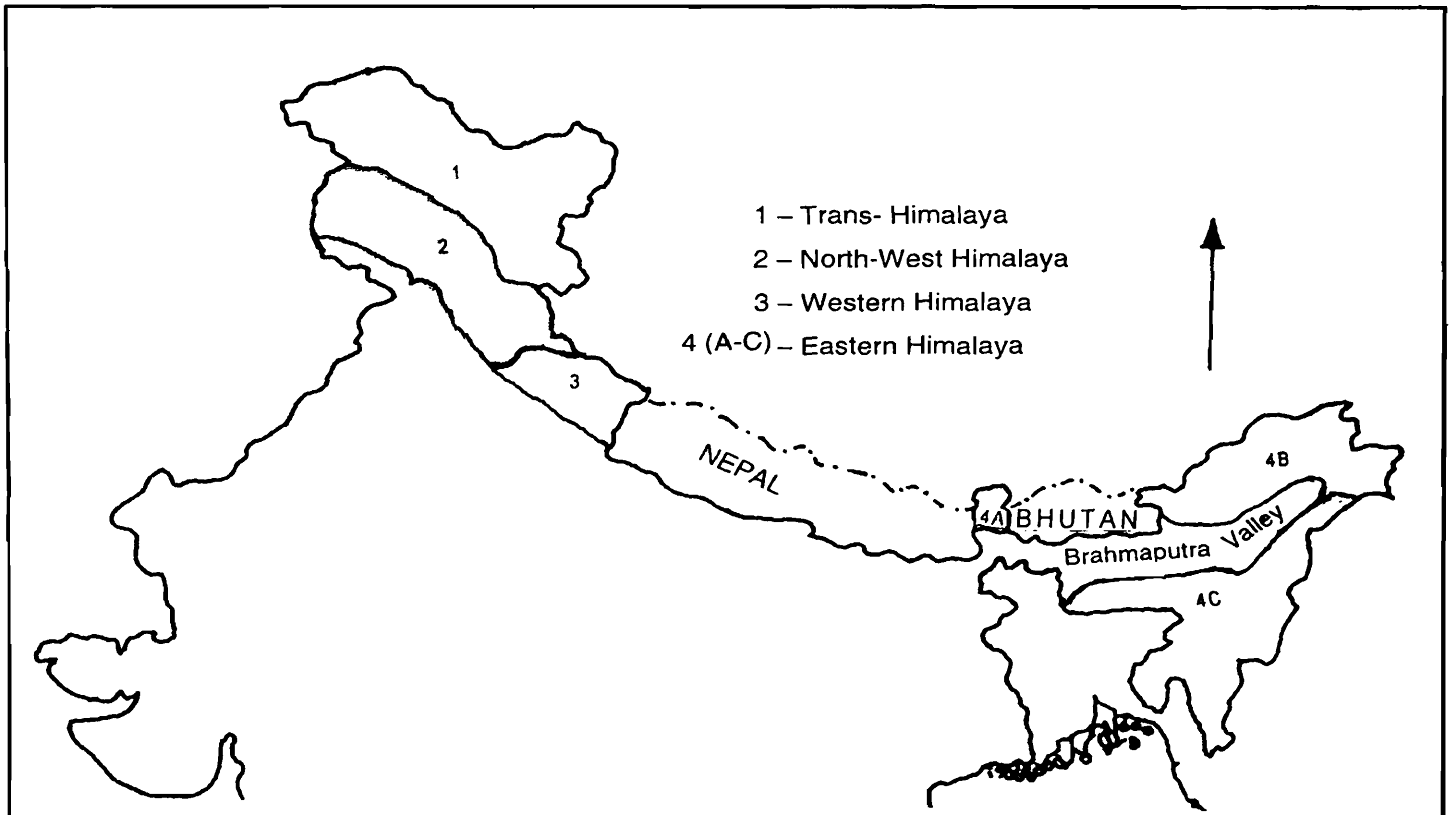


Fig. 1 : Biogeographic divisions of Indian Himalaya (only coloured area dealt with in the article)

Himalaya covering the states of Himachal Pradesh and Jammu & Kashmir excepting Ladak, Kargil and Spiti areas which constitute a separate and distinct unit, Trans-Himalaya and is dealt with in a separate article.

The floral and faunal diversity in Himachal Pradesh and Jammu & Kashmir is very rich and diverse, primarily due to varied climatic conditions ranging from tropical in the foothills to arctic environment in the Trans-Himalayan region. Historical influx of biota from adjacent biogeographical regions and subsequent speciation in relation to local environment has also enriched the biotic resources of the area. The state of Himachal Pradesh is unique as it is the only Himalayan region which is divided into eastern and western parts by an antecedentary river, the Sutlej, established much before the uplift of the Himalaya. Himachal Pradesh, therefore, encompasses parts of both the North-West Himalaya and the Kumaon-Garhwal Himalaya. This important geographical feature has significantly influenced the biogeography of this region. Like rest of the North-West Himalaya, the biota at higher elevations in Himachal Pradesh is Palaearctic, the dominant elements being derived from the Turkemenian and the eastern extension of the Mediterranean sub-regions. The Oriental species from the east are also encountered in the foothills and the Lesser Himalayan region of the state. Although it is difficult to delineate a boundary between the Oriental fauna of the east and the Palaearctic elements of the North-West Himalaya, the Sutlej defile appears to mark this biogeographical separation. The biota of Jammu & Kashmir is largely of Palaearctic origin.

Fig. 2 : Great Himalayan National Park (N-W Himalaya, district Kullu, Himachal Pradesh)

2. DESCRIPTION

The states of Himachal Pradesh (56,090 sq km) and Jammu & Kashmir (2,22,235 sq km) cover an area of 2,78,325 sq km, between approximately 30°18′ and 72°06′ N latitudes and 72°30′ and 79°04′ E longitudes. They are located in the North-West and Western sectors of the Himalaya. The principal parallel ranges from the south to the north comprise of the Siwaliks, the Lesser Himalaya, the Great Himalaya and the Trans-Himalayan Zanskar, Ladakh and Karakoram. The Siwalik ranges represent the southernmost zone of about 40-60 km width, comprising several highly eroded low ridges. A zone of medium to high ranges (about 80 km wide), the Lesser Himalaya runs north of the Siwaliks and parallel to the main range. The principal ranges in this zone are the Pir Panjal, the Dauladhar and the Nag Tibba. North of the Pir Panjal in Jammu & Kashmir lies the famous Kashmir Valley, which is the largest valley in the entire Himalayan range. It is about 135 km long and about 40 km wide, and has an area of about 4865 sq km. The Great Himalayan range lies just north of the Kashmir Valley and the Chandra-Bhaga (Chenab) river in the Lauhal-Spiti and Pangi regions of Himachal Pradesh. This range is nearly 24 km wide and comprises the great peaks rising up to an elevation of over 6000 metres amsl.

The area extends from the plains of Haryana and Punjab, and adjoining mountains of Uttar Pradesh to Pakistan in the west, Tibet, and Central Asia in the north. Its topography favours a wide range of altitudinal and temperature conditions. The elevation ranges from 300 m to over 6000 m amsl, more than one half of the area being higher than 3000 m amsl. The climate ranges beween scorching heat and arctic cold with intermediate subtropical, temperate and alpine grades. Average annual rainfall varies from 60 mm in dry Trans-Himalayan district of Ladakh in Jammu & Kashmir to about 2500 mm on the lower slopes of the Dauladhar in Kangra district of Himachal Pradesh. Precipitation at higher elevations is mostly in the form of snow. The hills at about an altitude of 3000 m are covered with a thick blanket of 3 metres of snow from December to March, while the area above an elevation of 4500 m remains almost perpetually under snow. Mean temperature drops by as much as 6°C for every 1000 m of ascent.

Fig. 2 : A view of Shiwalik hills (Punjab)

3. BIOLOGICAL DIVERSITY

3.1 Ecosystem/Habitat Diversity

Varied physiographic and climatic factors have given rise to diverse natural ecosystem/ habitats, namely, forests, grasslands and pastures, rivers, lakes and wetlands, glaciers, etc., in this region.

3.1.1. Forests : Natural vegetation of this area is classified into the following five broad types of forests:

(i) Tropical forests (confined to foothills) : Represented by two subtypes, namely, thorn-scrub of *Acacia* and *Zizyphus*, and dry deciduous forests of Sal (*Shorea robusta*); the latter is best developed in the Paonta area of district Sirmour in Himachal Pradesh.

(ii) Subtropical forests (500-1800 m) : Two subtypes of these forests can be distinguished in the area. These are : (a) Subtropical dry evergreen forests occurring below 1200 m along river Beas, dominated with species of *Terminalia*, *Albizzia*, *Olea*, etc.; (b) Subtropical pine forests of chir pine (*Pinus roxburghii*) found up to 1800 m.

(iii) Temperate forests (1500-3000 m) : They are distinguished into two subtypes. The Himalayan moist temperate subtype covers vast areas between 1500 m and 3000 m. The main constituents of this forest subtype are three species of oaks (*Quercus incana*, *Q. dilatata*, *Q. semicarpifolia*), deodar (*Cedrus deodara*), fir (*Abies pindrow*), blue pine (*Pinus wallichiana*) and horse chestnut (*Aesculus indica*). The Himalayan dry temperate subtype of Holm oak (*Quercus ilex*) and edible pine (*Pinus gerardiana*) is best developed at 2000-3000 m in the Trans-Himalayan valley of Chandra-Bhaga river and upper valley of Sutlej river in Kinnaur district of Himachal Pradesh and in the Kashmir Valley.

3.1.2. Lakes and Reservoirs : North-West Himalaya is bestowed with several natural freshwater and brackish water lakes and a few large man made reservoirs. They serve as an important support system and as habitats for birds, fishes and other aquatic life.

Natural lakes are distributed among different climatic zones of Himachal Pradesh. Some of these are Khajiar, Kuneri, Kunarwah and Rewalsar in Temperate Zone (1500-3000 m), and Renuka and Saketi in subtropical zone (below 1500 m). Some large reservoirs have been formed due to damming of rivers, *e.g.*, Pong and Pandoh on river Beas, and Gobind Sagar on river Sutlej. Renuka Lake, Pong, Pandoh and Gobind Sagar reservoirs have been declared as wetlands, which are biologically most productive. Among these, Renuka and Pong are of national importance. Renuka wetland exhibits great faunal diversity as it is well protected because of its remoteness and location amid a wildlife sanctuary of the same name. Studies conducted in 1992-93 by the scientists of High Altitude Zoology Field Station of the Zoological Survey of India at Solan show the

Fig. 4 : Forests and streams in lower Himalaya

occurrence of 427 faunal species in this wetland and surrounding marginal areas of the sanctuary. Pong wetland and surrounding wildlife sanctuary support a rich avifauna comprising more than 220 species. The wetland serves an excellent winter habitat for several thousands of migratory waterfowl, namely, Bartheaded goose, Pintail, Common teal, Spotbill, Shoveller, Mallard, Gadwall, Brahminy duck, Pochard, Tufted duck and Bluewinged teal.

3.1.3. Rivers and Streams : The Indus River system drains Jammu and Kashmir. The main tributaries of the Indus draining different parts of the state are: Shyok, Nubra, Hanle and Zanskar in Ladakh; Jhelum, Kishen Ganga and Lidder in Kashmir Valley; Chenab, Jhelum, Poonch and Tawi in Jammu region. Himachal Pradesh is drained by five river systems, namely Chandra-Bhaga (Chenab), Ravi, Beas, Sutlej and Yamuna.

An intricate network of perennial torrential streams traverses the entire North-West Himalaya. These streams support a rich fauna, dominated by a high diversity of aquatic insects. As many as 62 species of aquatic insects (species diversity index=2.13-2.66) have been recorded in a small section of a spring-fed stream in district Solan.

The fauna of hill streams is distinctive in possessing special features for survival in swift currents with high oxygen content and low temperature. Any large scale disturbance in a torrent has, therefore, an immense impact on the distribution and composition of its fauna. Some characteristic faunal species of the torrents are larvae of *Ecdyonurus, Ephemerella, Ironopsis* and *Choroterpes* (Ephemeroptera), *Capnia* and *Illiesonemura* (Plecoptera), *Deuterophlebia, Blepharocera, Horaia, Dixa, Antocha* and *Simulium* (Diptera), *Rhyacophila, Agapetus, Cheumatopsyche,* Hydroptilidae and Lepidostomatidae (Trichoptera), *Psephanoides* (Coleoptera), and *Corydalus* (Megaloptera); *Garra, Noemacheilus, Glyptothorax, Schizothorax* (Pisces) and tadpoles of *Amolops* (Amphibia).

River valley projects have brought considerable changes in the ecology of rivers and surrounding areas. In Himachal Pradesh, dams have been constructed at Bhakhra on river Sutlej and at Pandoh and Pong on river Beas, resulting in the formation of very large reservoirs. Studies on the impact of Pandoh dam on invertebrate fauna of river Beas show a significant decline in the diversity of stonefly and dipterous larvae in its downstream. This decline has been primarily attributed due to reduced water flow and organic enrichment received from nearby human habitation. On the contrary, the population of aquatic bugs, planarians, oligochaetes and molluscs has appreciably increased at this site. Changes in the densities of different invertebrate groups are bound to affect the distributional pattern of fish since they form important components in the food chain of torrential fishes. Dams also act as physical barriers to migration of certain fish species to their breeding grounds. *Tor putitora* or the Mahseer is an important commercial fish in the rivers of Himachal Pradesh. The Mahseer migrates from the main rivers to the tributaries for breeding in monsoon months and descends back before the onset of winter. Dams and barrages have been implicated in the decline of mahseer fishery in the state.

3.1.4. Pastures : Pastures encompass more area than any other ecosystem in North-West

Fig. 5 : North-West Himalaya High Attitude Pastures

Himalaya, providing nutrient rich forage for grazing livestock and wildlife. As much as 31% of the geographical area of Himachal Pradesh and 59.3% of the geographical area of Jammu & Kashmir are under permanent alpine pastures. Low altitude grasslands in Jammu and Himachal Pradesh are mostly man made, being the result of deforestation.

3.1.5. Agroecosystems : The present day agroecosystems in North-West Himalaya, once covered with natural vegetation, are the out come of permanent changes of the original ecosystems. Estimates show that 17.5% and 3.4% of the geographical areas of Himachal Pradesh are under agriculture and horticulture respectively.

3.2 Species Diversity

Several bioclimatic zones due to altitudinal effects have favoured rich species diversity in North-West Himalaya. Historical influx of biota from adjacent biogeographical regions and subsequent speciation in relation to local environment has also enriched the biotic resources of the area.

3.2.1. Flora : Flora of North-West Himalaya has been well explored. Floral diversity is fascinating due to species richness and diverse community structure. Data on the total number of floral species recorded from North-West Himalaya are not available. However, the following information on the floristic diversity of some areas indicates rich floral wealth of North-West Himalaya.

Approximately 3054 species of flowering plants have been reported from Kashmir Himalaya. Of these, 2403 species are dicots and 651 species belong to moncots. About one-third of the flora belongs to four families, viz., Compositae (392 spp.), Gramineae (314 spp.), Papilionaceae (181 spp.) and Cyperaceae 155 spp.). *Carex* is the largest genus with 74 species, followed by *Astragalus* (53 spp.), *Potentilla* (45 spp.) and *Polygonum* (41 spp.). Other genera like *Nepeta, Gentiana, Saussurea* and *Artemisia* are represented by a little more than 30 species each. *Ranunculus, Pedicularis, Veronica* and *Corydalis* are also well represented in terms of number of species.

Flora of the Kangra valley and Shimla area has been well explored. Approximately 1004 species belonging to 584 genera have been listed from the Kangra valley. Shimla is also very rich in flora. As many as 1326 species have been recorded from the area with majority of species distributed among the Gramineae (133 spp.). Papilionaceae (114 spp.) and Compositae (109 spp.).

The pteridophyte flora (ferns and fern-allies) of North-West and Western Himalaya is very rich. Out of a total of 353 species of ferns in India, 158 are found in Western Himalaya. Some of the main genera are *Athyrium, Diplazium, Dryopteris, Lepisorus, Polypodium* and *Polystichum*. Of 92 Indian

Fig. 6 : Roper wetland in lower Himalaya

species of fern-allies, 20 are represented in the Western Himalaya. Important genera of fern-allies occurring in the area are *Lycopodium* and *Psilotum*.

3.2.2. Fauna : Habitat conditions offered by various kinds of forests, soils, rivers, lakes, understones, rocks, snow, etc., are utilised by diverse faunal groups, ranging from microscopic Protozoa to large mammals. The faunal diversity of North-West Himalaya has been largely influenced by its unique geographical position. The Great Himalayan range separates the northern Trans-Himalayan fauna adapted to cold desert-like conditions, from the southern Himalayan fauna. The states of Himachal Pradesh and Jammu & Kashmir fall under four distinct biotic provinces. These are: (i) Trans-Himalayan eastern plateau which includes Ladakh and Spiti areas, dealt with a separate article; (ii) North-west Himalaya, west of Sutlej river; (iii) Parts of West Himalaya in Himachal Pradesh, east of Sutlej river; (iv) Semi-arid hot dry foothills.

Table 1. Estimated total faunal diversity in Himachal Pradesh (North-West Himalaya)

Group	Himachal (*)	% of India
Protozoa	89**	2.7
Porifera	3	0.6
Cnidaria	2	0.2
Platyhelminthes	90	5.6
Rotifera	16	4.8
Nematoda	132	4.6
Acanthocephala	2	0.9
Mollusca	73	1.4
Annelida	60	7.1
Arthropoda		
Crustacea	73	2.5
Myriapoda	11	4.2
Arachnida	195	3.4
Insecta	4362	7.3
Bryozoa	2	0.1
Chordata		
Pisces	81	3.2
Amphibia	17	8.3
Reptilia	44	9.6
Aves	447	36.3
Mammalia	77	19.7
Total	**5776**	**6.4**

Source : (*) Julka, 1998; (**) Das (*in press*).

Biogeographical studies indicate pronounced dominance of Palaearctic and endemic forms above timber line, and largely Oriental and some Palaeartic and Ethiopian elements at lower and middle altitudes. In the forest zone, the eastern humid tropical fauna is separated from western largely steppe fauna by the gorge of river Sutlej. The Oriental elements are generally restricted to the east of the Sutlej and the Mediterranean (Palaearctic) and Ethiopian elements are found to the west of this river, but there may be some infiltration of these elements on either side.

The fauna of Himachal Pradesh has been extensively explored as compared to Jammu and Kashmir. The following account is primarily based on these studies, which would be useful in assessing the faunal diversity of the rest of North-West Himalaya. So far about 89,450 species of animals are known from India (Alfred 1998). A total of 5,776 species of diverse faunistic groups have been reported from Himachal Pradesh, comprising 6.4% of Indian fauna (Table 1). Invertebrates constitute 88.4% (5,110 spp.) and vertebrates 11.6% (666 spp.) of the Himachal fauna. Insects and other arthropods form a predominant group (4,641 spp.) among invertebrates, whereas birds comprising 447 species dominate vertebrates.

Insects : The North-West Himalayan states of Himachal Pradesh and Jammu and Kashmir, together with Kumaon and Garhwal areas of Uttar Pradesh (now known as Uttaranchal), form the third richer habitat of insects, following tropical evergreen forests of Eastern Himalaya and rain forests of south India. The most outstanding feature of Himachal insect diversity is the marked predominance of the Palaearctic endemic species at high altitudes.

All species of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) in the nival zone have Palaearctic affinities.

About 4360 known species of insects are estimated to exist in Himachal Pradesh. These constitute about 85.6% of invertebrates and about 75.7% of total fauna that have been recorded from this state. Maximum number of species are found in areas enjoying subtropical to warm temperate climate at altitude ranging between 600 m and 1500m above mean sea level. In Himachal Pradesh, 648 insect pests have been listed. Of these, 113 species are considered major or serious pests, which constitute 2.6% of total insects known from the area. Majority of pest species belong to Hemiptera (aphids, jassids, coccids, and mealy and painted bugs), Lepidoptera (caterpillars of moths and butterflies) and Coleoptera (beetles). Important insect vectors in Himachal Pradesh are various species of mosquitoes *(Anopheles, Culex, Aedes)*, sandfly *(Phlebotomus)*, dim-dam fly *(Simulium)*, gadfly *(Tabanus)*, etc.

Indian insects belong to 27 orders, of which only three, Embioptera, Stepsiptera and Mecoptera have not been recorded from Himachal Pradesh. Butterflies and moths (Order Lepidoptera) form the dominant group, followed by Coleoptera, Diptera, Hymenoptera and Hemiptera. These five orders together constitute 89.6% of Himachal entomofauna. On the other hand, four orders of wingless insects, Thysanura, Protura, Diplura and Collembola are represented by only 22 species, comprising 0.5% of total insects. Ephemeroptera, Odonata and Plecoptera constitute 23.4%, 17.9% and 17.7% respectively of corresponding Indian fauna. High percentages of these amphibiotic insects in Himachal Pradesh is primarily due to the fact that the Northwest Himalayan region offers numerous and a variety of perennial as well as seasonal aquatic biotopes as habitats for their immature stages. However, another amphibiotic group, Trichoptera is represented by only 3.4% of Indian caddisfly fauna as these insects are yet to be fully explored in this area.

The wingless collembolan insects, commonly known as springtails, form significant components of soil community. Their altitudinal range extends up to 6000 m where there is hardly any trace of insect life. Sometimes, they form swarms on snowfields that look sooty-black from a distance. Representative species above timberline belong to *Isotoma, Proisotoma, Hypogastrura, Onychiurus, Isotomurus*, etc., whereas species of *Entomobrya, Seira, Brachystomella, Isotomiella, Subistoma*, etc., are found at lower elevations.

Mayflies, dragonflies and damselflies, stoneflies and caddisflies pass their major part of life cycle (immature stages) in aquatic envirous. A total of 22 species and 6 species of mayflies (Ephemeroptera) are known from Himachal Pradesh and Jammu & Kashmir respectively. *Baetis, Epeorus, Ephemerella, Iron, Ironopsis, Cloeon, Caenis, Baetiella, Ameletus, Ororotsia, Ephemera, Ecdyonurus, Choroterpes*, etc., represent them. As many as 88 species of dragonflies and damselflies (Odonata) have been reported from Himachal Pradesh. Characteristic odonate species at upper mountain reaches (about 2000 m amsl) belong to *Anisogomphus, Anisopleura, Bayadera, Calcicnemia*, etc. Between 500 m and 1500 m elevations, the dominant genera are *Anormogomphus, Anax, Bayadera, Crocothemis, Macromia, Neurobasis, Orthetrum, Rhinocypha, Sympetrum, Trithemis*, etc. Nearly 20 species of stoneflies (Plecoptera) have been recorded from the area. The dominant pleocopteran genera in Northwest Himalaya are *Nemoura, Amphinemoura, Indonemoura, Neoperla, Capnia*, etc. *Rhadiopteryx lunata* is one of the commonest species above timberline and its distribution extends up to an elevation of 4800 metres. Approximately 30 species of caddisflies (Trichoptera) occur in Himachal Pradesh. The genus *Rhyacophila* is widespread in the region. Other common genera of caddisflies in the area are *Agapetus, Chimarra, Stenopsyche* and *Cheumatopsyche*.

Table 2. Endangered butterflies in North-West Himalaya (Himachal Pradesh and Jammu & Kashmir) included in Schedule I of Indian Wildlife (Protection) Act, 1972

Scientific Name	Common Name	Altitudinal Name
Family SATYRIDAE		
1. *Calinaga buddha*	Freak	1400-2700 m
2. *Lasiommata (=Parage) menava maeroides*	Ladakh Wall	Above 3000 m
Family NYMPHALIDAE		
3. *Clossiana (=Argynnis) hegemone*	Ladakh Fritillary	Above 3000 m
4. *Diagora nicevillei*	Scarce Siren	1575-2100 m
5. *Dilipa morgiana*	Golden Emperor	1400-2330 m
6. *Neptis sankara sankara*	Broad-banded Sailer	800-1600 m
Family PAPILIONIDAE		
7. *Parnassius delphius*	Banded Apollo	Above 3000 m
8. *Parnassius stoliczkanus*	Ladakh Banded Apollo	Above 3000 m
Family PIERIDAE		
9. *Delias sanaca sanaca*	Pale Jezebed	1350-2300 m

In Himachal Pradesh, the orders Orthoptera, Dermaptera and Isoptera are represented by 80, 30 and 25 species respectively. The common genera of these insects are *Acrida, Euprepocnemis, Oxya, Aiolopus, Gryllus* and *Teleogryllus* (Orthoptera), *Forficula, Forcifula, Anechura, Nala* and *Diplatys* (Dermaptera), and *Odontotermis* (Isoptera).

Approximately 370 species of bugs, aphids, scale insects, etc., (Hemiptera) are known to occur in the area. Majority of hemipterans are pests of agriculture, forests and orchards. Some are also predators on other insects. Bugs like *Anisops, Enithares, Ranatra, Laccotrephes, Corixa, Micronecta, Plea* and *Lethocerus* have secondarily adapted to aquatic way of life. *Chimarrhohmetra, Onychotrechus* and *Metacoris* dwell on the water surface of streams and lakes. Serious Hemiptera pest species belong to *Aphis, Macrosiphion, Myzus, Empoasca, Nephotettis, Eulecanium, Psuedococcus, Bagrada, etc.*

As many as 1250 species of moths and butterflies (Lepidoptera) have been reported from Himachal Pradesh. The butterfly diversity comprises of about 250 species. Of these, 56 species (22.4%) are protected under the Indian Wildlife (Protection) Act, 1972. Nine species of butterflies from Himachal Pradesh and Ladakh district of Jammu & Kashmir are considered as endangered and included in the Schedule I of the Wildlife (Protection) Act Table 2). Species of *Argyreus, Euthalia, Charaxes, Vanessa, Neptis, Precis, Libythea, Mycalesis, Ypthima, Lethe, Melanitis, Pontia, Pieris, Eurema, Colias, Lycaena,* etc., restrict their range between 900 m and 1800 m. Some butterfly genera that are fairly common at an elevation of 1500 m and above are *Chilasa, Papilio, Parnassius, Aporia, Colias, Gonepteryx, Pieris, Aulocera, Mycalesis, Maniola, Parage* and *Lethe.* Species of *Parnassius* are also found at altitudes above 5000 m.

The neuropteran fauna (ant lions, lacewings) is represented by 30 species in this region. The representative genera are *Hemerobius, Tumeochrysa, Formicaleon, Myrmeleon, Stiphroneura, Glyptobasis, Helicomitus, Parosmylus, Distoleon* and *Macronemurus.*

The Himachal hymenopteran fauna comprises of 470 species. Parasitic ichneumonids and chalcids play an important role in the biological control of several crop insect pests. Some of these parasitic insects found in the area belong to the genera like *Isotima, Ephilates, Netelia, Ophion, Campoplex, Pimpha, Dirhinus, Pachyneuron, Aphelinus* and *Polynema*. Other important hymenopteran genera in this region are *Apis, Halictus, Bombus, Vespa, Vespula, Scolia, Pompilus, Polistes*, etc.

About 1100 species of Coleoptera (beetles) are known from the area. Of these, nearly 200 species are inhabitants of high altitude zone above timberline and show a high degree of endemicity. Typical beetle genera of this zone are *Bembidion, Amara, Carabus, Nebria, Calosoma* (Carabidae); *Agabus* (Dytiscidae); *Helophorus* (Hydrophilidae); *Atheta, Aleochara, Philonthus* (Staphylinidae); *Chaetocnema, Longitarsus* (Chrysomelidae); and *Hetronyx, Scepticus* (Curculionidae). Important genera at lower elevations are *Cicindella* (Cicendellidae), *Chlaenius* (Carabidae), *Gonocephalum* (Tenebrionidae), *Mylabris* (Meloidae), *Chrysomela* (Chrysomelidae), *Anomala* and *Papilio* (Scarabaeidae), and *Coccinella* (Coccinellidae). Larvae of *Psephenoides* (Family Psephenidae) have undergone remarkable morphological modifications for adaptation to withstand the water currents in the torrents.

Diversity in diptera (true-flies) appears to be of wide range in Northwest Himalaya, inhabiting various niches from foothills to an elevation of about 6000 m amsl. Nearly 720 species have been recorded from Himachal Pradesh. The well-known dipterous genera occurring in this area are *Anopheles, Aedes,*

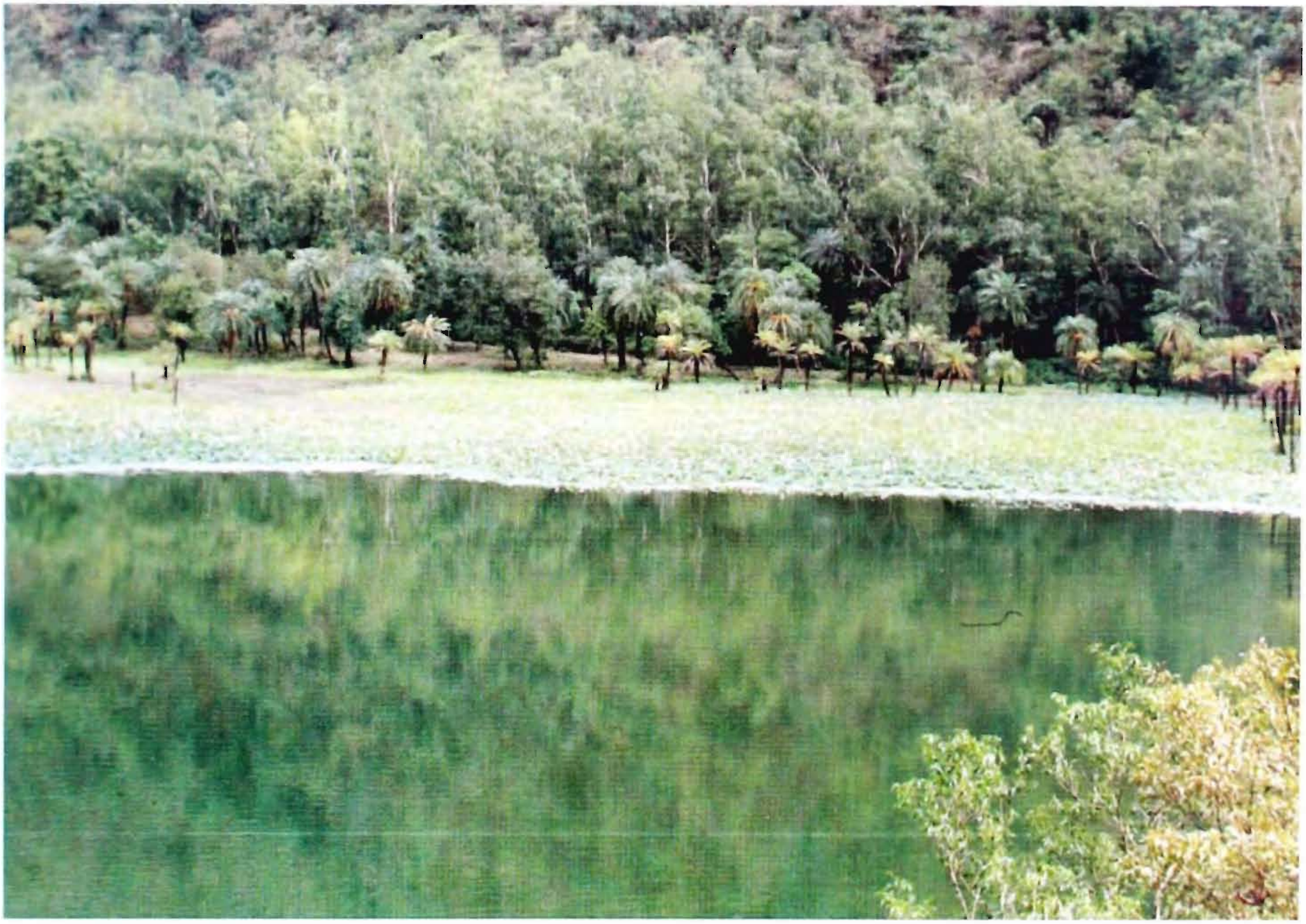


Fig. 7 : Renuka Lake

Culex and *Theobaldia* (Culicidae); *Sarcophaga* (Calliphoridae); *Syrphus* and *Melanostoma* (Syrphidae); *Simulium* (Simuliidae); *Psychoda* and *Pericoma* (Psychodidae); *Antocha* and *Tipula* (Tipulidae), *Blepharocera* and *Horaia* (Blepharoceridae); *Musca* and *Helina* (Muscidae) and, *Bibio* and *Plecia* (Bibionidae). The larvae of marsh-fly, *Ephydra glauca* inhabit saline and alkaline hot waters at temperatures ranging from 43°C to 49°C in some parts of North-West Himalaya.

Other invertebrates : Non-insect invertebrates constitute 12.6% (731 species) of Himachal fauna. Based on number of species, Arachnida (spiders, mites, scorpions) with 195 species is the largest group, followed by Nematoda 132 species, Platyhelminthes 90 species, Protozoa 89 species, Mollusca and Crustacea 73 species each, Annelida 60 species, Rotifera 16 species and Myriopoda 11 species (Table 1). The Porifera is represented by 3 species whereas Cnidaria, Acanthocephala and Bryozoa contain 2 species each. Most of those invertebrates are inhabitants of low altitudes.

Some species, however, are associated with high altitude biotopes and show strong Palaearctic affinities.

The most outstanding feature of non-insect invertebrate diversity in Himachal Pradesh is the existence of several species of microscopic zooplanktons in freshwaters. These primarily belong to Crustacea and Rotifera, and form about 60% of food of various commercially important and cultivable fishes, thus largely contributing to the maintenance of fisheries in the state. Common planktonic crustacean genera in Himachal Pradesh are *Daphnia, Alona, Alonella* and *Chydorus* among Cladocera, *Eucyclops, Mesocyclops, Neodiaptomus,* and *Canthocamptus* among Copepoda, and *Stenocypris* and *Strandesia* among Ostracoda. The rotifer plankton comprises species of *Asplanchna, Brachionus, Lecane* and *Keratella.*

Soil animals like earthworms (Oligochaeta) and millipedes (Diplopoda) are important components of invertebrates. These organisms play a vital role in enhancing soil fertility in arable pasture and forestlands due to their burrowing and feeding habits. Earthworms are represented by 42 species in Himachal Pradesh, comprising 7.2% of Indian oligochaetes. Of these, three species of *Perionyx* and one species of *Plutellus* are endemic to the area. Possibly, the remaining species have been transported to Himachal Pradesh in soil around roots of plants and feet of animals from other areas in the country as well as from other biogeographical realms. The millipede fauna has not been adequately explored in Himachal Pradesh. Relevant literature shows that not more than 5 species have been recorded from the area, the most common being *Streptogonopus phipsoni* and *Sundaniana nulla* described from Chamba district. A group of tiny organisms, orbited mites, is also closely associated with the soil ecosystem. They play an important role in the breakdown of organic matter in the soil. The Himachal orbited fauna consists of 46 species (about 15.7% of Indian soil mites), and belongs to 40 genera. Some widespread species are distributed among *Oppiella, Oribatella* and *Hypochthonius.*

Some non-insect invertebrates are endoparasites, causing serious diseases in human beings and livestock; for example, protozoans like *Plasmodium vivax, Entamoeba histolytica* and *Eimeria* sp. cause malaria, amoebiasis and coccidiosis respectively. As many as 89 species of Protozoa have been reported from Himachal Pradesh. Ecotoparasitic leeches are of great nuisance as they attack man and his animals to suck their blood. However, *Poecillobdella granulosa* has been used as a common medicinal leech in Himachal Pradesh. The leech fauna of this area is very rich because of availability of a wide range of aquatic and forest biotopes. About 30.5% (18 species) of Indian leech fauna occurs in Himachal Pradesh, showing a very high diversity as compared to other faunistic groups.

Nematodes, popularly called roundworms or threadworms, are one of the most economically important groups of invertebrates. Altogether 132 species occur in Himachal Pradesh. They are found in all kinds of habitats, sometimes in most inhospitable environment like ice, hot springs, etc. Nematodes have freeliving as well as parasitic mode of life. *Heterodera avenae* and *Anguina tritici* have been reported as destructive pests of wheat, whereas *Meloidogyne* spp. inflict damage to all kinds of agricultural and horicultural crops in Himachal Pradesh and elsewhere. *Helicotylenchus, Pratylenchus, Aphelenchoides, Enchodelus* and *Heterodera* are the predominant mematode genera in the region.

Vertebrates

Mammals : The mammalian fauna of Himachal Pradesh is represented by 77 species, which constitute about 19.7% of the total Indian mammals (390 species). The number may be increased to 78 species if the occurrence of Tibetan Wild Ass, *Equus kiang*, in Spiti area is confirmed. Diversity is much higher at generic level. Of a total of 135 genera of land mammals in India, 55 (40.7%) occur in Himachal Pradesh. Order-wise distribution of species is as follows: 2 species of shrews (Insectivora), 8 species of bats (Chiroptera), 2 species of monkeys and langurs (Primates), one species of pangolin (Pholidota), 25 species of carnivores, 14 species of goats, sheep, antelopes, boar, deer (Artyodactyla), 22 species of rodents and 3 species of hares and mouse hares (Lagomorpha).

Above snow line, the mammalian fauna is largely of Palaearctic origin. These are the Tibetan sheep or Nayan *(Ovis ammon hodgsoni)*, Bharal *(Pseudois nayaur)*, Himalayan ibex *(Capra ibex)*, Bobak marmot *(Marmota bobak)*, Mouse hare *(Ochotona roylei)*, Woolly hare *(Lepus oistolus)*, Snow leopard *(Panthera uncia)*, Altai weasel *(Mustela altaica)*, Himalayan brown bear *(Ursus arctos isabellinus)*. The fauna of temperate zone is represented by Musk deer *(Moschus chrysogaster)*, Ermine *(Mustela erminea)*, Yellow-throated marten *(Mares flavigulà)*, Leopard cat *(Felis bengalensis)*, Himalayan black bear *(Selenarctos thibetanus)*, Serow *(Capricornis sumatraensis)*, Himalayan tahr *(Hemitragus jemlahicus)*, Goral *(Nemorhaedus goral)*, species of bats, rats, mice, squirrels, hares, *etc.* The range of *Panthera pardus* extends from the Temperate Zone to the subtropical region. The foothills and lower valleys are inhabited by Sambar *(Cervus unicolor)*, Barking deer *(Muntiacus muntjak)*, Wild boar *(Sus scrofa)*, Jackal *(Canis alpinus)*, Chital *(Axis axis)*, Nilgai *(Boselaphus tragocamelus)* and Common fox *(Vulpes bengalensis)*. Some elements of the foothills like barking deer, jackal and common fox are also found in the Temperate zone. The mammalian from of the foothills shows strong Oriental affinities.

Large scale hunting and destruction of habitat of these animals have threatened the existence of several species in North-West Himalaya. As many as 60 species are at risk and protected under the Indian Wildlife (Protection) Act, 1972. Of these, 25 species are highly endangered and included in Schedule I of the Act (Table 3). All species of large mammals (40 species) in North-West Himalaya are threatened.

Birds : A total of 447 species of birds have been reported from the area, comprising 36.3% of the Indian bird diversity. They also constitute about 67% of known vertebrates in Himachal Pradesh. Ecologically, the Himachal avifauna is very interesting. About 35.5% of birds are residents in this state and other parts of the country. There are 15.7% winter visitors from South-East Asia, Europe and Siberia, 11.6% summer visitors from central India and foothills and 10.4% altitudinal migrants. 26.8% are birds of Himalayan ecosystem and show vertical movements.

Pheasants, also known as game birds, are represented by 7 species in Northwest Himalaya. These are Western tragopan *(Tragopan melanocephalus)*, Himalayan monal pheasant *(Lophophorus impejanus)*, Kaleej pheasant *(Lophura leucomelana)*, Koklass phesant *(Pucrasia macrolopha)*, Chir pheasant *(Catreus wallichii)*, Indian peafowl *(Pavo cristatus)* and

Fig. 8 : Barheaded geese during winter in lesser Himalaya

Indian junglefowl *(Gallus gallus murghi)*. They are spectacularly colourful birds and have brilliant metallic plumage. Due to extreme hunting pressure and loss of habitat their existence is seriously threatened. As a result, five species of pheasants are highly endangered and included under Schedule I of the Indian Wildlife (Protection) Act, 1972 (Table 3). Protection under the Act has also been provided to some endangered hunting birds, viz. Himalayan bearded vulture *(Gypaetus barbatus aureus)*, Himalayan golden eagle *(Aquila chrysaetos)*, Osprey or Fish-eating eagle *(Pandion haliaetus)*, Lagger falcon *(Falco biarmicus)* and Saheen falcon *(Falco peregrinus)*. Tibetan Snowcock *(Tetraogallus tibetanus)* and Blacknecked Crane *(Grus nigricollis)* are other species that are also included in the Act.

Endemic birds of North-West Himalaya are predominantly Palaearctic. Fourteen Palaearctic endemic species, which are confined to the Himalaya without adjacent relatives, are considered relict forms. Of these, nine species are found in these hills, viz., *Catreus wallichii* (Chir pheasant), *Callacanthis burtoni* (Cardueline finch), *Picoides himalayensis* (Himalayan pied woodpecker), *Garrulus lanceolatus* (Black-throated jay), *Parus melanolophus* (Crested black tit), *Zoothera wardi* (Pied ground thrush), *Pyrrhula erythrocephala* (Redheaded bullfinch), *Pyrrhula aurantiaca* (Orange bullfinch) and *Capella nemoricola* (Wood snipe).

Reptiles : Altogether 44 species of lizards, snakes and turtles have been reported from Himachal Pradesh. These constitute about 9.6% of Indian reptiles. Of four kinds of Monitor lizards inhabiting India, two species, Common Indian monitor *(Varanus bengalensis)* and Yellow monitor *(Varanus flavescens)*, occur in the area. Both species are on the endangered list (Table 3). Main threats to the Monitor lizards have been from the increasing trade in their skins. The Burrowing Common Himalayan Skink *(Scincella himalayanus)*, and Mountains Agamid Lizard *(Japalura kumaonensis)* are endemic to Northwest and Western Himalaya. *Agama tuberculata* (Himalayan rock lizard) is often seen basking on the boulders in the Temperate Zone.

The snake fauna in Himachal Pradesh consists of both poisonous and harmless species. Important poisonous snakes in the area are Russel's viper *(Vipera russelli)*, Himalayan Pit viper *(Agkistrodon himalayanus)*, Common krait *(Bungarus caeruleus)*, Indian cobra *(Naja naja)* and King cobra *(Ophiophagus hannah)*. Some non-poisonous species are Rat snake *(Ptyas mucosus)*, Checkered Keelback water snake *(Xenochrophis piscator)*, Brahminy Blind snake *(Ramphotyphlops braminus)*, Himalayan Cat snake *(Boiga multifasciata)* and Rock python *(Python molurus)*. Majority of snakes in the area is found below 3000 metres of altitude. The range of *Agkistrodon himalayanus*, however, extends from about 900 metres to 4800 metres amsl. Generally, people of Himachal Pradesh do not kill snakes because of religious sanctity attached to them, thereby helping in the conservation of these creatures. A decline in snake population is primarily due to increase in urbanisation and loss of suitable habitat. The current status of Rock python *(Python molurus)* is highly endangered. It is protected under Schedule I of the Wildlife Act.

A few species of freshwater and mud turtles inhabit lakes and rivers in Northwest Himalaya. Some of these are *Trionyx gangeticus* (Indian Shell turtle), *Lissemys punctata* (Indian Flap-shelled turtle) and *Kachuga kachuga*. The population of *Lissemys punctata* has declined considerably. It is an endangered species and has been listed in Schedule I of the Wildlife Act.

Amphibians : Amphibians are mostly inhabitants of areas below the snowline, but some species like *Bufo viridis, Bufo latestii* and *Scutiger sikkimensis* are found in the cold desert of district Ladakh of Jammu and Kashmir. As many as 20 species of frogs and toads have been reported from Northwest Himalaya, of which 17 species occur in Himachal Pradesh. Majority of these is inhabitant of forests, streams and ditches. The predominant amphibian diversity in the area comprises species of *Rana, Amolops, Bufo* and *Scutiger*. Some high altitude amphibians of Northwest Himalaya are *Bufo viridis, Rana liebigii, Rana vicinia* and *Scutiger sikkimensis*. *Polypedatus maculatus*, a common tree frog, is an inhabitant of forests.

Metamorphic activity of tadpoles of some high altitude frogs, like *Rana (Paa) minica* and *Rana liebigii* remains suspended during unfavourable conditions of extreme winter. The metamorphosis is characterised by prolonged and delayed development by a few years. They remain in tadpole stage for years depending upon climatic conditions. The metamorphic activity is regained as the favourable conditions prevail.

Fishes : Like other parts of the Himalayan ecosystem, fishes of the region are distinctive in possessing special features for survival in torrential streams and rivers. A total of 81 species have been recorded from Himachal Pradesh. The dominant genera are *Barilius, Labeo, Puntius, Noemacheilus, Tor* and *Glyptothorax*. Several species are endemic in these hills and mainly belong to *Tor, Schizothorax, Glyptothorax* and *Noemacheilus*.

Brown trout *(Salmo trutta fario)* and Rainbow trout *(Salmo gairdnerii gairdnerii)* are exotic and have been introduced throughout the Northwest Himalayan region primarily for sport and secondarily for food. Both species of trout are carnivorous, feeding upon a

Table 3. Endangered mammals, birds and reptiles in North-West Himalaya (Himachal Pradesh and Jammu & Kashmir) included in Schedule I under Indian Wildlife (Protection) Act, 1972.

Common name	Scientific name	Status
Mammals		
Indian Wolf	*Canis lupus pallipes*	V
Tibetan Wolf	*Canis lupus chanco*	V
Himalayan Brown Bear	*Ursus arctos isabellinus*	E
Oriental Small-clawed Otter	*Aonyx cinerea*	V
Ermine or Stoat	*Mustela erminea ferghanae*	I
Leopard Cat	*Felis bengalensis*	V
Palla's Cat	*Felis manul*	I
Rusty-spotted Cat	*Felis rubiginosa*	I
Leopard	*Panthera pardus*	V
Snow Leopard	*Panthera uncia*	E
Himalayan Lynx	*Lynx lynx isabellinus*	E
Tibetan Wild Ass or Kiang	*Equus kiang*	E
Hangul or Kashmir Stag	*Cervus elaphus hanglu*	E
Himalayan Musk Deer	*Moschus moschiferus*	V
Tibetan Gazelle	*Procapra picticaudata*	I
Tibetan Antelope	*Pantholops hodgsoni*	I
Yak	*Bos mutus*	C
Markhor	*Capra falconeri*	E
Himalayan Ibex	*Capra ibex*	E
Serow	*Capricornis sumatraensis*	V
Himalayan Tahr	*Hemitragus jemlachicus*	E
Great Tibetan Sheep or Nayan	*Ovis ammon hodgsoni*	V
Urial or Shapu	*Ovis vignei*	E
Blue Sheep or Bharal	*Pseudois nayaur*	V
Indian Pangolin	*Manis crassicaudata*	V
Birds		
Himalayan Bearded Vulture	*Gypaetus barbatus aureus*	E
Himalayan Golden Eagle	*Aquila chrysaetos*	E
Osprey or Fish-eating Eagle	*Pandion haliaetus*	V
Lagger Falcon	*Falco biarmicus*	E
Saheen Falcon	*Falco peregrinus peregrinator*	E
Western Tragopan	*Tragopan melanocephalus*	E
Himalayan Monal Pheasant	*Lophophorus impejanus*	E
Koklass Pheasant	*Pucrasia macrolopha*	V
Chir Pheasant	*Catreus wallichii*	E
Indian Peafowl	*Pavo cristatus*	V
Tibetan Snowcock	*Tetraogallus tibetanus*	E
Blacknecked Crane	*Grus nigricollis*	C
Reptiles		
Indian Flap-shelled Turtle	*Lissemys punctata*	V
Common Indian Monitor	*Varanus bengalensis*	E
Indian Flap-shelled Turtle	*Lissemys punctata*	V
Common Indian Monitor	*Varanus bengalensis*	E
Yellow Monitor	*Varanus flavescens*	E
Indian Rock Python	*Python molurus*	E

C Critical; E Endangered; V Vulnerable; I Insufficiently Known.

Source : The Red data book on Indian animals (ZSI), Part 1 : Vertebrata, 1994.

variety of insects and other fishes. Populations of indigenous fish species have declined, as they are not able to compete with the exotic trout species. Mahseer *(Tor tor* and *Tor putitora)*, Mrigal *(Cirrhinus mrigala)*, Rohu *(Labeo rohita)*, Katla *(Catla catla)*, Kalbasu *(Labeo calbasu)* and Seenghala *(Mystus seenghala)* comprise major fisheries in the area.

4. SPECIAL FEATURES

Faunal diversity of Himachal Pradesh can be differentiated into two major groups: forest and hypsobiont species. Forest forms are by and large confined to wooded areas at lower and middle altitudes whereas, hypsobiont elements are true inhabitants of high altitudes that never occur below timberline. However, there are transitional forms between these two groups. Forest fauna greatly surpasses the hypsobiont in their diversity, comprising nearly 90% of species so far recorded from the area. Endemicity among forest species is about 15% but, it is 60% above timberline.

There are some animals in Northwest Himalaya, which have created interest among naturalists and zoologists on account of their special modifications. The Orange oak-leaf butterfly, *Kallima inachus*, is an excellent example of camouflage. The undersides of its wings are indistinguishable from the dry leaves of oak on which it rests. Some high altitude animals like Marmots and Mouse hares are of interest to researchers because of their physiological adaptations to extreme cold and low atmospheric pressure. Many zoologists have been studying the development of adhesive organs in some torrential fishes *(Schizothorax, Garra, Noemacheilus)* and larvae of dipterous insects *(Horaia, Blepharocera, Deuterophlebia)* to cope with swift water currents.

Domesticated animal diversity in Northwest Himalaya is very rich. There are a number of breeds of sheep, goats and ponies, which are able to withstand hazards of mountainous areas. Some of these are Bhadarwah (Gaddi), Rampur Bushair, Biangi, Mewati, and Khand among sheep; Chamba, Gaddi, Pashmina and Chegu among goats; Spiti and Chummarti among ponies.

The percentages of threatened mammals in this highly fragile area are comparatively much higher. All species of pheasants occurring in this region are at risk because of habitat loss and hunting. Freshwater and soil fauna is under tremendous stress due to organic and chemical pollution of ponds, streams and wetlands. The situation is fast deteriorating due to indiscriminate spray of highly toxic insecticides in orchards and agricultural fields. International and unintentional introduction of exotic species has threatened the existence of certain soil and aquatic species, thereby disturbing various ecosystems in this part of the Himalaya.

5. INTRODUCED BIODIVERSITY

With the improvement in communication system, man has intensified cultivation in inner valleys under extremely difficult conditions. Fast-growing trees have been planted in several areas and vegetables and crops are being grown in Ladakh, Lahaul, Spiti, and other places where there were none before. New areas have been brought under cultivation of temperate fruit trees, extending even to high altitudes. These activities have led to significant introduction and proliferation of several kinds of viruses and insect pests of crops, fruit trees and forests. Exotic soil animals have been introduced, though unintentionally, in soil around roots of exotic plants from other regions. For example, peregrine and more adventurist limbricid earthworms are suspected to have been introduced in this way and have been colonised successfully in temperate areas of Himachal Pradesh. At places, these earthworm species have become numerically dominant, threatening native species of *Plutellus* and *Perionyx*.

The British introduced exotic fishes like Brown trout *(Salmo trutta fario)* and Rainbow trout *(Salmo gairdnerii gairdnerii)* in aquatic environs of the Himalaya mainly for sport. Realising their commercial value as food fish, these are now being cultured at various places in Northwest Himalaya. Introduced species of trout are carnivorous, feeding voraciously on other fishes and their food. Populations of endemic mahseer species *(Tor* spp.) have declined in streams and rivers where trout is being cultured.

6. VALUE

The rich biodiversity of North-West Himalaya has sustained population and hill communities from time immemorial. Kinnars and Ladakhis have a direct linkage with the flora and fauna of the region in their life and health care. Several endemic species have evolved in the area. These are particularly adapted to the Himalayan way of life, especially at high altitudes above timberline. There are also many valuable plants and animals from scientific and aesthetic points of view, and several of these are threatened due to large scale destruction of their habitats. Many interesting unknown taxa may become extinct before they are even discovered. Considering the ecosystem as a gene bank, if populations of species are reduced, there may be a genetic drift and gene loss, which is potentially an important loss.

North-West Himalaya is bestowed with distinctive biota having aesthetic, cultural, commercial and genetic values. Beautiful birds like Himalayan monal, Koklass and Tragopan Pheasants, Red-billed blue magpie, Paradise flycatcher and Himalayan snow-cock and papilionid and nymphalid butterflies are of great aesthetic value. In fact, they have enriched the aesthetic life of hill people and are admired for adding liveliness to nature. The unique colour shades and designs of butterflies have caught the imaginations of poets, naturalists, fashion designers, collectors, etc. Products of some animals like honey, wax, musk and skins are commercially valuable. Two species of honeybees, *Apis mellifera* and *Apis indica* are cultured for the production of honey and wax. Species of non-mulberry silk moths, *Antheraea paphia* (Indian Tassor Moth) and *Antheraea cynthia* (Indian Eri Moth) can be exploited for yielding wild silk. Snow trout *(Schizothorax* sp.) and Golden mahseer *(Tor putitora)* are of fishery importance. Earthworm species like *Eisenia fetida* and *Perionyx excavatus* and other species of *Perionyx* can be easily reared on various kinds of organic waste materials in the state for the production of vermicompost and vermiprotein. Rhesus macaque, *Macaca mulatta,* is of great biomedical importance all over the world.

All varieties of domestic sheep have been derived from three species of *Ovis* found wild in the mountainous regions of Asia and Europe. The Wild yak *(Bos mutus)* has given rise to the domestic yak. All domestic varieties of pigs are descendants of wild boar *(Sus scrofa),* and Indian varieties of fowl have been derived from Indian Red Jungle fowl *(Gallus gallus murghi).* North-West Himalaya harbours these genetic resources of immense value. Two species of *Ovis, O. vignei* (Shapu) and *O. ammon* (Nayan), and the wild yak occur in the Ladakh and Spiti regions. The wild boar and Indian Red Junglefowl are common at lower altitudes.

North-West Himalaya is a store house of several medicinal plants. These are exploited for utilising in the pharmaceutical and perfume industries. There are numerous species of plants in the area, which provide food, oil, gum, resins, fodder, forage, fuel, timber and fibre. Several plant species are also of ornamental value.

7. THREATS

The biota in this world is under tremendous stress due to increasing human population pressure. Many natural habitats have been over-exploited, degraded and even destroyed. Severe depletion of biodiversity poses a serious threat to the very existence of mankind. The Northwest and Western Himalaya have also come under a strong threshold of development. Development without destruction of natural resources is rarely possible, and consequently these highly fragile areas are facing severe threats of ecological degradation. Natural ecosystems harbouring characteristic biota are being rapidly modified and fragmented due to increasing human and livestock population pressures. Vast tracts of original wildlife habitat have been converted into artificial ecosystems or exploited and degraded to such an extent that they fail to replenish and lost for ever along with their fauna and flora. Remote sensing based data show that in 1979 Himachal Pradesh had 15,075 sq km of land (27.1% of geographical area) under forest cover which has depleted to 12,502 sq km (22.4% of geographical area) in 1993. This amounts to a loss of 17.1% (2,573 sq km) of forest cover over a period of 14 years. The figures for Jammu and Kashmir indicate a 10.6% loss of forest land in 12 years. Such rapid deforestation has not only created disastrous changes in habitats and their biota but also led to depletion of scarce top soil. The World Conservation Centre at Cambridge, U.K. has, thus, identified the whole of Northwest and Western Himalaya as threatened habitat with the possibility of losing biodiversity of inestimable value. There are more endangered taxa in this region than anywhere else in the country. The whole Himalayan belt has been designated as a "mega hot-spot" Ladakh and Kashmir Himalaya along with six other areas in the Himalaya are especially critical.

The hill people rear large number of domestic animals like cattle, goats, sheep, *etc.*, for milk and wool production, ploughing fields and collection of dung for use as organic manure. Grazing by these animals exerts a great biotic pressure on forests. Often overgrazing leads to ecological problems like formation of gullies in tracks frequented by cattle, abundance of coarse and poor grasses in pastures because of selective feeding, trampling of seedlings, saplings, and soil erosion. The people hunt wild animals for their fur, meat, musk, *etc.* Forests are sometimes set on fire for inducing good growth of grass and mushrooms. Forest fires are very harmful to environment, causing erosion, destroying valuable faunal and floral diversity and hampering regeneration. Human demographic pressure causes shrinkage of forests leading to loss of biodiversity. Increased agricultural and horticultural practices have also introduced several exotic taxa in the area.

Sewage disposal is a major problem in almost all urban and semi-urban places in hilly areas. Most of sewage is dumped into lakes and rivers, which affects the required healthy level of dissolved oxygen for the survival of aquatic fauna. Large quantities of pesticides are applied for enhancing crop and fruit yield. Toxic substances from pesticides are drained into different aquatic bodies, and adversely affect the physiology and biology or organisms living therein.

Ecological degradation has rendered almost entire Trans-Himalayan zone of Ladakh, Lahaul and Spiti into a cold desert, which is spreading rapidly eastwards. Natural subtropical evergreen forests, once widespread in the foothills of Northwest Himalaya, have almost been cleared.

8. CONSERVATION

Two general approaches are followed to maintain or conserve biodiversity. It may be maintained where it occurs naturally (*in situ* conservation), or it may be removed from the site and kept elsewhere (*ex situ* conservation). In situ maintenance of biodiversity is the most effective way to conserve maximum biological diversity on the long-term basis.

The main *in situ* conservation strategy in India is the protected area network (PAN), *viz.*, wildlife sanctuaries (WLS), national parks (NP) and biosphere reserves. Biodiversity is also being conserved in several reserve forests and sacred groves. The latter are densely wooded areas set aside on religious grounds. In Northwest Himalaya, there is no biosphere reserve, although it is proposed to establish a Cold Desert Biosphere Reserve in the Spiti area. Total PAN in the states of Himachal Pradesh and Jammu & Kashmir is only about 7.6% of their geographical area.

The history of setting up PAN in Himachal Pradesh goes back to just a few decades. Initially, four wildlife sanctuaries, Manali, Kias, Khokan and Kanawar in Kullu district were notified in 1954. These covered an area of 114.04 km^2 and accounted for a mere 0.2% of the geographical area of the state. Over the years, the protected areas (PA) in Himachal Pradesh have increased to 34 covering 7031.87 km^2 or 12.53% of the state. Of these, two are national parks, the Great Himalayan NP (620 km^2) in district Kullu and Pin Valley NP (675 km^2) in district Lahaul and Spiti. The size of wildlife sanctuaries ranges from the smallest Shilli WLS (2.13 km^2) in Solan district to the largest Kibber WLS (1400.50 km^2) in the Spiti area. As many as 11 WLS are very small, less than 50 km^2 each, and are not suitable to hold viable populations of large mammals. Various conservation measures in the state have, however, led to noticeable increase in the population of some large mammals, *e.g.*, leopard *(Panthera pardus)*, Rhesus macaque *(Macaca mulatta)* and Common langur *(Presbytis entellus)*.

The PAs in Himachal Pradesh have been established to cover all biotic provinces in the state. There are 2 PAs (2075.50 km^2) in Trans-Himalaya, 17 PAs (3394.02 km^2) in Northwest Himalaya, west of Sutlej river, 13 PAs (1539.30 km^2) in West Himalaya, east of Sutlej river and 2 PAs (23.05 km^2) in Semi-arid Zone. District-wise distribution of PAs shows that there are no PANs in districts Una and Hamirpur (Table 4). The PA in each of districts Sirmour, Shimla, Solan and Bilaspur is less than 5% of the total PA in the state.

There are 19 PAs in Jammu and Kashmir. These cover an area of 14,057.74 km^2, which are about 6.3% of its geographical area. The PAs comprise 4 national parks and 15 wildlife sanctuaries. Hemis National Park in the cold

Table 4. District-wise distribution of Wildlife Sanctuaries (WLS) and National Parks (NP) in Himachal Pradesh.

District	WLS (No.)	NP (No.)	Area(km^2) (WLS+NP)	% of total protected area in state
Bilaspur	2	-	256.34	3.6
Chamba	5	-	723.88	10.3
Hamirpur	-	-	-	-
Kangra	2	-	1251.29	17.8
Kinnaur	3	-	805.89	11.5
Kullu	6	1	885.16	12.6
Lahaul & Spiti	1	1	2075.50	29.5
Mandi	3	-	533.69	7.6
Shimla	3	-	176.25	2.5
Sirmour	3	-	79.20	1.1
Solan	4	-	244.67	3.5
Una	-	-	-	-
Total	32	2	7031.87	-

Source : Wildlife Institute of India Database Cell; State Forest Department, H.P.

desert of Ladakh is the largest with an area of about 3350 km². The largest WLS is Karakoram comprising an area of approximately 5000 km². Changthang WLS with an area of about 4000 km² is located in the Northeast Ladakh adjoining Tibet plateau.

Ex situ conservation of faunal diversity in India is restricted to zoological parks, aquaria, animal breeding centres, gene banks, etc. There does not exist any worthwhile attempt in *ex situ* conservation of faunal resources in Northwest Himalaya. The Himachal Forest Department maintains a small zoological park at Kufri/Tutikandi near Shimla. Efforts to breed Musk deer at Kufri and Western tragopan and other pheasants at Sarahan Bushahr in Shimla district have not made much progress because of paucity of funds and lack of modern technology. Mini zoos have been established at Renuka, Rewalsar and Dharamsala. National Bureau of Plant Genetic Resources of Indian Council of Agricultural Sciences has centres at Srinagar and Shimla to store seeds and tissue samples. They deal primarily with crops used in agriculture, horticulture and forages for animal husbandry.

9. FUTURE DIRECTIONS

Since the Himalayan ecosystem has suffered most due to human activity, a multidisciplinary approach is required for its conservation:

- Total protected area in Himachal Pradesh and Jammu & Kashmir is to be raised to at least 20% of their geographical area.
- Forest cover is to be increased with better management; there should be initially selective logging, leaving riverine and inaccessible land for entirely natural development, where no logging and grazing by domesticated animals should be permitted. In the first instance, recovery of vegetation is to be allowed; maintenance of balance between available food and wildlife and livestock is to be followed at a later stage.
- Reduction in pressure of human population by way of effective decline in overall birth rate.
- Population and quality of livestock should be in line with ecological requirements.
- Alternative sources of fuel for cooking may substantially be provided to reduce increasing demand for firewood.
- Provision of enhanced food from outside the ecosystem or intesfication of agriculture on more suitable arable land for reduction of demand for agricultural land.
- Involvement of people in effective afforestation of denuded areas and soil erosion control measures.
- Public awareness about benefits and importance of biodiversity.
- Setting up selective Pilot Projects for restoration of biodiversity.
- Evaluation of current status of endangered species.
- Population studies of invertebrates in different ecosystems.

10. SELECTED REFERENCES

Alfred, J.R.B. 1998. Faunal diversity in India: an overview: 1-9. *In*: J.R.B. Alfred, A.K. Das and A.K. Sanyal (eds.). *Faunal diversity of India. ENVIS* Centre, Zoological Survey of India, Calcutta.

Ali, S. 1981. The Himalaya in Indian ornithology: 16-31. *In*: J.S. Lall. *The Himalaya, aspects of change.* Oxford University Press, Delhi.

Anonymous. 1970. *The wealth of India, livestock (including poultry) raw materials,* vol. VI (suppl.) 274 pp. CSIR, New Delhi.

Anonymous, 1995. *Statistical outline Himachal Pradesh.* Economics and Statistics Department, Shimla.

Bhalla, O.P. and Pawar, A.D. 1977. *A survey of insect and non-insect pests of economic importance in Himachal Pradesh,* 80pp. College of Agriculture, Solan.

Chowdhury, H.J. and Wadhwa, S.M. 1984. *Flora of Himachal Pradesh,* vol. 1&2. Botanical Survey of India, Howrah.

Dhar, U. 1996. Overview of Himalayan biodiversity, 3-20. *In*: G.S. Gujral and V. Sharma (eds.). *Changing perspectives of biodiversity status in the Himalaya.* The British Council, New Delhi.

Ghosh, A.K. 1996. *Faunal diversity*: 43-50. *In*: G.S. Gujral and V. Sharma (eds.). *Changing perspectives of biodiversity status in the Himalaya.* The British Council, New Delhi.

Jairajpuri, M.S. 1991. Animal resources of India: Protozoa to Mammalia an overview, xi-xxvii. *In*: *Animal resources of India Protozoa to Mammalia State of the Art.* Zoological Survey of India, Calcutta.

Julka, J.M. 1998. Biodiversity conservation fauna. In : *Status report on environment of Himachal Pradesh.* H. P. Department of Science & Technology, Shimla.

Julka, J.M., Vasisht, H.S. and Bala, B. 1999. Distribution of aquatic insects in a small mountain stream in Northwest Himalaya, India. *J. Bombay nat. Hist. Soc.,* **96**(1) : 55-63.

Mahabal, A.S. (In press). Avifauna, *In: Studies on the Himalayan ecosystem: Fauna of Western Himalaya (Himachal Pradesh).*

Mani, M.S. 1962. *Introduction to high altitude entomology,* 302 pp. Methuen & Co. Ltd., London.

Mani, M.S. 1974. *Ecology and biogeography in India.* Dr. W. Junk, B.V. Publishers, The Hague.

Negi, S.S. 1990. *A handbook of the Himalaya,* 350pp. Indus Publishing Company, New Delhi.

Pandey, S. 1989. The birds of Pong Dam Lake bird sanctuary. *Tiger Paper,* **16**(2) : 20-26.

Pirazizy, A.A. 1993. *Mountain environment: Understanding the change,* 194pp. Ashish Publishing House, New Delhi.

Rodger, W.A. and Panwar, H.S.E. 1988. *Planning a wildlife protected area network in India,* vols. 1&2. Wildlife Institute of India, Dehra Dun.

Sahai, B. and Garg, J.K. 1993. Himalayan bioresources: a remote sensing perspective: 327-338. *In:* Dhar, U. (ed.). *Himalayan biodiversity conservation strategies.* Gyanodaya Prakashan, Nainital.

Sehgal, K.L. 1971. Fisheries survey of Himachal Pradesh and some adjacent areas with special reference to trout, mahseer and allied species. *J. Bombay nat. Hist. Soc.* **70**(3) : 458-474.

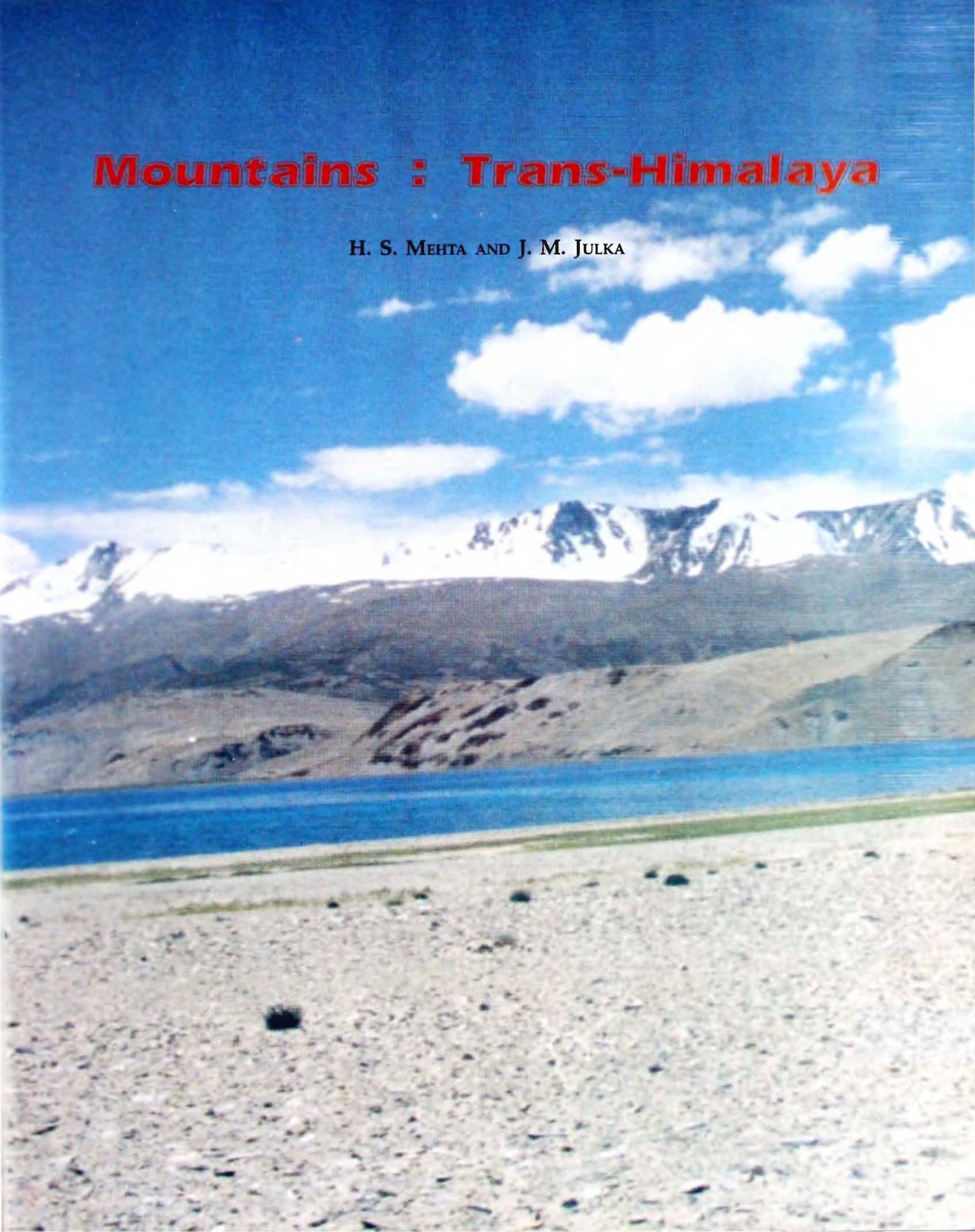
Sharma, B.D. 1994. *High altitude wildlife of India,* 291pp. Oxford and IBH Publishing Company, New Delhi.

Singh, A. and Julka, J.M. (1990). *Impact of construction and completion of BSL Project (Stage I&II) on changes in the faunal components with particular reference to their distribution and abundance.* Final Technical Report, MAB Programme, Department of Environment, New Delhi.

Trishal, C.L. 1996. Wetland biodiversity in the Himalayan region, 63-70. *In*: G.S. Gujral and V. Sharma (eds.). *Changing perspectives of biodiversity status in the Himalaya.* The British Council, New Delhi.

Mountains : Trans-Himalaya

H. S. MEHTA AND J. M. JULKA



ENVIS–*Zool. Surv. India*
Ecosystems of India : 73-92, 2001.

Mountains : Trans-Himalaya

H. S. MEHTA AND J. M. JULKA

High Altitude Zoology Field Station
Zoological Survey of India, Solan, Himachal Pradesh

1. INTRODUCTION

The Himalaya is a gigantic mountain wall on the northern border of India and plays an important role in regulating the climate of the entire Indian subcontinent. It is an effective barrier against the movement of rain bearing southwest monsoon to the regions lying north of it. This has created a vast rain shadow zone to the north of the main Himalayan range, the Trans-Himalaya, which receives very little precipitation. The Trans-Himalaya is a distinct biogeographic unit with very harsh climatic conditions and is usually referred to as a cold desert (Roger and Panwar, 1988). Major portion (92.8%) of this zone lies outside the Indian Territory, primarily in the Tibetan Autonomous region of China. The Indian Trans-Himalaya includes

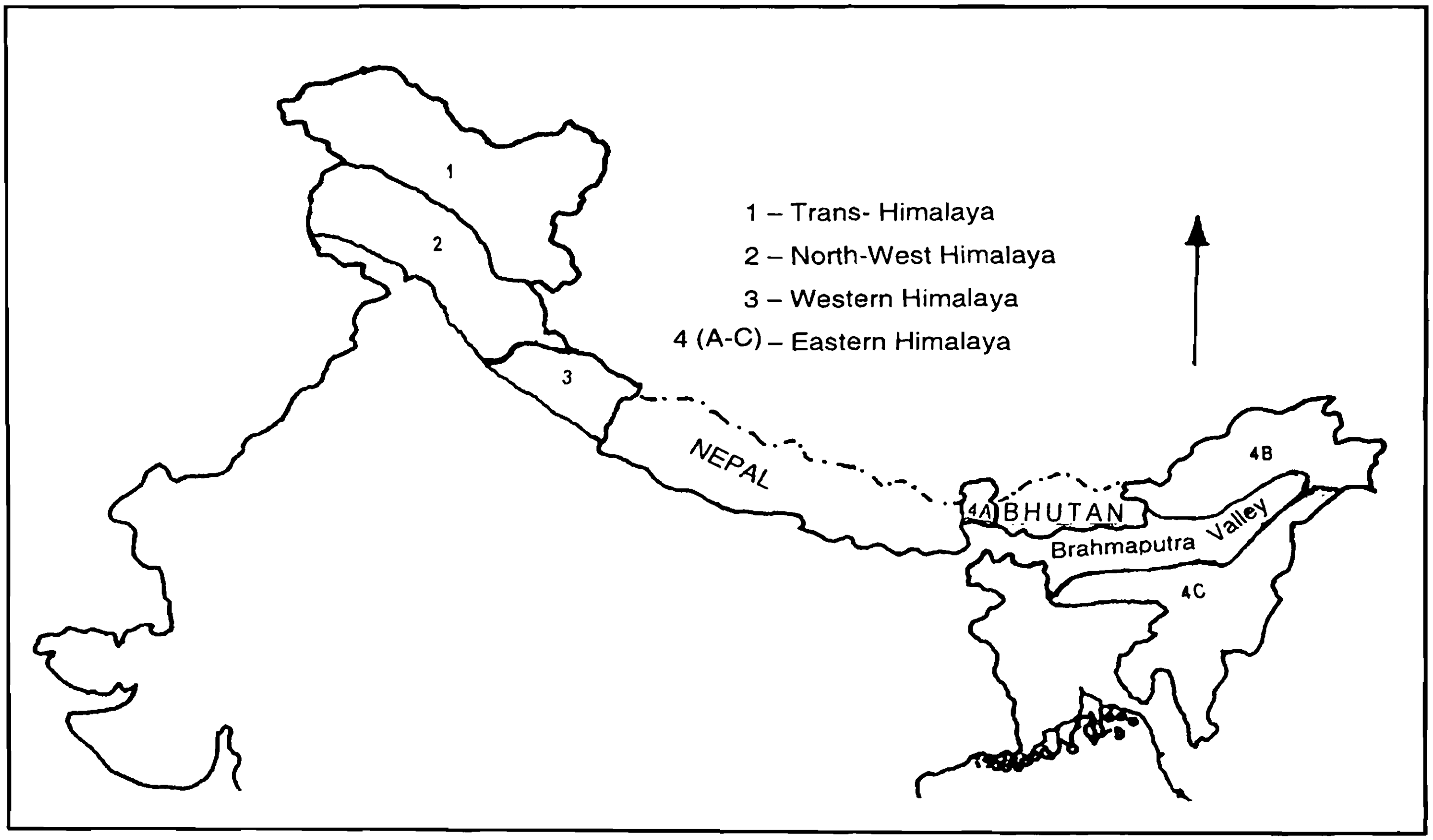


Fig. 1 : Biogeographic divisions of Indian Himalaya (only coloured area dealt with in the article)

Fig. 2 : A view of Trans-Himalaya in Spiti (Himachal Pradesh)

mainly the districts of Ladakh and Kargil in Jammu & Kashmir, and Spiti valley, Lingti plains (Lahaul valley), and Pooh tehsil (district Kinnaur) in Himachal Pradesh. Small areas in the rain shadow of Nanda Devi range (Uttar Pradesh) and Kangchendzonga range (Sikkim) are also a part of this zone. The following account on the biodiversity of Indian Trans-Himalaya, however, primarily pertains to Ladakh, Kargil and Spiti areas.

General topography of the Trans-Himalaya is that of a plateau or tableland intersected by a complex network of barren mountain ranges, *e.g.*, the Zanskar, Ladakh and Karakoram ranges in Ladakh and Kargil areas. Elevations vary from 2800 m in the Indus Valley to over 7000 m the Himalayan and Karakoram ranges. Ladakh and Kargil region is drained by the river Indus, Spiti valley and Pooh area by the river Spiti and Lahaul valley by the river Chandra-Bhaga. Ladakh is bestowed with some very large brackish water lakes namely Pangong Tso, Tso Morari, Tso Kar, etc. The area also harbours some vast freshwater marshes in the river valleys. There are several glaciers of various sizes in the upper slopes of mountain ranges.

The floral and faunal diversity in the Indian Trans-Himalayan zone is very rich and diverse, primarily due to its location at the confluence of two of the world's main biogeographical regions i.e. the Palaearctic and the Oriental. Influx of biota from these biogeographical regions and subsequent speciation in relation to local environment has greatly enriched its biotic resources (Mani, 1974). High levels of species richness and endemism exist in the alpine and steppe ecosystems. Both plants and animals of this region are unique, as they have evolved to withstand the rigours of extreme aridity, severe cold, reduced atmospheric pressure, and high solar radiation. For example, eight species of wild ungulates are found in this region. Of these, the wild sheep and goats (Subfamily Caprinae) are represented by four species. Thus the Trans-Himalaya constitutes a unique 'biodiversity hotspot' of the Caprinae, and is considered to be a part of their original centre of evolution.

Ecology and biodiversity of the Trans-Himalaya are under severe stress due to severe pressures. Ladakh and Kargil districts have been greatly disturbed since 1962 because of extensive military activity. Since 1992, tourists and others have been allowed to visit some pristine areas. There has been tremendous increase in human and livestock populations. Increased agricultural and developmental activities have further contributed to the loss of wildlife in the area. The situation is critical, as almost all the large mammals in this zone are on the endangered list.

2. DESCRIPTION

The Trans-Himalaya covers an area of approximately 2,600,000 km^2 lying to the north of the Great Himalayan range. In India, it comprises an area of about 186,200 km^2 (Dhar, 1996) which is about 7.2% of its total area. Indian portion of the Trans-Himalaya is located between approximately 75°E and 79.40°E longitudes, and 32°N and 26.10°N. Its borders touch with those of Afghanistan, Pakistan. Central Asia, China and Indian states of Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh, Terrain is rugged consisting of deep valleys and high plains. Vegetation is sparse and mostly confined to valleys and sheltered places.

Main valleys in Ladakh are Dras, Suru, Zanskar, Nubra, Shyok and Indus formed by the tributaries of the river Indus. It has an average elevation of more than 3000 m above mean sea level. The high plain of Rupshu, an area of large brackish water lakes, lies in the southeast Ladakh and has a uniform altitude of about 4,100 m amsl. Pangong Tso, Tso Morari and Tso Kar are very large brackish water lakes in this area. There are also some freshwater lakes in the region.

Lingti plain lies to the north of Baralacha range in Lahaul valley (Himachal Pradesh). Topographically, these plains along with Spiti area are very similar to Rupshu plateau of Ladakh. Spiti consists of three distinct geographic regions : Spiti valley, Pin valley and northern high mountains. It experiences heavy snowfall during winter and its average elevation is 5485 m (Negi, 1995).

The climate is extremely dry and cold, approaching arctic conditions. Average annual rainfall in Ladakh rarely exceeds 10 cm though some areas may receive slightly higher annual rainfall. Snowfall varies greatly with the heaviest fall in the Zanskar range, but decreasing northeastwards. Large tracts in Changthang Wilderness area even remain snow-free during the winter. Daytime temperature in summer rises to 35°C but in winter, it remains below the freezing point. Minimum temperature during winter may be as low as -40°C. Spiti also receives very little precipitation with average annual rainfall below 10 cm. Temperature remains below the freezing point for long periods. High velocity winds lash most parts of Spiti throughout the year.

3. BIOLOGICAL DIVERSITY

3.1 Ecosystem/Habitat Diversity

3.1.1 Forests : The entire Trans-Himalayan region is barren with very little natural vegetation, which is restricted to moist and sheltered spots. Vegetation in Ladakh ranges from alpine meadow on northern slopes of the Great Himalaya to steppe type in valleys.

Varieties of poplar (*Populus* spp.) and willow (*Salix* spp.) have been planted along some water courses. Negi (1990, 1995) recognises the following types of natural forests in this zone.

- Dry Temperate Forest (2000-3000 m) : It is largely an open forest. Open patches of grasslands are also found in this type of forest. This type of forest is best developed in the valley of river Chandra-Bhaga in Lahaul and upper valley of river Sutlej in Kinnaur district of Himachal Pradesh. The characteristic tree species in this forest are Holm oak (*Quercus ilex*) and edible pine (*Pinus gerardiana*). At some places, more or less pure stands of deodar (*Cedrus deodara*) are also found.

Fig. 3 : A view of cultivated field and willow trees in Trans-Himalayan region, Ladakh

- Dry Juniper Scrub (2700-4300 m) : It is an open evergreen forest comprising dwarf and stunted trees. It is characterised by dwarf junipers (*Juniperus macropoda*) mixed with *Rosa* spp.
- Sub-alpine Forest (3000-3400 m) : This type of forest is usually found in the transition zone as well as core zone of the Trans-Himalaya. The principal tree species in this forest are characterised by birch (*Betula utilis*), fir (*Abies spectabilis*) and *Rhododendron campanulatum*.
- Dry Alpine scrub (3200-3800 m) : It comprises of two subtypes : Moist Alpine Scrubs which are found just below snowline, *e.g.*, *Rhododendron campanulatum* at elevations of 3200-3500 m and Dry Alpine Scrubs of juniper (*Juniperus communis*) between 3400 m and 3800 m altitudes.

3.1.2 Lakes : Trans-Himalaya is bestowed with some very large brackish water natural lakes *e.g.* Pangong Tso, Tso Morari and Tso Kar in the Changthang area of Ladakh, which are of freshwater origin. They are believed to be relicts of ice age, formed by the melt waters of retreating glaciers. The freshwater lakes had no outflow and changed to brackish water largely due to evaporation caused by highly desiccating arid environments. Tso Kar with an area of about 15.6 km^2 is now a hyper-saline lake. It is situated at an altitude of about 4500 m. Tso Morari, which attracts thousands of migratory waterfowl, has been identified as a potential Ramsar site by the Ministry of Environment & Forests, Government of India. It is the second largest lake in Ladakh (area, 138 km^2) and is located at an elevation of approximately 4500 m. Pangong Tso is the largest brackish water lake in the area, having an area of about 700 km^2. Its maximum estimated length is about 135 km and average width as 5 km. Two-thirds of Pangong Tso lies in Tibet. Other notable brackish water lakes in Ladakh are Tso Khyagar (alt. 4672 m) and Mitpal Tso (alt. 4874 m). This region also harbours a few freshwater lakes. Hanle Tso and Tso Startsakpuk are large freshwater lakes in Ladakh.

Fig. 4 : Trans-Himalayan cold desert, Ladakh (Jammu & Kashmir)

The Trans-Himalayan lakes provide vital support systems and habitats for birds, fishes and other aquatic life. Biotic diversity of brackish water lakes is very low. In Tso Morari, *Potamageton pectianus* is the only macrophyte though *Carex* sp. occurs in nearby marshy areas of the lake. Algae are represented by species of *Oocystis*, *Cyclotella*, etc. Zooplankton comprises species of *Keratella*, *Cyclops*, *Daphina* and *Alona*. Chironomid and other dipterous larvae form important components of the benthic fauna. The hyper-saline Tso Kar has no littoral vegetation. Phytoplankton diversity is very low whereas zooplankton is well represented by *Daphnia* spp., *Brachionus plicatilis*, *Notholca striata* and *Notommata epaxia*. Among oligochaetes, *Tubifex* sp. has been reported from brackish water Tso Startsakpuk. High altitude fish, *Nemacheilus* sp., and shells of aquatic molluscs of the family Lymnaeidae have also been recorded from this lake. *Branchionecta orientalis*, a crustacean, is common in ponds of melt water (Togarmo Tso). Another crustacean, *Gammarus pulex* is widely distributed in the lakes of Ladakh and Lahaul between altitudes 3700 and 5334 m (Mani, 1962).

Most of the wetlands in Ladakh are important transit spots and breeding ground for some waterfowl. They represent the only breeding ground of Barheaded Geese *(Anser indicus)* and Blacknecked Crane *(Grus nigricollis)* outside China. Other waterfowl species breeding in this zone are Ruddy Shelduck *(Tadorna ferruginea)*, Great Crested Grebe *(Podiceps cristatus)*, Common Merganser *(Mergus merganser)* etc. These wetlands also support significant populations of Lesser Sand Plover *(Charadrius mongolus)*, Black-necked Grebe *(Podiceps griseigena)* and other migratory birds.

3.1.3 Rivers and Marshes : The Indian Trans-Himalayan region is primarily drained by the Indus drainage system. Main tributaries of this river in Ladakh are Hanle, Gurtang, Zanskar, Shigar and Shyok. The Chenab, another major tributary of the Indus, is an important river in the Lahual valley. The river Spiti is an important river of the Spiti valley and discharges into the river Sutlej, which also belongs to the Indus system. These rivers support a rich fauna, which is distinctive in possessing special features for survival in swift currents with high oxygen content and low temperature. Some characteristic faunal species of the Trans-Himalayan rivers are the larvae of *Epeorus*, *Baetis*, *Baetiella* and *Ironopsis* (Ephemeroptera), *Capnia* and *Illiesonemura* (Plecoptera), *Deuterophlebia*, *Blepharocera*, *Pericoma* and *Simulium* (Diptera); *Schizothorax*, *Schizopygopsis*, *Diptycus*, *Gymnnocypris*, *Schizothoraicthys*, *Triplophysa* (Pisces) and tadpoles of *Scutiger* (Amphibia).

Accumulation of melt water at some places in Changthang has resulted in the formation of vast but shallow marshes and borax-loaded bogs, *e.g.*, Hanle and Chishual marshes. These marshes probably harbour the largest biodiversity in the harsh cold and arid environment. They provide breeding grounds for several species of dipterous and other insects, which are important components in the food of waterfowl and other birds. Endangered Blacknecked Crane *(Grus nigricollis)* often constructs its nests on small-elevated mounds in the marshes. Several species of mammals and other birds including waterfowl are also attracted to these highly productive habitats.

A few hot springs are found in the Trans-Himalaya. The famous Puga hot spring occurs in the Rupshu plateau (altitude 4527 m) of east Ladakh. An hygrophile dipterous fly, *Ephydra glauca* (Family Ephydridae), has been reported from its water at a temperature of 49°C.

3.1.4 Pastures : Alpine pastures form an important ecosystem in Indian Trans-Himalaya, in terms of biodiversity, ecology and economy of the local people. They provide nutrient rich forage for grazing livestock and wildlife. Pastures in this zone are usually found at very high elevations between snowline and tree line. They descend to lower slopes where there are very few trees. Arid alpine pastures in Ladakh are dominated by low thorny scurb *(Lonicera spinoides, Hippophae rhamnoides)*, Tibetan furze *(Caragana* sp.) and a variety of grasses (*Festuca* sp. *Carex* sp., *Artemisia* spp., *Draba* sp., etc.).

3.1.5 Agroecosystems : The present day agroecosystems in Trans-Himalaya have mostly been developed by clearing natural vegetation and by irrigating desert soils. Various kinds of vegetables and fruits are grown. Several kinds of insect pests and predators inhabit these systems. Willow and poplar trees have been extensively planted along water channels.

3.2 Species Diversity

3.2.1 Flora : Floral diversity is fascinating due to species richness and diverse community structure. Data on the total number of floral species recorded from Trans-Himalaya are not available. Howerver, the following information on the floristic diversity of some areas indicates rich floral wealth of this zone. Approximately 880 species of flowering plants are known from the cold desert of Ladakh (Kachroo, 1993), the dominant families being Compositae (125 spp.) and Gramineae (101 spp.). Species distribution among dominant genera is 29 spp. in *Astragalus*, 22 spp. in *Polygogum*, and 19 spp. in *Potentilla* and in *Artemisia*.

The flora of Trans-Himalaya is known for its richness of legumes, which characterise the steppe vegetation. Some important legumes occurring in the region are species of *Astragalus, Oxytropis, Hedysarum, Trigonella, Cicer*, etc. This area is also considered as a storehouse of medicinal plants, which are well adapted to cold desert and alpine conditions, *e.g., Artemisia* spp., *Codonopsis clematida, C. rotundifolia, Ephedra gerardiana, Picrorhiza kurroa*, etc. Kaul (1997) has listed 169 species of plants having medicinal value from Ladakh. Of these, many are endemic to the area.

Majority of plants in Trans-Himalaya has adapted to endure the rigors of extreme cold and dry environment, and wind velocity. They grow close to the ground and remain characteristically short and dwarfed. For example, shrubs like *Caragana versicolor, Acantholium* sp. and *Thylacospermusm* sp. are cushion-shaped, and *Stachys tibetica* forms tufted patches. Such cushion-like plants are well adapted to withstand the blizzards. Other dwarf plants in this zone are mat forming, *e.g., Hippophae* sp. and *Carex* spp. Some herbs like *Anemone* spp., *Ranunculus pulchellus, R. hyperboreus, Oxygraphis glacialis* and *O. polypetala* (Family Ranunculaceae) and *Cheiranthus* spp. (Family Cruciferae) have perennial underground rootstocks from which arise annual prostate or cushion-like plants.

3.2.2 Fauna : The fauna of Indian Trans-Himalaya has not been explored extensively. However, faunistic studies indicate that the vertebrates, especially mammals, birds and fishes have received more attention as compared to insects and other invertebrates. The faunal diversity in this region has been greatly influenced by its unique geographical position and arctic climate. Biogeographical studies indicate pronounced dominance of Palaearctic and endemic forms.

Interbetrates

Insects : Order Coleoptera dominates insect diversity in the nival zone of the northwest Himalaya, which also includes the Indian Trans-Himalaya (Mani, 1962). The beetles represent about one-half of the nival insects. Most of these are true geophiles, occurring under stones and boulders, in soil, in rock crevices, and on the edges of streams, lakes and melting snow. The phytophagous beetles are poorly represented, as there is a scarcity of vegetative growth in the area. Some other important Trans-Himalayan insect orders are Lepidoptera, Diptera, Hemiptera, Hymenoptera, Orthoptera, Dermaptera, Ephemeroptera, Collembola, and ectoparasitic Mallophaga and Anoplura.

Two coleopteran families, namely, Carabidae and Staphylinidae constitute more than two-thirds of the beetle diversity in this zone. The Tenebrionidae and Curculionidae are also well represented. Nearly half the carabid species in the Indian Trans-Himalaya are endemic and the majority of the rest are indigenous to the entire northwest Himalaya, Pamirs, Tibet and central Asia. Endemic carabids in the Trans-Himalayan areas of Ladakh and Lahaul & Spiti primarily belong to the Himalayan genera *Amara* (3 spp.) and *Bembidion* (7 spp.) A few endemic carabid species are also distributed among the cosmopolitan *Colosoma*, and holarctic genera like *Cymindis*, *Carabus* and *Nebria*. *Amara brucei*, a protected beetle under Schedule II of the Indian Wildlife (Protection) Act 1972, has been reported from an amazing altitude of 5300 m above mean sea level. *Cymindis rubriceps* is found near permanent snow at an elevation of 5200 m. Members of the genus *Bembidion* are remarkable in being apterous or flightless. Other endemic coleopterans belong to *Atheta*, *Aleochara* and *Philonthus* (Family Staphylinidae), *Ascelosodis*, *Blaps* and *Cyphogenia* (Family Tenebrionidae), *Heteronyx*, *Lagenolobus*, *Leptomias* and *Sitones* (Family Curculionidae), *Articephala*, *Callistopopillia* and *Adoretus* (Family Scarabeidae), and *Merista*, *Podagarica* and *Plagiodera* (Family Chrysomelidae). The curculionid and chrysomelid beetles are mostly inhabitants of grassy meadows. A few species of aquatic beetles of the Dytiscidae, Gyrinidae and Hydrophilidae have been recorded from lakes, ponds and streams in Ladakh. These belong to the genera *Agabus* and *Potamonectus* (Family Dytiscidae), *Platoambus* (Family Gyrinidae), and *Helophorus* (Family Hydrophilidae).

Butterflies and moths (Order Lepidoptera) also constitute a major group of insects in this zone. Nevertheless, the number of species is much less compared to that of beetles. Trans-Himalayan butterflies are predominantly represented by Palaearctic elements. Endemic species/subspecies mostly belong to the families Papilionidae, Satyridae, Pieridae, Nymphalidae and Lycaenidae. The Palaearctic *Parnassius* (Family Papilionidae). which includes Snow Apollos, is the dominant genus of butterflies in the Trans-Himalaya as well as the adjacent region of Pamir-Northwest Himalaya (Mani, 1986). This vast area is considered the main amphitheater of its origin and evolution. *Parnassius* has maximum endemic species and high frequency of subspecies differentiation in the area. Out of 13 species of *Parnassius* known from the Himalaya, eight species with 19 distinct subspecies are found in the Indian Trans-Himalaya. Most of these species occur at about 4000 m altitude. Nevertheless, *Parnassius acco acco*, *P. acco tagalangi*, *P. delphius delphius* and *P. simo zarraensis* have been recorded at elevations above 5000 m in Ladakh and Lahaul & Spiti. *P. acco acco* is even found above 5500 m near glaciers. Other paplionids in this area are two subspecies of the Holarctic *Papilio* *machaon*. Both the Satyridae and Pieridae are well represented in the Indian Trans-Himalaya with approximately 15 and 12 species/ subspecies respectively. These belong to *Callerebia, Karanasa, Lasiommata, Maniola* and *Paroensis* (Family Satyridae). and *Baltia, Colias, Metaporia, Pieris* and *Pontia* (Family Pieridae). The Nymphalidae and Lycaenidae of this zone comprise about seven species/subspecies each. The nymphalid species primarily belong to *Boloria, Clossiana* and *Fabriciana* (earlier placed in *Agrynnis), Aglais* and *Polygonia* (= *Vanessa*), *Melitaea* and *Limenitis*. Some important lycaenid genera in the area are *Albulina, Lycaeides* and *Philotes* (all resurrected from *Polyommatus), Polyommatus, Strymon* (= *Thecala)* and *Thersamonia* (= *Lycaena)*.

Order Diptera appears to have rich species diversity in the Trans-Himalayan zone. It may be one of the dominant groups of insects in the area. The dipterous fauna in this zone primarily comprises species of apterous *Chiona* (Family Tipulidae), *Kozlovea* (Family Sarcophagidae), *Bibio* (Family Bibionidae), *Deuterophlebia* (Family Deuterophlebidae), *Simulium* and *Prosimulium* ((Family Simuliidae), *Paratendipes* (Family Chironomidae), *Pericoma* (Family Psychodidae), *Aedes* and *Theobaldia* (Family Culicidae), and *Ephydra* and *Holmatopota* (Family Ephydridae), Some species of the families Syrphidae and Anthomyiidae have also been reported from the Trans-Himalaya. A few dipterans have been adapted well to breed in adverse habitats. The larvae of marsh-fly, *Ephydra glauca* occurs in saline and alkaline hot waters at temperatures ranging from 43°C to 49°C in Rupshu area of Ladakh at an elevation of about 4520 m. Another ephydrid fly *Holmatopoda hutchonsoni* has been recorded from hyper-saline TSO Kar Lake at same altitude. The mosquitoes *Theobaldia niveitaenia* and *Aedes pullatus* breed in shallow melt water pools and swamps in the Changthang and other areas of Ladakh.

Order Hemiptera (bugs, aphids, etc.) is primarily represented by Palaearctic elements. Approximately 15 species of aphids (Family Aphididae) are known from the Lahaul and Spiti area. These belong to the genera *Aphis, Acyrthosiphon, Brachycaudus, Brevicoryne, Capitophorus, Cavariella, Hyalomyzus, Macrosiphum* and *Metopolophium*. Family Lygaeidae appears to be well adapted to the arid and cold environment of this region. The lygaeid bugs like *Bianchiella adelungi, Lamprodema brevicollis, Microplax hissarensis* and *Nysius ericae* are found between altitudes 3400 m and 5000 m. *Dolmacoris deterrana* and *Emblethis horvathiana* have even been reported at elevations of 5200. Family Pentatomidae is represented by a single endemic species, *Phimodera rupshuensis*, occurring on the banks of Tso Morari. Some other bugs of this zone are *Strictopleurus* sp. (Family Coreidae), *Dicyphus physochlaenae, D. sengge* and *Tibetocoris margaretae* (Family Miridae), *Chiloxanthus alticola* (Family Saldidae), and *Gerris sahlbergi* (Family Gerridae).

Very little information is available on the Trans-Himalayan Hymenoptera. Most of the species are referable to the families Formicidae, Bombidae and Ichneumonidae. They are mostly confined to an altitude of about 3000 m. Nevertheless, an endemic ant species, *Formica (Serviformica) picea*, has been recorded up to an elevation of 4800 m. It inhabits grassy meadows, and shores of hot springs and glacial lakes. *Cataglyphis (Monocombus) cugei*, another ant species is primarily associated with arid *Artemisia* steppe. *Bombus longiceps* and *Subterraneobombus melanurus subdistinctus* (Family Bombidae) are endemic to the Trans-Himalaya. Other commonly found bombids in the area are *Bombus alticus, B. vallestris, Lapidariobombus saparandus, L. alagesianus pamirus* and *Mendacibombus margeriteri*. Some parasitic ichneumonids are known to exist in Lahaul & Spiti area. Most of these are transitional forms, which also occur at lower elevations and belong to *Netelia, Ophion, Lissonota, Exetastes, Pterocormus* and *Triptognathus*.

The Trans-Himalayan grasshopper (Order Orthoptera) and earwing (Order Dermaptera) diversities have not been extensively explored. Some grasshoppers of the area are *Bryodema luctuosa, Sphingonotus savignyi, Catantops humilis,* etc. *Bryodema luctuosa* is endemic to the area and is typically an inhabitant of *Artemisia*-steppes and stony localities. Tropical *Catantops humilis* is sparsely found in the grassy meadows in Spiti. Three species of earwigs, *Anechura zubaskii, Forficula schlagintweiti* and *Isolabidus burri,* are known from this region. They are commonly found under stones near streams and other water bodies.

Immature stages of some insects like mayflies, dragonflies, caddisflies and stoneflies are aquatic. Very little information is available on the diversity of these amphibious insects in Trans-Himalaya. However, a few endemic species of mayflies (Order Ephemeroptera) are known from Lahaul & Spiti and Ladakh regions. *Baetis chandra, B. himala, B. himalayana, Epeorus lahulensis* and *Ironopsis* sp. have been reported from Lahaul & Spiti. The endemic mayfly fauna of Ladakh comprises of *Ororotsia hutchinsoni, Ameletus primitivus* and *Baetiella ladakae.* The larvae of *Ororotsia hutchinsoni* inhabit Ororotse Tso, which is the highest freshwater lake (altitude 5297 m) in Ladakh. The dragonflies (Order Odonata) in this region are represented by circumtropical *Pantala flavescens* and endemic *Lestes manaliensis* from Lahaul & Spiti, and the Palaearctic *Aeshna juncea* and *Sympetrum meridionale* from Ladakh.

The wingless Collembola, commonly known as springtails, are able to thrive at high altitudes where insect life is possible (Mani, 1962). Their altitudinal range extends up to 6000 m where there is hardly any trace of insect life. *Orchesella boraoi* occurs from 5200 m (Shakya La) to 5600 m (Marsimik La) in Ladakh. *Proisotoma ladaki,* an endemic species in Ladakh, has been reported from the edges of Mitpal Tso and Togarma Tso. Mass assemblage is common in *Proisotoma.* A widely distributed species, *Sminthruides (Stenacidia) violaceus,* is found on the surface of melt water pools and ponds at elevations between 4000 m and 4700 m. It is known to occur in some parts of Trans-Himalaya Tibet. A cosmopolitan thysanuran *Ctnolepisma longicaudatus,* another wingless insect, is frequently associated with man. It is major house holds pest in Lahaul & Spiti.

Among neuropteran insects (ant lions, lacewings) only two species are present in the Indian Trans-Himalaya. A Palaearctic ant lion species, *Mymecaelurus punctulatus* occurs in the Indus Valley in Ladakh (altitude 3450 m). This species is also known from south Russia and Hungary. Another neuroptera *Parosmylus promineus* has been recorded from the Lahaul valley.

Ectoparasitic chewing-lice (Order Mallophaga) have been caught living on various kinds of Trans-Himalayan wild mammals and birds. Approximately eight species of lice occur in Ladakh. These are *Brueelia biocellata* (Host : *Pica bacteriana), B. varia* (Host : *Corvus corax, C. monedula, P. bacteriana), Cuculotogaster tetraogallus* (Host : *Tetraogallus h. himalayensis), Goniodes colchici* (Host : *T. h. himalayensis, T. t. tibetanus), G. dispar* (Host : *Alectoris gracea chukar, A. g. pallescens), Philopterus atratus* (Host : *Corvus macrorhynchus, C. corax), P. garruli* (Host : *Pica bactriana)* and *Syrrhaptoecus tibetans* (Host : *Syrrhaptes tibetans).* A few species of sucking lice (Order Anoplura) that are parasitic on mammals are also found in this area. They include *Neohaematopinus palearctus* (Host : *Marmota caudata), Hoplopleura captiosa* (Host : *Mus booduga), H. phaiomydis* (Host : *Microtus* sp.) *Linognathus stenopsis* and *L. ovillus* (Host : Domesticated sheep and goats), and *Polyplax serrata* (Host : *Mus musculus; Apodemus* sp.).

Other invertebrates : Diversity of invertebrates other than insects is very low in the Trans-Himalaya, as most of these organisms are inhabitants of lower elevations. Some of non-insect invertebrates in this area belong to nematodes, oligochaetes, molluscs, rotifers, and arthropods like myriapods, mites, ticks, spiders, scorpions, isopods and crustaceans.

Distribution of majority of soil invertebrates is restricted to moist places in cultivation and near irrigation channels and marshes. Plant soil nematodes, popularly called threadworms, are one of the most economically important groups of non-insect invertebrates. They are known to damage all kinds of agricultural and horticultural crops. Some common plant and soil nematodes of Lahaul and Spiti are exotic *Meloidogyne javana* and *M. incognita* (Family Meloidogynidae), and endemic *Mylonchulus apapillatus* (Family Mylonchulidae). Earthworms (Oligochaeta) play a vital role in enhancing soil fertility in arable land and pastures due to their burrowing and feeding habits. Five species of exotic lumbricids and one exotic species of megascolecids are found in areas of intensive cultivation and willow plantation in Lahaul and Spiti. They include *Allolobophora parva, Aporrectodea caliginosa caliginosa, Ap. caliginosa trapezoides, Octolasion tyrtaeum* and *Dendrodrilus rubidus* (Family Lumbricidae), and *Amynthas corticis* (Family Megascolecidae). *Dendrodrilus rubidus* also occurs in Ladakh at suitable places. A freshwater oligochaete, *Tubifex* sp. has been reported from water bodies in Ladakh.

Most molluscs of this zone are inhabitants of freshwaters in pools, lakes and streams. Shells of some freshwater species have been found in ancient lacustrine clay deposits above the present level of brackish water lakes like Pangong Tso. Tso Morari, etc. This amply supports the freshwater origin of these lakes. The freshwater molluscan fauna of Ladakh is dominated by gastropod species, viz., *Lymnaea lagotis costulata, L. lagotis solidissima, Gyraulus pankongensis, G. nanus* and *Valvata piscinalis.* Two species of freshwater bivalves of the Pisidiidae, a family of great antiquity, also occur in Ladakh. These species, *Pisidium stoliczkanum* and *P. zugmayeri,* are found near Man-Spangmik and Pangong Tso lakes. A few land gastropods have been reported from the Indian Trans-Himalaya. Examples of these are *Vallonia ladakensis* (Family Vallonidae) and *Pyramidula humilis* (Family Pupillidae).

Microscopic zooplanktons bloom in both freshwater and brackish water bodies in Ladakh. They comprise of endemic cladoceran species like *Ceriodaphinia pulchella* and *Gurnaella rephaelis,* and endemic rotifers like *Trichotria pocillum* and *Asplanchnopus multiceps.* Species of *Alona* (Cladocera), *Cyclops* (Copepoda) and *Keratella* (Rotifera) have also been collected from the area.

A few species of parasitic mites (Acari) are known from Lahaul and Spiti. They belong to *Hypoaspis, Laelaps, Hirstionyssus, Liponyssoides, Eulaelaps* and *Haemogamstus.* A large number of water mites are found in the Trans-Himalayan glacial streams and springs. *Protziella hutchinsoni* has been recorded from elevations ranging from 3000 to 4000 m and *Elyais hamata* inhabits areas between 4000 and 4300 m. A species of ixodid ticks, *Dermocenter raskemensis,* is also found in this area.

An amphipod *Gammarus pulex* is commonly met with in small pools and both freshwater and brackish water lakes through out Ladakh and parts of Lahaul valley, at elevations ranging between 3700 m and 5330 m. *Branchinecta orientalis* (Branchiopoda) is found in melt water ponds and lakes up to an elevation of 5217 m (lake Togarmo Tso in Ladakh) in the Indian Trans-Himalaya. *Protracheoniscus nivalis,* an isopod, is a significant member of under stone community near glacial streams.

An endemic scorpion, *Chaerilus insignis,* has been recorded from Ladakh between 3600 m and 3900 m. and is found in Garhwal and Kumaon hills of the western Himalaya. The pseudoscorpion *Microcreagris kazanakovi* is widespread in Central Asia and Tibet. Its subspecies *M. kazanakovi lahulensis* is endemic to Lahaul valley. The web-spiders (Family Lycosidae) are represented by endemic *Paradosa ladakensis* in Ladakh.

The Chilopoda represents the Trans-Himalaya myriopods. Some important chilopod species in the region include *Lithobius (Archilithobius) electus electus* and *L. (A.) electus secessa* at elevations ranging from 3500 to 5200 m. *Lithobius (A.) bispinosus, L. (A.) pulverispinata* and *L. (A.) materiatus* are common at about 4000 m altitude. Two species of the widespread genus *Otostigmus, O. amballae* and *O. pilatus* have been reported from the Lahaul and Spiti.

Verbetrates

Fishes : The fish fauna of Indian Trans-Himalaya is dominated by the species belonging to the Subfamily Schizothoracinae (Family Cyprinidae) and Subfamily Nemacheilinae (Family Balitoridae). The Schizothoracinae comprising hill trouts is a specialised group inhabiting torrential streams in the higher altitudes in the Himalaya and Central Asia. These fishes have originally dispersed from the heart of the Palaearctic region in USSR, China, Tibet, etc (Tilak, 1987). In Ladakh, the Schizothoracinae is represented by endemic species belonging to six genera, namely, *Diptychus* (one species), *Gymnocypris* (One species), *Ptychobarbatus* (one species), *Schizopygopsis* (one species), *Schizothoraicthys* (three species) and *Schizothorax* (one species). The genus *Ptychobarbatus* is monotypic and restricted to Ladakh. The distribution of *Gymnocypris biswasi* is also restricted to this area. *Schizothorax richardsoni* and *Diptycus maculatus* are widespread through out the Trans-Himalaya. The range of *Schizopygopsis stolioczkae* extends to Central Asia whereas that of *Schizothoraicthys escocinus* and *Schizothoraicthys labiatus* includes Afghanisthan. *Schizothoraicthys micropogon* is distributed through out Ladakh and Kashmir Valley.

The Nemacheilinae comprises fishes, which are commonly known as hill stream loaches. Seven species of these fishes are known from Ladakh and they belong to the genus *Triplophysa*. All these species are endemic to Ladakh with *T. ladacensis* and *shehensis* being restricted to the area. The distribution of other species extends to neighbouring areas, *viz*., T. *gracilis, T. stoliczkae* and *T. tenuicauda* to Western Tibet, *T. microps* to Spiti and *T. yasinensis* to Kashmir Valley and Pakistan.

Herpatofauna : The diversity in the Trans-Himalaya cold blooded animals like amphibians and reptilians is very low because of extreme cold climatic conditions in the area. Nevertheless, some species of lizards have adapted to the extreme climate so well that they occur at high elevations up to 4500 m in this zone. The Himalayan agamid lizard, *Agama himalayana* is common in Ladakh and is usually seen basking at the sun among rocks and boulders. It is endemic to Ladakh, Tibet and East Turkestan. Toad-headed lizards *Phrynocephalus theobaldi* and *P. reticulatus* (Family Agamidae) are typical inhabitants of Ladakh and other Trans-Himalayan area. *P. theobaldi* lives in colonies, generally sandy places. It is said to be viviparous and monogamous in habits (Smith, 1934). Skinks (Family Scincidae) are represented by

Fig. 5 : A lizard *Mabua carinata* in Trans-Himalaya

Leilolopisma ladacense and *L. sikkimensis*. The former is endemic to Ladakh and is found up to an altitude of about 4800 m. The Trans-Himalayan gecko lizards (Family Gekkonidae) comprise an endemic *Cyrtodactylus stolczikae*. The Himalayan Pit Viper *(Agkistrodon himalayanum)* is perhaps the only poisonous snake in the area. It has been recorded at an elevation of about 4800 m, which perhaps represents the highest altitude record for snakes. The non-poisonous snakes in Ladakh belong to the Family Colubridae. They are represented by *Elaphe hodgsoni* and *Argyrogena (= Coluber) rhodorachis*.

Toads and frogs (Amphibia) mostly inhabit areas, which are below the snowline, However, a few species like *Bufo latastii, B. viridis* and *Scutiger occidentalis* have been reported from the Trans-Himalaya. The green toad, *B. viridis* is possibly the only amphibain that occurs even at an elevation of 5000 m.

Birds : About 275 species of birds have been reported from Ladakh (Mallon, 1987) and they constitute approximately 22.4% of the Indian bird diversity. Ecologically, the avifauna of Ladakh is very interesting. Holmes (1986) has listed 128 species from the Suru Valley. Of these, about 35.9% breed in the valley, which probably also provides breeding ground for another 21.1% of species. Approximately 15% of Suru Valley birds are considered as migrants.

The Trans-Himalayan avifauna comprises of diverse birds and most of these show Palaearctic affinities. The sky is ruled by eagles and vultures (Family Accipitridae) like Lammergeir or Bearded Eagle *(Gypaetus barbatus)*, Golden Eagle *(Aquila chrysaetos)*, Osprey *(Pandion haliaetus haliaetus)* Blackeared Kite *(Milvus migrans lineatus)*, Griffon Vulture *(Gyps himalayensis)*, etc. The falcons (Family Falconidae) constitute Peregrine Falcon *(Falco peregrinus)*, Central Asian Hobby *(F. subbuteo centraliase)*, European Kestrel *(F. tinnunculus tinnunculus)*, etc.

Partridges and pheasants (Family Phasianidae), also known as game birds, comprise of Snow Partridge *(Lerwa lerwa)*, Tibetan Partridge *(Perdix hodgsoniae)*, Chukar *(Alectoris chukar)*, Tibetan Snowcock *(Tetraogallus tibetanus)* and Himalayan Snowcock *(T. himalayensis)*. Ali and Ripley (1983) include Ladakh in the range of highly endangered Western Tragopan *(Tragopan melanocephalus)*, but its present status in this area is not known. Due to extreme hunting pressure and loss of habitat, both Tibetan Snowcock and Western Tragopan have become highly endangered species. These beautiful pheasants are now protected under Schedule I of the Indian Wildlife (Protection) Act, 1972. Protection under the Act has also been provided to some other endangered Trans-Himalayan birds like Lammergeir, Golden Eagle, Osprey, Peregrine Falcon and Blacknecked Crane *(Grus nigricollis)*.

The Trans-Himalayan wetlands and other bodies attract several species of water birds for breeding as well as transit migratory spots. Notable among these are Bar-Headed Goose *(Anser indicus)*, Ruddy Shelduck *(Tadorna ferruginea)*, Common Teal *(Anas crecca)*, Northern Pintail *(A. acuta)*, Garganey *(A. querquedula)*, Northern Shoveler *(A. clypeata)*, Common Merganser *(Mergus merganser)*, Blacknecked Crane *(Grus nigricollis)*, Lesser Sand Plover *(Charadrius mongolus)*, Black-necked Grebe *(Podiceps griseigena)*, Brownheaded Gull *(Larus brunnicephalus)*, Great Blackheaded Gull *(L. ichthyaetus)*, Arctic Tern *(Sterna paradisaea)*, Common Redshank *(Tringa totanus)*, Common Greenshank *(T. nebularia)*, Ibis *(Ibiodorhyncha struthersii)*, Yellow Wagtail *(Motacilla flava)*, etc.

Desolate rocky and sandy areas are also inhabited by a host of birds like Redbilled Chough *(Pyrrhocorax pyrrhocorax)*, Yellowbilled Chough *(P. graculus)*, Hodgson's Grandala *(Grandala coelicolor)*, Horned lark *(Eremophila alpestris)*, Tibetan Sandgrouse *(Syrrahaptes tibetanus)*, Rock Thrush *(Monticola saxatilis)*, Little Owl *(Athene noctua)*, Snow Pigeon

(Columba leuconota), Hill Pigeon *(C. rupestris)*, Altai Accentor *(Prunella himalayana)* and Alpine Accentor *(P. collaris)*.

Caragana Furze and other bushes provide shelter to Pleschanka's Pied Chat *(Oenanthe pleschanka)*, Robin Accentor *(Prunella rubeculoides)*, Brown Accentor *(P. fulvescens)*, Snow finches *(Montifringilla adamsi, M. taczanowskii* and *M. blanfordi)*, Mountain finches *(Leucosticta nemoricola* and *M. brandti)*, Mongolian Trumpeter Bullfinch *(Carpodacus mongolicus)*, Crimsonwinged Desert Finch *(Callacanthis sanguinea)*, Great Rosefinch *(Carpodacus rubicilla)* and Eastern Great Rosefinch *(C. puniceus)*, etc. Whiterumped Magpie *(Pica pica)* is commonly seen near habitation.

Mammals : As many as 40 species of mammals are known from the Indian Trans-Himalaya and these constitute about 50% of the Northwest Himalayan and about 10.7% of Indian mammals. They comprise 12 species of rodents, 6 species of hares and mouse hares (Lagomorpha), 2 species of bats (Chiroptera), 8 species of ungulates and 12 species of carnivores. Most of the mammalian species in this zone are Palaearctic origin.

The rodents are represented by Marmots *(Marmota bobak himalayana, M. caudata caudata)*, Flying squirrels *(Petaurista p. albiventer, Hylopetes fimbriatus fimbriatus)*, High mountain voles *(Alticola roylei* 3 subspp., *Alticola stoliczkanus* 2-subspp., *Pitymus leucurus*

Fig. 6 : Himalayan Marmot in Trans-Himalaya in Ladakh

Fig. 7 : Tibetan Wild Ass, Kiang in Trans-Himalaya in Ladakh

leucurus), Hamster *(Cricetulus alticola)*, rats *(Rattus rattus gangutrianus, R. rattoides turkestanicus, Apodemus flavicollis wardi)* and mice *(Mus musculus bactrianus, M. sublimis)*. The Trans-Himalaya harbours a rich diversity of pikas (Mouse hares). These are Nubra Pika (*Ochotona pusilla nubrica)*, Royle's Pika *(O. roylei wardi)*, Large-eared Pika *(O. macrotis macrotis)* and Ladakh Pika *(O. ladacensis)*. Other lagomorphs in the region are Cape Hare *(Lepus capensis tibetanus)* and Wooly Hare *(Lepus oiostolus oiostolus)*.

Among ungulates, the wild sheep and goats alone are represented by four species, namely, Asiatic Ibex *(Capra siberica)*, Bharal or Blue Sheep *(Pseudois nayur)*, Great Tibetan Sheep or Nayan *(Ovis ammon hodgsoni)* and Ladakh Urial or Shapu *(Ovis vignei)*. Other wild ungulates known from this zone are Tibatan Antelope or Chiru *(Panthalops hodgsoni)*, Tibetan Gazelle *(Procapra picticaudata)*, Wild Yak *(Bos mutus)* and Tibetan Wild Ass or Kiang *(Equus kiang)*.

As the herbivore diversity (rodents, lagomorphs and ungulates) is very rich in the Trans-Himalaya, the carnivore species richness is also very high in the region. The Trans-Himalayan carnivores include Snow Leopard *(Panthera uncia)*, Himalayan Lynx *(Lynx lynx isabellinus)*, Palla's Cat *(Felis manul)*, Tibetan Wolf *(Canis lupus chanko)*, Indian Wild Dog *(Cuon alpinus)*, Red Fox *(Velpes vulpes montanus)*, Brown Bear *(Ursus acrtos)* and weasels *(Mustela siberica, Mustela altaica temon, Mustela kathiah caporiaccoi, Martes foina)*.

4. SPECIAL FEATURES

The Indian Trans-Himalaya has high levels of biodiversity and endemism in both flora and fauna because of its location at the confluence of the Palaearctic and the Oriental biogeographical regions. This vast region along with adjacent area of Pamir-Northwest Himalaya is considered as main centre of origin and evolution of butterflies belonging to *Parnassius* and other genera. The Changthang region of Ladakh is globally unique for having preserved almost intact the whole assemblage of its wild ungulates and predators. The wild sheep and goats alone are represented by four species. This region thus constitutes a unique hot spot for the Caprinae and form part of their original centre of evolution.

Domesticated animal diversity in Indian Trans-Himalaya is very rich. This region is a storehouse of several breeds of sheep, goats ponies, horses, yaks and camels, which are able to withstand extreme arctic climate. Various breeds of sheep in the area are Gaddi, Rampur Bushair, Tibet type, and

Fig. 8 : A view of topography of Trans-Himalaya in Ladakh

Changthangi, and those of goats are Pashmina, Changthangi, Chegu and Gaddi. The breeds of ponies include Spiti and Chummarti, which are hardy and sure-footed. The Zanskari breed of horse is found in the Zanskar valley in Kargil district of Ladakh region. It is one of the rare breeds, which can survive under hypoxic conditions of the area (Balain, 1996). The domesticated yak is an excellent pack animal throughout the Trans-Himalayan region. The double-humped camels are reared in the Nubra Valley of Ladakh.

5. VALUE

The Trans-Himalayan biodiversity has sustained the people of the area since time immemorial. They have a direct linkage with the flora and fauna in their life and health care. This region is a repository of several species of very valuable medicinal plants. The use of these plants is an important link between the dwelling communities and the biodivesity of the area. The poeple of Ladakh use different parts of 169 medicinal plants for curing various ailments (Kaul, 1997). There are also numerous species of plants in the area, which provide food, fodder, forage, fuel, timber and fibre.

Some Trans-Himalayan wild animal species are genetic resources of immense value. All varieties of domestic sheep have been derived from three species of *Ovis*, which are found

Fig. 9 : Trans-Himalayan Cold Desert in Ladakh (Jammu & Kashmir)

wild in the mountainous regions of Asia and Eurpoe. Two species of *Ovis*, *O. vignei* (Shapu) and *O. ammon hodgsoni* (Nayan), occur in the Ladakh and Spiti regions. The wild yak *(Bos mutus)* has given rise to the domestic yak. Trans-Himalayan domesticated animal diversity is in the form of subspecies, breeds, types, varieties, strains, specific population groups/subgroups, etc. These genetic resources represent unique genotypes, which have evolved as per the local agro-climatic conditions.

The domesticated yak is an excellent pack animal under hypoxic climate of the Trans-Himalaya. It is a vital source of milk, meat, hair, hide and wool to the local people. The Zanskari breed of horse, which can also thrive well under hypoxic conditions, is used for transport, riding and polo. The Spiti horse, a breed of ponies, is hardy and sure-footed like other hilly horse breeds. The Changthangi and Chegu breeds of goats provide the expensive pashmina wool.

6. THREATS

Ecological degradation has rendered almost entire Trans-Himalayan zone of Ladakh, Lahual and Spiti into a cold desert, which is spreading rapidly eastwards. This highly fragile zone is facing various types of threats to its biodiversity. Large-scale hunting and destruction of habitat of mammals, birds and butterflies have threatened the existence of several species in Trans-Himalaya. As many as 13 species of mammals, 5 species of birds and 5 species of butterflies are highly endangered and protected under Schedule I of Indian Wildlife (Protection) Act, 1972 (Tables 1 and 2). All species of large mammals in the area are threatened.

Majority of the people, especially in the remote and pristine areas, is pastoral normads. They owe several thousands of grazing animals like sheep, goats, yaks, horses, etc. Rough estimates show that a population of about 8,000 nomads in the Changthang area of Ladakh has a stock of 1,24,858 heads of grazing animals (Kitchloo, 1994). These animals graze in pastures even at very high elevations and compete for grazing with herbivorous wildlife. Often overgrazing leads to abundance of coarse and poor grasses in pastures because of selective feeding, trampling of seedling, saplings, and wind soil erosion.

Demographic pressure has increased the demand for more food and fuel, which has brought more areas under cultivation and tree plantation. Diversion of watercourses for irrigation has greatly affected freshwater wetland communities, especially near villages in Chushul, Chumur and Hanle areas.

Most of the interior areas have been opened to tourists in 1994. Tourism in the Indian Trans-Himalaya is essentially restricted to the summer months, which enhances its adverse impact on the faunal diversity of the area. During the summer months majority of

Table 1. Threatened butterflies in Indian Trans-Himalaya

Name of species/ subspecies	Protected under Wildlife (Protection) Act, 1972 Schedule No.
Family PAPILIONIDAE	
Parnassius charltonius charltonius	II
P. epaphus hillensis	II
P. stoliczkanus stoliczkanus	I
Family PIERIDAE	
Baltia butleri butleri	II
Colias cocandica thrasibulus	I
C. eogene eogene	II
C. ladakensis	II
Pieris deota	II
P. krueperi devta	I
Pontia chloridice alpina	II
Family SATYRIDAE	
Callerabia (= Erebia) kalinda kalinda	II
C. mani mani	II
Lasiommata (= Parage) menava maeroides	I
Moniola davendra davendra	II
Family LYCAENIDAE	
Albulina (= Polyommatus) m. metallica	II
Polyommatus devanica devanica	II
Family NYMPHALIDAE	
Boloria (= Argynnis) pales korla	II
Clossiana (= Argynnis) hegemone	I
Fabriciana (= Argynnis) adippe pallida	II

the fauna is at its peak breeding and other biological activities. Increased and uncontrolled tourism has also created problems of organic and inorganic pollution in the area.

There has been an appreciable rise in the population of dogs attached to nomads and army personnel. The pet dogs, left by the departing soldiers, form small packs and feed on leftovers. They multiply in an uncontrolled manner and after sometime become semi-feral. The packs of semi-feral dogs particularly prey upon small mammals like marmots, pikas hares and young ungulates. They also pose a serious threat to breeding birds like Barheaded Goose and endangered Blacknecked Crane and their offspring.

7. BIODIVERSITY CONSERVATION

Only *in situ* conservation efforts have been made for conserving biodiversity in the Trans-Himalaya by establishing protected area network (PAN), *viz.*, wildlife sanctuaries

Table 2. Endangered birds and mammals in Indian Trans-Himalaya protected under Indian Wildlife (Protection) Act, 1972 (Schedule I)

Common name	Scientific name	Status
Birds		
Himalayan Bearded Vulture	*Gypaetus barbatus aureus*	E
Himalayan Golden Eagle	*Aquila chrysaetos*	E
Osprey or Fish-eating Eagle	*Pandion haliaetus*	V
Saheen Falcon	*Falco peregrinus peregrinator*	E
Blacknecked Crane	*Grus nigricollis*	C
Mammals		
Tibetan Wolf	*Canis lupus chanco*	V
Himalayan Brown Bear	*Ursus arctos isabellinus*	E
Palla's Cat	*Felis nanul*	I
Snow Leopard	*Panthera uncia*	E
Himalayan Lynx	*Lynx lynx isabellinus*	E
Tibetan Wild Ass or Kiang	*Equus kiang*	E
Tibetan Gazelle	*Procapra picticaudata*	I
Tibetan Antelope	*Pantholops hodgsoni*	I
Yak	*Bos mutus*	C
Himalayan Ibex	*Capra ibex*	E
Great Tibetan Sheep or Nayan	*Ovis ammon hodgsoni*	V
Urial or Shapu	*Ovis vignei*	E
Blue Sheep or Bharal	*Pseudois nayaur*	V

C—Critical; E—Endangered; V—Vulnerable; I—Insufficiently Known.
Source : Red data book on Indian animals (ZSI).

(WLS) and national parks (NP). The Lahaul and Spiti area has two PANs, *i.e.*, Kibber WLS and Pin Valley NP. The Kibber WLS covers an area of 1400.5 km^2 and the Pin Valley extends over an area of 675 km^2. In Ladakh, there is one national park (Hemis NP), which now encompasses an area of approximately 4800 km^2. The wildlife sanctuaries in Ladakh are Changthang WLS (4000 km^2) and Karakoram WLS (5000 km^2). There is proposal to set up a number of protected areas at Lugnag, Tso Kar, Khemmer, Shang, Kangi, Rangdum, Nubra-Shyok, Chengchenmo, Rupshu and Daulotbeg (Negi, 1995). A proposal to set up a Trans-Himalaya Cold Desert Biosphere Reserve is under active consideration of the Ministry of Environment and Forests.

8. FUTURE DIRECTIONS

- To raise total protected area in Indian Trans-Himalaya further by setting up new wildlife sanctuaries and biosphere reserves.
- To monitor changes in land use practices especially in areas of endangered animals.
- To regulate population and quality of livestock.
- To provide alternative sources of fuel for cooking substantially to reduce increasing demand for firewood.
- To encourage controlled and ecofriendly tourism.
- To eliminate semi-feral dogs.
- To provide enhanced food from outside the ecosystem or intensify agriculture on more suitable arable land for reduction of demand for agricultural land.
- To create public awareness about benefits and importance of biodiversity.
- To set up selective Pilot Projects for restoration of biodiversity.
- To evaluate current status of endangered species.

9. SELECTED REFERENCES

Balain, D.S. 1996. Livestock diversity, *In* : G.S. Gujral and V. Sharma *(eds.). Changing perspectives of biodiversity status in the Himalaya.* The British Council, New Delhi, 59-62.

Dhar, U. 1996. Overview of Himalayan biodiversity, *In* : G.S. Gujral and V. Sharma *(eds.). Changing perspectives of biodiversity status in the Himalaya.* The British Council, New Delhi, 3-20.

Holmes, P.R. 1986. The avifauna of the Suru River Valley, Ladakh, *Forktail,* **2** : 21-41.

Julka, J.M.; Alfred, J.R.B.; Mehta, H.S. and Paliwal, R. 1999. Status survey of Kiang (Tibetan Wild Ass) in Ladakh. ENVIS Newsletter Vol. **5** : 2-4

Kachroo, P. 1993. Plant diversity in northwest Himalaya A preliminary survey : 111-132. *In* : Dhar, U. *(ed.). Himalayan biodiversity conservation strategies.* Gyanodaya Prakashan, Nainital.

Kaul, M.K. 1997. *Medicinal plants of Kashmir and Ladakh,* 173 pp. Indus Publishing Company, New Delhi.

Kitchloo, N.A. 1994. *Unified ecosystem management plan for the Changthang Wilderness Area, Ladakh,* Department of Wildlife Protection, Jammu & Kashmir Government, 45pp.

Mallon, D.P. 1987. The winter birds of Ladakh, *Forktail,* **3** : 27-41.

Mani, M.S. 1962. *Introduction to high altitude entomology.* Methuen & Co. Ltd. London, 302 pp.

Mani, M.S. 1974. *Ecology and biogeography in India.* Dr. W. Junk, B.V. Publishers, The Hague.

Mani, M.S. 1986. *Butterflies of the Himalaya.* Oxford & IBH Publ. Co., New Delhi, 181 pp.

Negi, S.S. 1990. *Himalayan forests and forestry.* Indus Publishing Company New Delhi, 304 pp.

Negi, S.S. 1995. *Cold deserts of India.* Indus Publishing Company, New Delhi, 248

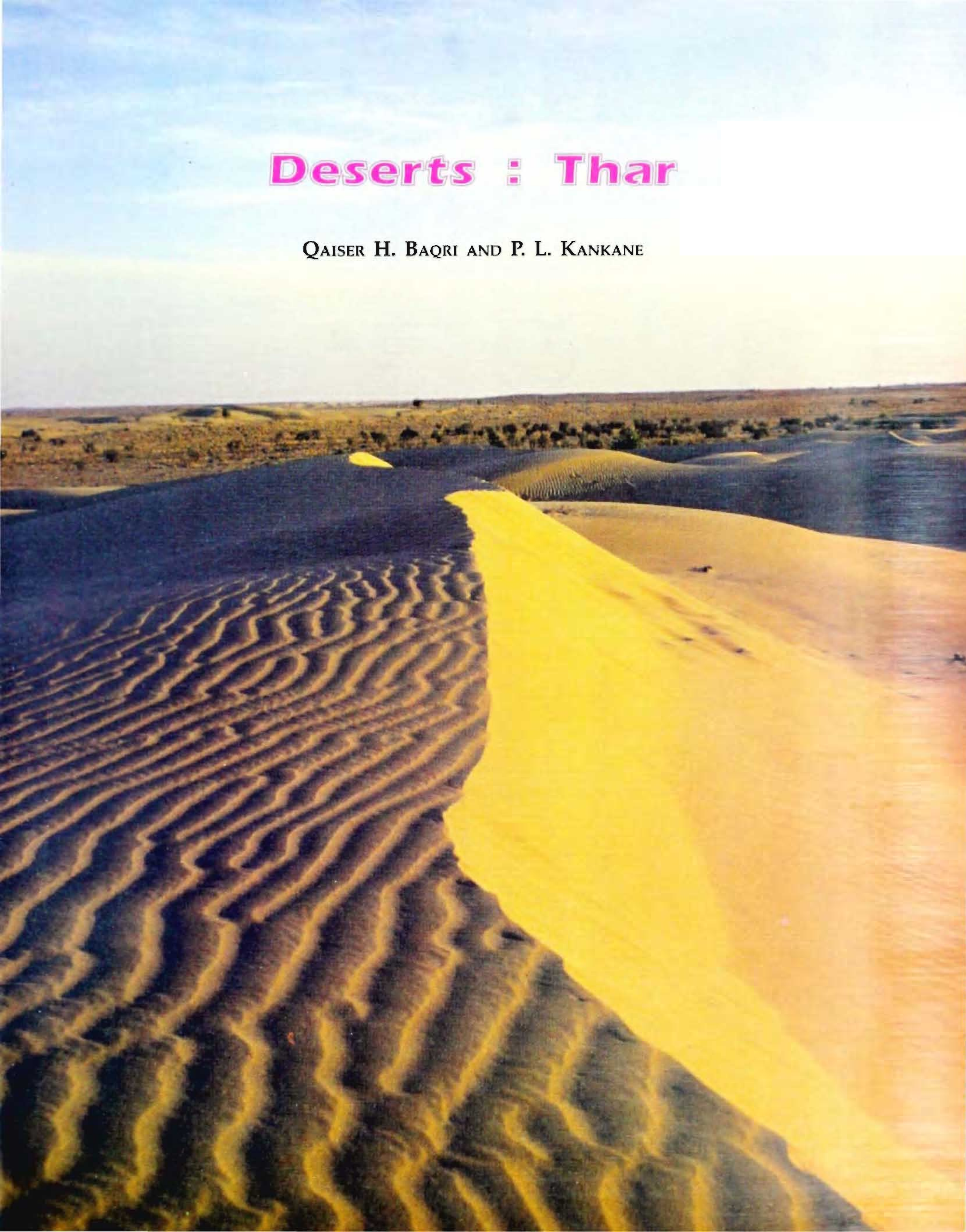
Rodger, W.A. and Panwar, H.S.E. 1988. *Planning a wildlife protected area network in India.* Vols. **1&2.** Wildlife Institute of India, Dehradun.

Smith, M. 1934. *The fauna of British India including Ceylon and Burma. Reptilia and Amphibia vol. II, Sauria,* Taylor and Francis, London, 400 pp.

Tilak, R. 1987. *The fauna of India* : Sub-family Schizothoracinae, Director, Zoological Survey of India, Calcutta, 299 pp.

Deserts : Thar

QAISER H. BAQRI AND P. L. KANKANE



ENVIS–*Zool. Surv. India*
Ecosystems of India : 93-109, 2001.

Deserts : Thar

Qaiser H. Baqri and P. L. Kankane*

Desert Regional Station
Zoological Survey of India, Jodhpur

1. INTRODUCTION

Desert does not mean all sand. It may have sand, gravel, bare rock, sun-baked mud and clay. All the deserts are characterised by low rainfall, arid land and an expanse of sand, salt or rock, largely barren except for very sparse or seasonal vegetative cover.

The Indian Desert is generally called Thar Desert or Thali in Rajasthan. The Thar was also called Tharparkar earlier. Though Thar is one of the smallest deserts in world, it exhibits a wide variety of habitats and biodiversity. This is the most thickly populated desert in the world by having an average density of 83 persons per sq km as against 6-9 persons in other deserts. The livestock population is also very high and is still increasing, *i.e.*, 46-226 per sq km in different districts. Thar is also considered to be a unique desert because of its location at the crossing where Palaearctic, Oriental and Saharan elements of biodiversity are found. This desert has sustained great civilization particularly in Ghaggar and Indus River basins.

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

According to Gupta and Prakash (1975), the origin of the Indian Desert lies with

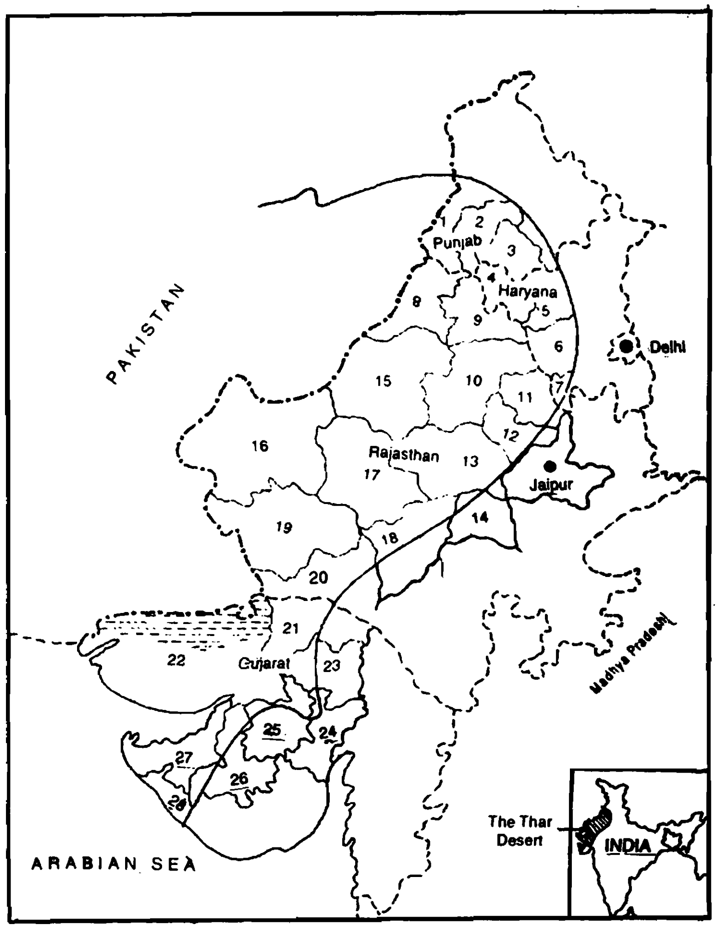


Fig. 1 : Geographical limits of Indian Thar Desert

I. PUNJAB :	1. Firozpur, 2. Faridkot, 3. Bhatinda
II. HARYANA :	4. Sirsa, 5. Hisar, 6. Bhiwani, 7. Mahendragarh,
III. RAJASTHAN :	8. Sri Ganganagar, 9. Hanumangarh 10. Churu, 11. Jhunjhunu, 12. Sikar, 13. Nagaur, 14. Ajmer, 15. Bikaner, 16. Jaisalmer, 17. Jodhpur, 18. Pali, 19. Barmer, 20. Jalore
IV. GUJARAT :	21. Banaskhantha, 22. Kutchch, 23. Mahesana, 24. Ahmedabad, 25. Surendranagar, 26. Rajkot, 27. Jamnagar, 28. Junagarh

* Northern Regional Station, Zoological Survey of India, Dehra Dun

geotectonic and climatic changes during the upheaval of Himalaya and several glaciations epochs. Indian Thar Desert is an extension of Sahara desert, through Arabian and Persian deserts. In India, it extends from Punjab, Haryana, Rajasthan to Gujarat state. This is bounded by the Aravalli hills in the east, the fertile Indus and Nara valley in the west, the great salt marsh of Kutchch in the south and semiarid districts of Haryana and Punjab in the North, lying bewen 22°30′ N and 32°05′ N latitudes and 68°05′ E to 75°45′ E longitudes. The entire desert in the Indian subcontinent (India and Pakistan) covers an area of nearly half of the Arabian desert and $^1/_7$th of the Sahara desert. The Indian desert occupies about 2,78,330 sq km area, of which 1,96,150 sq km is in Rajasthan, 62, 180 sq km in Gujarat and about 20,000 sq km in Punjab and Haryana states (Fig. 1). This has an elevation of about 350-450 m above sea level at the Aravalli range in the east, about 100 m in south and west and about 20 m in Rann of Kutchch.

One of the interesting aspects of Thar is its origin. Some authors believe that the Thar was not arid until 2000-3000 years ago and a few rivers passed through this region, while others believe that it is much older and aridity must have started establishing late during the Pleistocene. These conflicting theories have become debatable from zoogeographical point of view.

The Indian Desert may be subdivided into the following four subdivisions although it is difficult to fix the exact boundaries of each subdivision (Fig. 2) : (i) Thar : sea of sand, sand hills, silt covered valleys; (ii) Pat : lower sand hills with north south orientation, flat sandy soil lying on impervious clay called salt lakes *"Dhands"*, plateau like drains and hollows filled with fresh or saline lakes called *"Kochars"* Floodwaters of eastern Nara and the Raini are available for irrigation; (iii) Ghaggar : relics of a gigantic river system in which flood water of Sutlej river still enters.

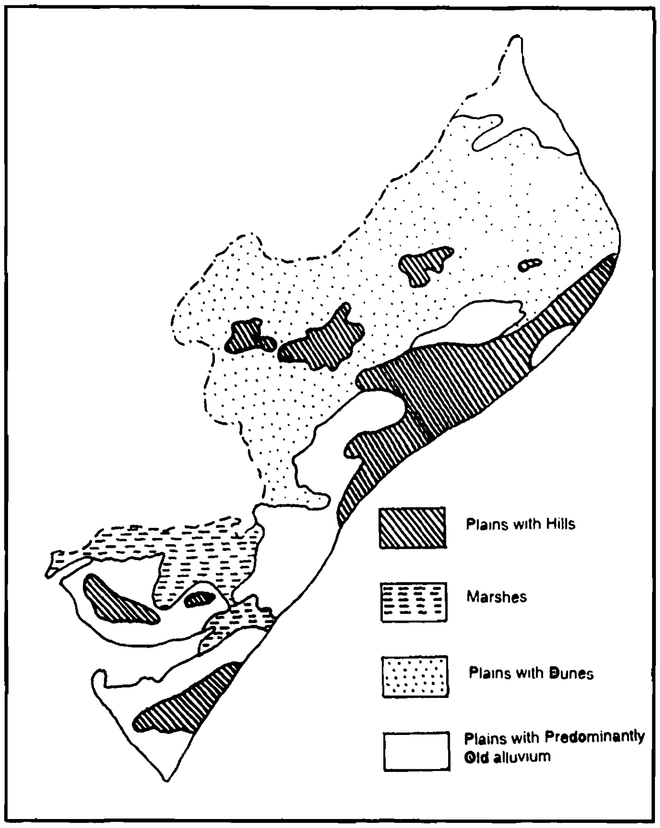


Fig. 2 : Four types of Desert Landscapes (After Gupta and Prakash, 1975)

The soil is quite fertile; (iv) Steppe desert : uplands of Rajasthan, more or less rocky plateau along the north and western fringes, turned into pene-plains of arid wasteland. Luni river with its tributaries drain into the Rann of Kutchch.

The Indian desert has also been divided into four types of landscapes, *viz.*, hills, plains with hills, marshes and plains with sand dunes (Fig. 2). The region of sand dunes is most spectacular and the typical part of Thar desert. It covers more than 1,00,000 sq km in India and extends into Pakistan. These landforms are separated at a number of places by small or big hills and plateau, rocky and buried pediment and pediment plains. The sand dunes of Rajasthan occupy about 58% area of the desert. These are in varying degree of frequency and may be subdivided into two chains : (i) the western part of Barmer, Jaisalmer and Bikaner districts up to the height of about 20-100 m and many kilometers long and (ii) the eastern part of Bikaner and Churu districts. The latter is discontinuous and scattered and extended in Haryana and Gujarat states. The dunes are highly sandy and contain 0.12-0.18 mm size grains, 1.8-4.5% clay and 0.4-1.3% silt. In the major part of Pali and parts of Nagaur, Jodhpur and Jalore districts of Rajasthan along with the Mahesana and Banaskantha districts of Gujarat, the soil is brown and grey loam. Parts of Jamnnagar and Kutchch districts (Gujarat) are covered with medium black soils. Hills, rocky pediments, the Rann, salt basin and coastal sandy plains constitute the rest which are mostly devoid of vegetation. A few saline depressions are also present in the Thar, *viz.*, Taal Chhapar, Didwana, Pachpadra, Lunkaransar and Kuchaman. The Rann of Kutchch represents a vast saline flat which forms a separate ecosystem in the Thar of Gujarat state and is dealt with in a separate article. The information regarding the districts and area covered by Indian desert in each state is being furnished in Table 1.

The extreme of cold and heat is a special feature of desert climate. There is a wide range of temperature not only between summer and winter but also between day and night. The temperature ranges from freezing point in winter to about 50°C in summer at some places. Since the Thar Desert is beyond the full force of both the south-west monsoon rising from Arabian sea and north-east monsoon from the Bay of Bengal, the rainfall is erratic and scanty in this region. The winter rains are rare and drought occurs quite frequently. The monsoon remains active from July to September and the average rainfall is 450 mm in Eastern Rajasthan, 100 mm in Western Rajasthan, 300-500 mm in Gujarat and 200-450 mm in Punjab/Haryana desert. The maximum rainfall is received during the months of July and August, but rainfall may be irregular or scanty or there may be no rains. The relative humidity remains comparatively low. During summer, the winds are generally violent (with 130 km velocity per hour), hot and scorching *(loo)* with dust (vortices of dust). As a result, the shifting of sand dunes is very common in the desert. During winter, the velocity of wind remains considerably low, 4-10 km per hour. With the exception of few plant species, the quick shifting of sand dunes does not allow the plants to settle. Since the light intensity is too high and the relative humidity drops down almost to zero, the evaporation in the desert is excessive during summer season.

Table 1. Area occupied in various districts and States

State	Area in sq km	Concerned Districts
1. Gujarat	62,180	Entire : Kutchch Part : Banaskantha, Mahesana, Ahmedabad, Surendranagar, Rajkot, Jamnagar & Junagarh.
2. Rajasthan	196,150	Entire : Ganganagar, Bikaner, Jaisalmer, Barmer, Jodhpur & Churu Part : Nagaur, Ajmer, Pali, Jalore, Jhunjhunu and Sikar
3. Haryana	11,000	Part : Hissar and Mohindergarh.
4. Punjab	9,000	Entire : Bhatinda and Ferozpur Part : Sangrur
Total	278,330	Entire : 9 districts Part : 16 districts

Luni is the main river in western Rajasthan, which has about half a dozen tributaries. It originates near Puskar (Ajmer) and runs about 320 km up to Rann of Kutchch. In Jhunjhunu district of Rajasthan,. there is a small river Kantli, which runs to 135 km up to Churu district only. The water flows in the rivers only during the monsoon period from June to September.

The Indira Gandhi Canal carrying water from Ravi-Beas through Punjab and Haryana enters Rajasthan. The total length of the main canal is 649 km from Harikki barrage in Punjab to Jaisalmer. The main canal combined with many feeder channels comes to about 8000 km in length. After completion of the project 11% area of western Rajasthan will be irrigated. Though Indira Gandhi Nahar Pariyojna (IGNP) is considered to be hope for future agriculture in Rajasthan, the project has become a subject of debate.

3. BIODIVERSITY

Despite all these harsh climatic conditions, the desert is very rich in biodiversity. Surprisingly the desert plants grow and propagate very quickly during the first few days of the monsoon activity. The plants have generally wide spread deep-rooted system, or like cactus they store water in their system or they drop leaves to avoid hot and dry condition. Most of the animals are not visible on the surface. They prefer to live under stones, among the plant root and leaves and, in burrows and long tunnels. Most of them are nocturnal because they go inside their burrows during day time. Flashy footpads or special systems to conserve the water are special adaptations. Both plants and animals species in the Thar region constitute an invaluable stock of rare and resistant germ plasm which are too valuable from biological point of view.

3.1 Flora

Ecologically the vegetation of the desert is quite sparse and fall under the category "Thorn forest-type" Much of the area is occupied by dry open grassland with trees and thorny bushes. All the plants are well adapted to xeric environment. The flora of the Thar has been described by Bhandari (1978), Shetty and Singh (1991) and a few others.

The trees of Khejri (*Prosopis* sp.) are commonly found and are religiously maintained by the people. The forests are almost negligible in the desert, comprising about 1.8% of the total desert area. The stabilized dunes and sandy plains are generally covered with *Capparis decidua, Calotropis procera, Acacia senegal, A. jacquemontii, Prosopis cineraria, Areva javanica, Aristida funiculata, Dactyloctenium aegyptium, Tecomella undulata, Salvadora oleoides, Zizyphus nummularia, Crotalaira burhia, Farsetia hamiltonii, Heliotropium* sp., *Leptedenia pyrotechnica, Tephrosia* sp., *etc.* Amongst the creepers, *Citrullus* and *Cucumis* are commonly found in sandy plains. In the

Fig. 3 : Characteristic flora in Thar desert

gravelly pediments, low hills and rocky areas the following species of trees and shrubs are predominant : *Acacia senegal, Prosopis cineraria, Salvadora oleoides, Maytenus emarginatus, Calotropis procera, Euphorbia caducifolia,Capparis decidua* and *Anogeissus pendula.*

On both the sides of Indira Gandhi Canal, *Acacia nilotica, Dulbergia sisoo, Eucalyptus camadulensis, Prosopis cineraria, Tecomella undulata and Zizyphus mauritiana* have been planted under afforestation programme. The scientists of Central Arid Zone Research Institute (CAZRI) have classified the vegetation into four main types, *viz.*, the moist deciduous, the semi-evergreen, the desert thorn and northern tropical thorn vegetation and, scrub woodland and thorny scrub in the hill slopes. The following plants speices are the natural vegetation and are of economic importance in the Thar : *Anogeissus pendula, Acacia catechu, A. senegal, A. nilotica, Prosopis cineraria, P. juliflora, Capparis decidua, Zizyphus nummularia, Balanites aegyptica, Azadirachta indica, Salvadora persica, S. oleoides, Ephedra foliata, Calotropis procera, Calligonum polygonoides* (on dunes), *Haloxylon salicornicum* (interdune), *Saccharum bengalensis, etc.* Dhak *(Butea monosperma)* and Mahendi *(Lawasonia alba)* are the best dyes while Isabgol *(Plantago avata)* and Gugal *(Commiphora wightii)* are used in medicines. *Salvodara oleoides* (Jal) and *Citrullus colocynthis* (Tumba) are nonedible plants. In Rann of Kutchch, the following species are abundant : *Aerva tomentosa, Cyperus arenarius, Aleuropus lagopoides, Sporobolus helvolus, etc.*

The grasslands of the Thar desert come under *Lasiurus–Cenchrus–Dichanthium* type, *i.e., L. sindicus* (Sewan), *C. biflorus, C. rajasthanensis, C. prieuri* and *D. annulatum*. Among these, *Lasiurus sindicus* is considered to be very important.

The bajra *(Pennisetum typhoides)*, small millet, wheat *(Triticum aseticam)*, barley *(Hordeum vulgare)*, maize *(Zea mays)*, Jowar *(Sorghum vulgare)*, guwar *(Cyamopsis tetragonoloba), etc.* are the main crops in the desert region.

3.2 Fauna

As mentioned earlier, the desert is fairly rich in animal life. Almost all the major phyla of vertebrates and invertebrates ranging from the tiny microscopic protozoa to blue bull are found here. Though the vertebrates are now more or less adequately known taxonomically, the same is not true for invertebrates and perhaps 2-3 times or more of the existing fauna still remains to be explored.

Roonwal (1982) made an initial attempt to put together all the information about the known fauna of the Indian desert. He reported nearly 1100 species from the arid districts of Rajasthan. A recently published multiauthored compendium "Faunal Diversity in the Thar Desert : Gaps in Research" edited by Ghosh, Baqri and Prakash (1996) reports about 2043 species from single celled animal Protozoa to Mammalia. Of these, 619 species are of vertebrates and the rest are invertebrates. This faunal diversity comes to about 2.12% of total Indian fauna, though the Thar occupies about 9% area of the country. The group wise information on the faunal diversity in the Thar region is furnished in Table 2.

Invertebrates

Protozoa : The protozoans are represented by 52 species only while 2577 species are known from India. Out of 52, only 10 species are parasitic. Among the parasitic species, the occurrence of *Plasmodium falciparum* has been attributed to the vector mosquito species, *Anopheles culicifacies* which could breed throughout the year due to Indira Gandhi Canal. Over all, only 2% Protozoa fauna of India has been explored from the Thar. Das (1996) and Tyagi (1996) have listed important species of protozoa from the Thar desert. The important parasitic species are : *Entamoeba histolytica, Plasmodium malariae, P. ovale, P. falciparum, Plasmodium vivax, Leishamania* sp., *etc.*

Porifera : The phylum Porifera is represented by 7 species of freshwater sponges

Table 2. Approximate number of species in the Great Indian Desert

Taxonomic Group	Number of species in India	Number of species in Thar
Protozoa	2577	52
Porifera	486	7
Cnidaria	842	–
Platyhelminthes	1622	87
Nematoda	2850	170
Rotifera	330	8
Gastrotricha	100	–
Kinorhyncha	10	–
Acanthocephela	229	4
Entoprocta	10	–
Annelida	840	26
Arthropoda	68389	1035
Arachinda	5818	157
Crustacea	2934	57
Diplopoda	162	1
Chilopoda	100	8
Insecta	59353	812
Thysanura	31	–
Diplura	16	–
Collembola	210	–
Ephemeroptera	106	2
Odonata	499	31
Plecoptera	113	–
Grylloblattoidea	–	–
Orthoptera	1750	40
Phasmida	146	–
Dermaptera	320	7
Embioptera	33	–
Dictyoptera	348	20
Isoptera	253	46
Psocoptera	90	–
Mallophaga	200	40
Hemiptera	6500	75
Thysanoptera	693	21
Neuroptera	335	13
Mecoptera	15	–
Anoplura	56	7
Lepidoptera	15000	300
Trichoptera	812	–
Diptera	6093	80
Siphonaptera	52	5
Hymenoptera	10000	65
Coleoptera	15500	60
Strepsiptera	18	–
Mollusca	5070	24
Bryozoa	200	11
Echinodermata	765	–
Protochordata	119	–
Chordata	4952	619
Pisces	2546	142
Amphibia	209	8
Reptilia	456	51
Aves	1232	350
Mammalia	390	68
Total		4509

whereas 486 species are known from India, of which only 31 species are freshwater sponges. Only a few freshwater bodies have been surveyed in Rajasthan region while the work on sponges in the water bodies in Gujarat, Haryana and Punjab states is yet to be initiated. The following are the important species from the Thar region of Rajasthan : *Corvospongilla caunteri, C. ultima, C. lapidosa, Dosilia plumosa, Eunapius carteri, etc.* Saxena (1996) has reported all the species from the Thar of Rajasthan.

Cnidaria : No living *Cnidaria* are found in the desert region.

Platyhelminthes : Though the members of the phylum Platyhelminthes include some important parasites of vertebrates (including human), only 87 species of trematodes and cestodes have been reported from the Thar Region while 1622 species are known from India. This comes to about 5.3% of the known fauna of Platyhelminthes from India. As per records, only 15-18% species of vertebrates have been examined for these worms in the Thar. Hafeezullah (1996) has discussed state of knowledge of trematodes and cestodes in the Indian Desert. The important species are : *Fasciola* sp., *Schistosoma* sp. *Taenia solium, Taenia saginata*, etc. Unfortunately nothing is known in Turbellaria group of Platyhelminthes from the desert.

Acanthocephala : Hafeezullah (1996) has listed 4 species of this phylum from the Thar whereas 229 species are known from India. The following 4 species have been recorded as parasites of birds and rodents : *Mediorhynchus rajasthanesis, Centrorhynchus globuli, C. sexicoloides* and *Moniliformis moniliformis.*

Rotifera : These are also poorly known from the Indian desert. Out of 330 species known from India, only 8 have been recorded from the Thar.

Nematoda : Out of 2850 species of nematodes known from India, 170 have been recorded from the Thar region. Out of these, 55 are parasites of plants, 15 predaceous species from soil around roots of agricultural crops, 50 species are freeliving from soil and freshwater and 50 species as parasites of vertebrates. Our knowledge is nil about nematode parasites of invertebrates. Baqri (1996) has listed all the important species and discussed the achievements and gaps in research on nematodes from the Thar desert. A few important nematode species are as follows : *Ascaris lumbricoides, Dracunculus medinensis, Trichuris trichiura, Enterobius vermicularis, Tylenchorhynchus* spp., *Hoplolaimus Helicotylenchus* spp., *Pratylenchus* spp., *Anguina tritici, Heterodera avenae, H. zeae, Meloidogyne incognita, Meloidogyne hapla, etc.*

Annelida : Little information is available on the annelid fauna (earthworms and leeches) of the Thar desert. Out of 840 species known from India, only 12 species of earthworms and 14 species of leeches have been listed by Julka (1996) from Rajasthan. The class Polychaeta still remains unrepresented and most of the water bodies are yet to be explored.

Arthropoda : The members of the phylum Arthropoda constitute the largest and most diversified group in the animal Kingdom. They constitute one of the most economically important groups and are found everywhere on earth. In all, 68389 species belonging to different classes and orders have been reported from India. Of these, 1035 species have been recorded from the Thar region. The information about species diversity of each group of the phylum Arthropoda is being furnished in Table 2.

Crustacea : Crustaceans are mostly aquatic. Roy (1996) and Tiwari (1996) have reviewed the literatures on crustaceans from the Thar desert. Out of 2934 species of crustacea from India, 57 have been recorded from the Thar region. Since the number of water bodies is limited in the region, state of fauna of crustaceans appears to be satisfactory. The following are the commonly found species : *Artemia salina, Triopos canciformis, Streptocephalus simplex, S. dichotomus, Branchinella kugenumaensis, B. biswasi, etc.* The Shambhar lake and a few other lakes in Jaisalmer and Jodhpur have been surveyed extensively while most of the water bodies in the Thar are yet to be explored.

Insecta : Amongst all the classes of Arthopoda, Insecta forms the largest group. Though all the major orders of Insecta have been explored in the Thar desert, a wide gap still exists in their faunal status. The information about the state of fauna about the orders represented in the Thar region is furnished in Table 2. The analysis of literature reveals that the orders Protura, Diplura, Mecoptera, Thysanura, Plecoptera, Phasmida, Embioptera, Strepsiptera, Psocoptera, Trichoptera and Collembola still remain unrepresented from the Indian Thar desert.

The important orders like Ephemeroptera, Odonata, Dermaptera, Hymenoptera, Coleoptera, Hemiptera Thysanoptera and

Diptera are insufficiently known from this region. However, the species of the orders : Neuroptera, Dictyoptera, Isoptera, Anoplura and Lepidoptera are well reported. Tandon (1996), Prasad (1996), Bhargava (1996), Parihar (1996), Rathore (1996), Varshney (1996), Ghosh, Biswas and Ghosh (1996), Vyas (1996), Satya Vir (1996), Tak (1996), Tyagi (1996), Tak and Rathore (1996) have provided excellent review in a multiauthored compendium edited by Ghosh, Baqri and Prakash (1996) on different groups of insects from the Thar desert.

Arachnida : Out of 5818 known species of Arachnida, 152 have been reported from the Thar region. According to Gupta (1996), a total of 126 species of mites are known from this region. These include plant mites, water mites, vertebrate parasitic mites, invertebrate parasitic mites and store product mites. Sanyal and De (1996) have reported 26 species of ticks.

Diplopoda and Chilopoda are represented in this region by one and 8 species respectively.

Mollusca : In comparison to other deserts in the world, our knowldege on molluscs in the Thar region is poor because only 24 species have been recorded till date while 5070 species have been recorded from India. Of these, 8 species are of freshwater snails and 16 species are of land snails (Subba Rao, 1996).

Bryozoa : These are represented by 11 species from this region.

Chordata

The Thar provides habitat/breeding ground to a number of endangered species of reptiles, birds and mammals. A number of species are endemic to the region. As per records, Indian desert sustained a dense population of reptiles, birds and mammals even during the first half of 20th century. However, populations of many species are dwindling very fast.

Pisces : Pisces are important because they are considered to be the best source of protein for human population. Out of 2546 species recorded from India, only 142 are known from the Thar, *i.e.*, about 5.5% of the Indian fish fauna. Of these, about 112 species have been recorded from Rajasthan, 100 from Punjab and Haryana and only 25 from Gujarat. The known species belong to the following main groups : carps (71), loaches (13 spp), catfishes (17 spp), murrels (4 spp), spiny eels (3 spp). Yazdani (1996) has furnished a detailed information about the distribution of fishes in Thar region. The important and commonly found species are : *Oxygaster bacilia, Carassius carassius, Labeo bata, L. boga, L. boggut, Catla catla, Puntius sophore, P. sarana, P. ticto, P. vittatus, Gambusia alfium, Channa marulius* etc.

Amphibia : The ambhibian fauna in India is represented by 209 species whereas only 8 species are known in the Indian desert. They include six species of frogs including one species of Hyla and two species of toads. The following are the species :*Rana hexadactyla, R. cyanophlyctis R. limnocharis* and *R. breviceps.* The toad species are *Bufo melanostictus* and *B. andersoni* while the Hyla species is *Microhyla ornata*. Among these, *Rana hexadactyla* and *Microhyla ornata* are rare and recorded from the eastern region of the Thar. Not even a single amphibian species is endemic in the Thar.

Reptilia : The reptilian fauna is significantly known from the Thar desert. Out of 456 species of reptiles from India, 51 species are known from the Thar. Crocodiles are absent from the Thar while three species of turtles and tortoise *(Trionyx gangeticus, Lissemys punctata punctata, Geochelone elegans)* are commonly found in Rajasthan districts. Sharma (1996) has also listed 23 species of lizards and 25 species of snakes from the entire desert region. The analysis of literature concludes that lizards are fairly known while our knowledge is insignificant on the snakes from Churu, Jhunjhunu, Sikar, Jalore, Kutchch, Banaskantha, Surendernagar and Junagarh.

Fig. 4 : Indian Cobra–*Naja naja*

The following species are abundantly found : Lizards : *Stenodactylus orientalis, Cyrotodactylus kachhensis, C. watsoni, Hemidactylus brooki, Agama agilis, Ophisops jerdoni, Uromastix hardwickii, Varanus bengalensis.* Snakes : *Eryx johni, E. conicus, Echis carinatus, Sphalerosophis diadema diadema, Psammophis leithi, Naja naja, etc.*

Aves : Rahmani (1996, 1997) has compiled the information on avifauna from the Thar desert. About 350 species of birds are found in the Indian desert. According to Rahmani, the bird fauna is fast changing in the Thar mainly because of Indira Gandhi Nahar Pariyojna (IGNP). Under the changing scenario, many water–loving birds (about 3 dozen species) are now seen in the vicinity of IGNP, *viz.*, Great Cormorant, Little Cormorant, Darter, Purple Heron, Grey Heron, Large Egret, White Ibis, Spoonbill, Purple Moorhen, Baya, *etc.*

Fig. 5 : Great Indian Bustard–*Ardeotis nigriceps*

Some of the commonly found species of birds are : Great Cormorant *(Phalacrocorax carbo)*, Black Ibis *(Pseudibis papillosa)*, Greater Flamingo *(Phoenicopterus ruber)*, Gadwall *(Anas strepera)*, Common Teal *(Anas crecca)*, Shovellar *(Anas clypeata)*, Common Pochard *(Aythya ferina)*, Demoiselle Crane *(Anthropoides virgo)*, Black Shouldered Kite *(Elanus caeruleus)*, Egyptian or Scavanger Vulture *(Neophron perenopterus)*, Tawny Eagle *(Aquila rapax vindhiana)*, Laggar Falcon *(Falco birmicus jugger)*, Cream-coloured Courser *(Cursorius cursor)*, Blue Rock Pigeon *(Columba livia)*, Indian Ring Dove *(Streptopelia decaocta)*, Blackcorwned Finch Lark *(Eremopterix nigriceps)*, Common Babbler *(Turdoides caudatus)*, Common Crow *(Corvus splendens)*, Common Myna *(Acridotheres tristis)*, House Sparrow *(Passer domesticus)*, Baya *(Ploceus philippinus)*, Common Peafowl *(Pavo cristatus), etc.*

Mammalia : Alfred and Agarwal (1996) have reviewed the literature on the distribution of mammals in the Indian Thar Desert. According to them, there are 68 species/subspecies of mammals in this region. These species are spread over the following orders : Insectivora (4 spp.), Primates (2 spp.), Chiroptera (18 spp.), Pholidota (one sp.), Carnivora (16 spp.), Perissodactyla (one sp.), Artiodactyla (5 spp.), Rodentia (20 spp.) and Logomorpha (one sp). Out of these, 29 species are listed in the

Fig. 6 : Black Buck–*Antilope cervicapra* in Thar Desert

4. SPEICAL FEATURES

As mentioned earlier, the Indian Thar desert has been undergoing a vast ecological transformation because of the increasing pressure of human population and developmental activities (mainly IGNP). The population of some animals, which were abundantly found, is dwindling very fast, *viz.*, Lion, Panther, Jungle Cat, Desert Fox, Wolf, Jackal, Hayena, Ratel, Wild Boar, Wild Ass, Black Buck, Chinkara, etc. However, the Thar inhabits the largest number of Indian Gazelle and Black Buck in the country. Since the Schedule I-IV under Wildlife Protection Act, 1972. As per records, the Indian desert sustained a dense population of mammals up to the first half of 19th century. The following are the important mammals in the Thar : *Suncus murinus, Presbytes entellus, Felis chaus, Vulpes bengalensis, Canis lupus, Boselaphus tragocamelus, Antilope cervicapra, Gazella bennetti, Herpestes edwardsi, Rhinopoma microphyllum kinneari, Taphozous perforatus, Sus scrofa, Gerbillus nanus, G. gleadowi, Rattus rattus, Mus musculus,* etc.

Fig. 7 : Jackal–*Canis lupus*

Vishnoi Community considers these two species sacred, the maximum concentration is found around their villages. Amongst the largest mammals, Nilgai *(Boselaphus tragocamelus)* is also commonly found in the Thar of Rajasthan. In a few pockets, these animals are being considered as pests of agricultural crops. Moreover, Caracal has become critically endangered and Cheetah has already vanished from this region. The Asiatic Lion and Wild Ass are restricted in the Gujarat state while Leopard is rarely sighted. The main reason for the decline of wildlife is the altered habitat in the desert and the shooting of the animals. The grasslands have been converted into agricultural fields and thus the natural vegetation is fast disappearing. On the both sides of the Indira Gandhi Canal, afforestation programmes have been undertaken. The availability of water and the plantation of tall trees like *Eucalyptus* have attracted a large number water-loving species which were not seen earlier in the desert. Thus the present scenario has adversely affected the xeric flora and fauna. As a result, the typical xeric biodiversity elements are gradually being replaced by mesic elements.

4.1 Threatened and endemic species

Surprisingly, serious attempts have not been made to assess the threats to the invertebrate fauna in the changing scenario, though they become the first victim of any habitat destruction. In order to ascertain the endemic distribution, intensive surveys are required to explore and identify the fauna of invertebrates. However, significant work has been done on the vertebrate species in the Thar region.

Fishes and amphibians : There is no record of any endemic species either of fishes or amphibians while amphibians, *Rana hexadactyla* and *Microhyla ornata,* are rare in the desert.

Reptiles : The following species of lizards and snakes from Thar desert are considered threatened or endangered : Lizards : *Uromastix hardwicki, Chamaeleo zeyanicus, Varanus bengalensis.* Snakes : *Ptyas mucosus, Elaphe helena, Argyrogena ventromaculatus, Sphalerophis arenarius, Ahaetulla nasutus, Oligodon taeniolatus, Boiga trigonata, Naja naja naja, Naja naja oxiana* and *Eıyx conicus.*

Table 3. Endemic vertebrates of the Thar

Common Name	Scientific Name
Mammals	
Asiatic Lion	1. *Panthera leo persica*
Wild Ass	2. *Equus hemionus khur*
Rodents	3. *Gerbillus gleodowi*
	4. *Millardia gleadowi*
Bats	5. *Scotoecus pallidus*
Birds	
Whitebrowed Bushchat	6. *Saxicola macrorhyncha*
Reptiles	
Lizards	7. *Ablepharus grayanus*
	8. *Cyrtodactylus Kachhensis*
	9. *Phynocephalus laungwalensis*
	10. *Stenodactylus Orientalis*
Snake	11. *Lytorlynchus paradoxus*
Fishes	Nil
Amphibians	Nil

Five species of reptiles are endemic to the Thar (Sharma, 1996) as listed in Table 3.

Birds : According to Rahmani (1996), the following are threatened or important birds of the Thar : Great Indian Bustard *(Ardeotis nigriceps),* Houbara *(Chlamydoits undulata),* Demoiselle Crane *(Anthropoides virgo),* Common Crane *(Grus grus),* Pintail Sandgrouse *(Pterocles alchata),* Imperial Sandgrouse *(Pterocles exustus),* Cream-coloured Courser *(Cursorius cursor),* White-browed Bushchat *(Saxicola macrorhyncha),* King Vulture *(Sarcogyps calvus),* Peafowl and Falcons. Of these, Great Indian Bustard and White browed Bushchat may be considered as critically endangered.

Endemic to desert : White-browed Bushchat (Table 3).

Mammals : The following species found in the Thar are being listed in Schedule I : Scaly

Fig. 8 : Wild Dog–*Cuon alpinus*

Anteater *(Manis crassicaudatus)*, Wolf *(Canis lupus pallipes)*, Desert Fox *(Vulpes pusilla)*, Desert Cat *(Felis silvestris ornata)*, Caracal *(Felis caracal)*, Indian Gazelle *(Gazella bennetti)*, Four-horned Antilope *(Tetracerus qudricornis)*. The other important/threatened species in the area are : Jackal *(Canis aureus aureus)*, Bengal Fox *(Vulpes bengalensis)*, Small Indian Civet *(Viverricula indica)*, Hyaena (*Hyaena hyaena*), Jungle Cat *(Felis chaus)*, Wild Boar *(Sus scrofa cristatus)*, Nilgai or Blue Bull *(Boselaphus tragocamelus)*, Striped Squirel *(Funambulus pennanti)*, Hanuman Langur *(Semnopithecus entellus entellus)*, etc.

Endemic mammals are listed in Table 3.

Fig. 9 : Indian Gazelle–*Gazella bennetti*

5. RECENT IMMIGRATION OF FAUNA

The Indira Gandhi Canal, which is considered to be a lifeline of the Thar desert in Rajasthan, has changed the landuse (cropping) pattern and other vegetation in the command area. This has threatened the xeric fauna, which is gradually being replaced by the mesic fauna. This is the main reason for recent migration of many species, which were hitherto not known in the area.

The following species have recently been recorded mainly because of IGNP project.

Insecta : *Anopheles annularis, A. culicifacies* and *A. nigerrimus* as vector of malaria, stemborer *(Sphenoptera gossypii)* on cotton, whitegrub *(Adoretus bembinator)* on sugarcane, army worms *(Mythimnra separata* and *M. lorey)* on wheat and gram, paddy hopper *(Nephotettix sp.* and *Sogatolla sp.)* on paddy, painted bug *(Beeada druciferarum)* on groundnut, *Chrysodeixis chalcites* on moong and moth.

Birds : Little Carmornat, Grey Heron, Purple Heron, Pond Heron, Painted Stork, White Ibis, Little Egret, Medium Egret, Coot, Bearheaded Goose, Darter, Common Crane, Purple Moorhen, various Kingfishers, *etc.*

Mammals : Rodent : *Bandiocota bengalensis.*

6. VALUE

Many animal species found in the Thar desert are of great economic importance to mankind, some are friends or foes while others maintain the balance in the ecosystem. A good number of invertebrate species are responsible for serious human diseases either as parasite or vectors. Amongst the parasites of man and livestock, the following species are important : *Entamoeba histolytica, Giardia sp., Plasmodium falciparum, P. vivax, Leishmania sp., Taenia solium, T. saginata, Fasciola* sp., *Schistosoma* sp., *Ascaris lumbricoides, Dracunculus medinensis, Trichuris trichiura, Enterobius vermicularis,* etc. Amongst the vectors, the following speices of mosquitoes are important : *Anopheles culicifacies, An. splendidus, An. annularis, An. nigerrimmus, An. d'thali, An. barbirostris, An. vagus, etc.* A large number of species belinging to phyla Nematoda and Arthropoda cause heavy losses to agricultural crops and the stored food grains. Besides, some species of birds and mammals (rodents) are also potential pests of agricultural crops.

Fishes and several species of birds and mammals are the direct source of protein or their byproducts, used as oil or medicine. A few species of fishes and amphibians act as agent in the biological control of vectors and insects of agricultural importance. Some organisms act as indicator of pollution. The species of turtles and fishes check the growth of weeds in the water bodies while lizards and snakes mostly feed on insects including agricultural pests. Insects and birds play important role in pollination. There are some animal species, which have religious or aesthetic value in the area, *viz.,* Chinkara, Blackbuck, Blue bull, Cobra, *etc.* These are considered sacred by many communities in the Thar region.

7. THREATS

The desert being a fragile ecosystem is further threatened because of the rapid increase in human population specially in Rajasthan state. In recent years, human population in Rajasthan is further increasing by 3% against 1.8% at the national level.

The rapid increase in the population of livestock has also resulted in tremendous pressure on the grasslands. In most of the Thar districts of Rajasthan, the livestock population is more than double of the human population. Hence, the typical herbivorous desert animals which can survive in the harsh climate may also perish, mainly due to continuous shrinkage of the grazing area.

Though Indira Gandhi Canal has transformed more than 11% un-inhabitated desert grassland into a fertile land, the indigenous biodiversity is under threat because the canal has changed the soil moisture, soil texture and vegetation composition. The Canal has caused the rise in the water table and about 1/3rd command area remains flooded. The flooded conditions have increased the salinity, which has further affected the native biodiversity. This altered desert ecosystem has been responsible for the increase in the cutaneous lieshmaniasis and malaria, invasion of the new agricultural pests, weeds and other plant diseases.

Mining of stones and other natural resources without monitoring has also resulted in the loss of biodiversity.

Though there are few communities in Rajasthan who love animals and plants and save them even by sacrificing their life, poaching and cutting of trees are still considerable threats to wildlife in the region.

8. CONSERVATION

State Government has declared number of areas as portected in the Thar desert region (Table 4).

The objective of the Desert National Park (DNP) is to protect the xeric elements of biodiversity. This provides protection especially to Chinkara, Nilgai, Jackal, Indian Fox, Desert Fox, Desert Cat, Jungle Cat, Great Indian Bustard, Houbara, Sandgrouse (4 spp.), White Browed Bushchat, etc. The State Government of Gujarat has established a Wild Ass Sanctury and Gir National Park to protect two endangered endemic mammal species, *i.e.*, Wild Ass and Asiatic Lion. Besides, the establishment of Gaga Sanctury by the Gujarat Government is a great hope for the conservation of the great Indian Bustard, an endangered majestic bird of the Thar region. The Gir National Park supports not only endemic and endangered species (Asiatic Lion) but also a few more threatened species like Leopard, Jungle Cat, Hyena, Jackal Mongoose, Civet Cat, Desert Cat, Chital, Rusty Spotted Cat, Sambar, Four-horned Antelope, Chinkara, Pangolin, Wild Boar, *etc.*

9. FUTURE DIRECTIONS

The following are the suggestions for future directions :

- Both plants and animals species in Thar region constitute an invaluable stock of

Table 4. Protected areas in Thar Desert

State	Name of protected area	Legal status	District	Area sq km
Rajasthan	Tal Chappar	Sanctuary	Churu	7.90
	Tadgarh	do	Ajmer	405.27
	Desert National Park	National Park	Jaisalmer	3162.00
Gujarat	Balram Ambaji	Sanctuary	Banaskantha	542.80
	Barda	do	Jamnagar	192.30
	Kutchch Desert	do	Kutch	7506.22
	Little Rann of Kutchch	do	Kutch	4953.70
	Chinkara Narayan Sarovar	do	Kutch	444
	Gaga Great Indian Bustard	do	Jamnagar	1153
	Khijadiya	do	Jamnagar	6
	Hingolgarh	do	Jamnagar	180
	Nalsarovar	do	Ahmedabad & Surenrangar	120.8
	Rampura	do	Rajkot	15
	Thol	do	Mahesana	6.90
	Gir	National Park	Junagarh	258.71
Punjab	Abohar	do	Ferozpur	185.50

rare germplasm, which are very much valuable from the biological point of view. Hence, it is necessary to restore the original status of desert. For that we must create awareness amongst the people. This is well known that the conservation programme cannot be sucessful without people's participation.

- Survey should be conducted to identify the total number of plant and animal species in the Thar region. Status surveys of the threatened species should also be undertaken before formulation of any conservation policy.
- In order to fill up the already identified gaps (Ghosh, Baqri & Prakash, 1996), Desert Regional Station of the Zoological Survey of India has recently undertaken a project (sponsored by Ministry of Environment & Forests, New Delhi) to explore the fauna of vertebrates and agricultural pests belonging to phyla Nematoda and Arthropoda in the desert of Rajasthan. However, the identified gaps in other groups should also be filled up at the earliest.
- Since the Indian Desert is the most densely populated deserts in the world, human population should be checked and their financial status should be raised.
- To bring down the population of the livestock, it is suggested to rear the right type of livestock, at the right place. Attempts should be made to improve the breed of cattle, goat, etc., so that the people may require only a few animals. This is also suggested to develop improved grass species and also to properly manage the grazing land for the livestock (Rational Grazing Policy). Attempts should be made to conserve the grasslands having native species of grasses.
- More Protected Areas should be created (as recommended by Rodgers and Panwar in 1988, Table 5) for the conservation of endangered species of plants and animals. There is an immediate need of Protected Areas in the vicinity of Indira Gandhi Canal so that the native biodiversity may be conserved in the natural habitat. The people living in and around the reserves should not be alienated in the conservation programme.
- Restrictions may be imposed on cultivation area so that the shrinkage of the grassland may be checked. Besides, the farmers may be encouraged to grow crops like barley and bajra, etc., instead of wheat or chilli, which require 10-20 irrigations. Thereafter, a policy of water management may be formulated and the farmers may be asked to use water more judiciously.
- Proper policy should be made for mining. Law should be enforced to stop illegal mining.

Table 5. Proposed Protected Areas in the Thar Desert

Name	Area in sq km	Proposed status	District/state
1. Ramgarh	5.00	Sanctuary	Jaisalmer/Rajasthan
2. Diyatra-Bap	10.00	do	Bikaner/Rajasthan
3. Nokha	50.00	do	Bikaner/Rajasthan
4. Siwana	200.00	d0	Barmer/Rajasthan
5. Salavas	10.00	do	Jodhpur/Rajasthan
6. Mandvi	20.00	do	Kutch/Gujarat
7. Nimbi	6.00	d0	Mahendragarh/Haryana

- Alternative energy sources like biogas and solar energy should be provided in the villages so that the use of wood as fuel may be minimized.
- Alternative opportunities of employment should be provided to minimise the human-population pressure on land. Eco-friendly tourism, cottage industries, fish culture, *etc.*, should be encouraged in the region.
- Soil erosion which is causing a considerable loss to the biodiversity may be checked by planting windbreaks and adapted grasses and shrubs.
- In view of the very thin and limited cover of forests in the Thar, illegal cutting of trees be checked. More Electric Crematorium should be provided in big cities to save the use of wood in burning the dead bodies.

10. SELECTED REFERENCES

Alfred, J. R. B. & Agrawal, V. C. 1996. The Mammal Diversity of the Indian Desert. In : *Faunal Diversity in the Thar Desert : Gaps in Research* (Ed. by A. K. Ghosh, Q. H. Baqri & I. Prakash); Scientific Publishers, Jodhpur, India; 335-348.

Baqri, Q. H. 1996. Faunal Diversity of Nematoda in the Thar Desert : Assessment and futuristic Approach. In : *Faunal Diversity in the Thar Desert : Gaps in Research* (*Ed.* by A. K. Ghosh, Q. H. & I. Prakash); Scientific Publishers, Jodhpur, India; 51-70.

Bhandari, M. M. 1978 (revised in 1990). *Flora of Indian Thar Desert*. Scientific Publishers, Jodhpur.

Ghosh, A. K. Baqri, Q. H. & Prakash, I. (Editors). 1996. *Faunal Diversity in the Thar Desert : Gaps in Research* : Scientific Publishers, Jodhpur, India; 410 pp.

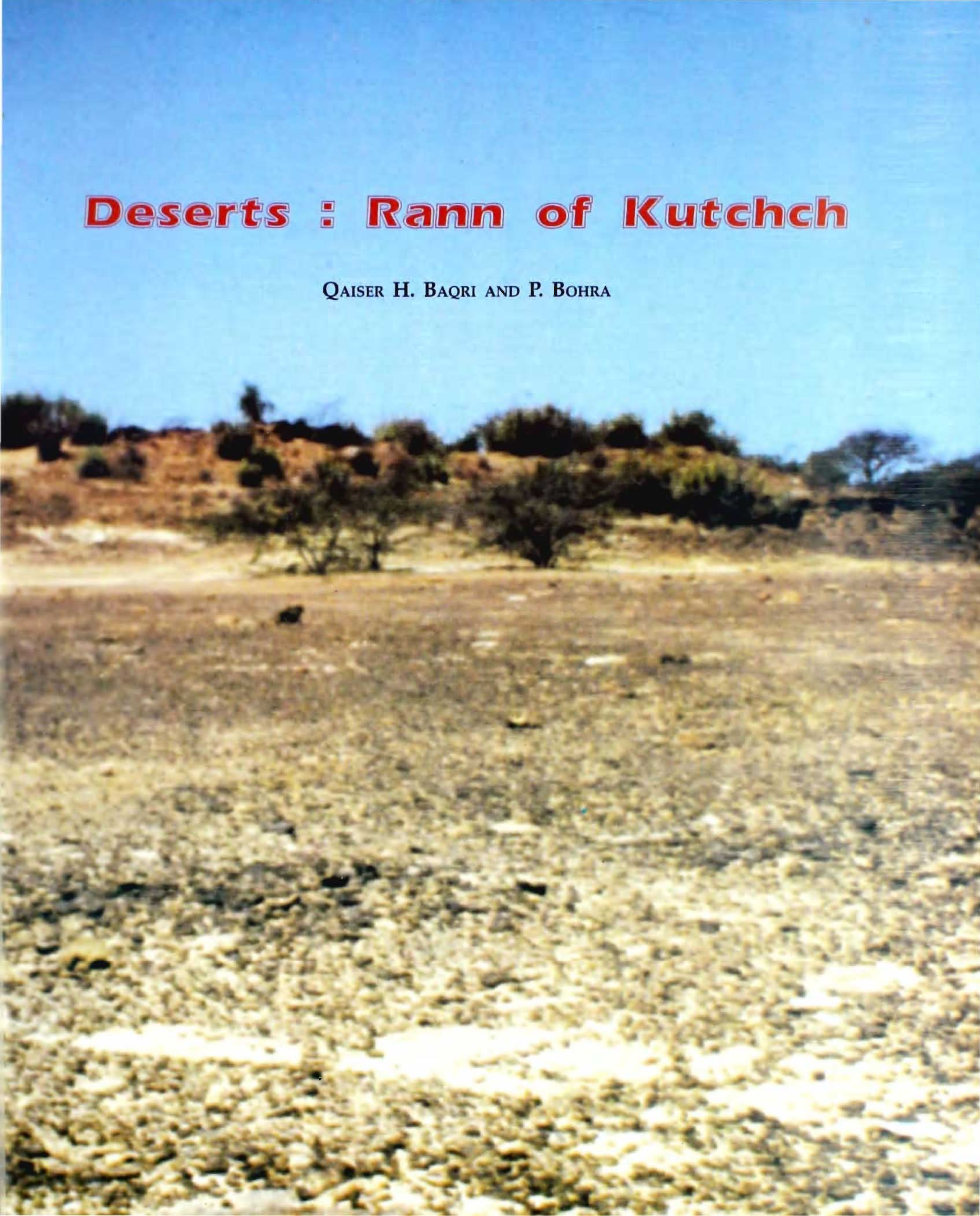
Gupta, R. K. and Prakash, I. 1975. *Environmental Analysis of the Thar Desert.* English Book Depot. Dehra Dun; 484 pp.

Rahmani, A. R. 1997. *Wildlife in the Thar*. WWF India, New Delhi and Amit Printers, New Delhi; 100 pp.

Rodgers, W. A. and Panwar, H. S. 1988. *Planning a Wildlife Protected Area Network in India*. 2 Vols. Wildlife Institute of India, Dehra Dun.

Roonwal, M. L. 1982. Fauna of the Great Indian Desert. Past and Present Composition, Zoogeography, Ecology, Biology, Physiology and Conservation. In : *Desert Resources and Technology*. Scientific Publishers, Jodhpur, 1-86.

Shetty, B. V. & Singh, V. 1987, 1991, *Flora of Rajasthan*, Vol. 1 & 2; Bot. Surv. India, Calcutta.



Deserts : Rannn of Kutchch

Qaiser H. Baqri and P. Bohra

ENVIS–*Zool. Surv. India*
Ecosystems of India : 111-122, 2001.

Deserts : Rann of Kutchch

QAISER H. BAQRI AND P. BOHRA

Desert Regional Station
Zoological Survey of India, Jodhpur

1. INTRODUCTION

The district Rann of Kutchch or Kutch-Bhuj in Gujarat state forms of separate agroclimatic zone within the Thar desert of India. Like other parts of Indian Thar, Rann of Kutchch is also characterised by a low rainfall and sparse vegetation. However, this region has a special and different topography from the rest of the desert because of its location near the sea and low-lying areas by which the marine water enters into its vast expanse. As a result, Rann of Kutchch is an admixture of saline, marshy and coastal desert where water and soils are extremely saline. This has made the area special from biodiversity point of view because it harbours populations of several

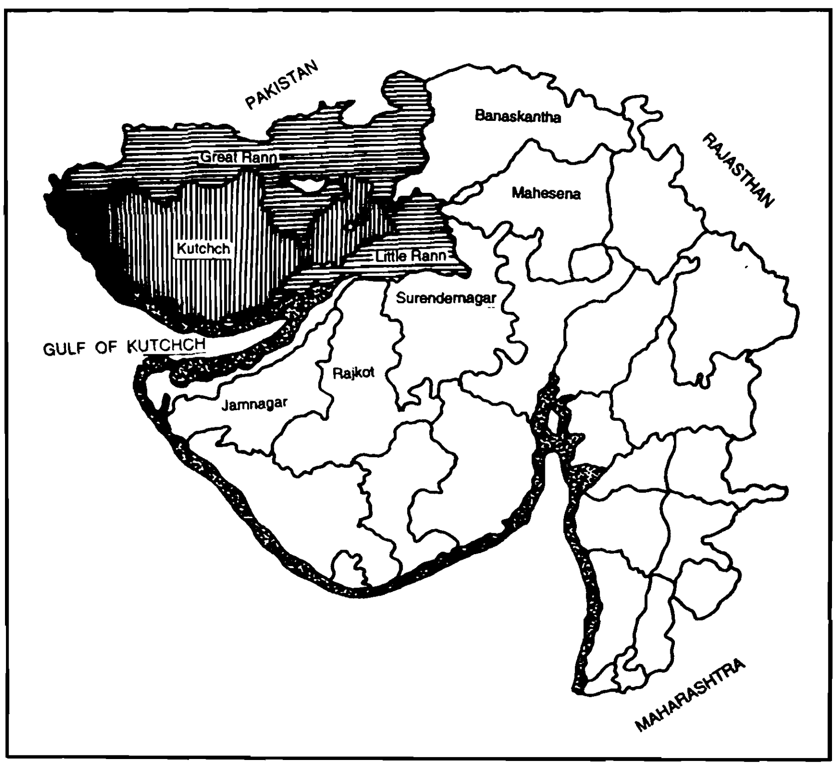


Fig. 1 : Gujarat State showing Rann of Kutchch

endemic and threatened species of plants and animals. The other significant aspect of this zone is its geological history. All these factors have necessitated a separate write up on the biodiversity of Rann of Kutchch.

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

The Thar desert in Gujarat state spreads over 62,180 sq km which comes to about 22.34% of the entire Thar. The Rann of Kutchch, occupying an area of 23,310 sq km, is located in extreme north-west of Gujarat and stretches between 22°41′ 11″ and 24°41′ 47″ N latitudes and 68° 9′ 46″ to 71° 54′ 47″ E longitudes. In north it is bordered with Sind (Pakistan), in south with northern Surendranagar, Banaskantha and Mahesana districts; while in west and south-west it is surrounded by the Arabian Sea. In west, the Arabian Sea enters the landmass to form the Gulf of Kutchch which has always been very useful from commercial and navigation point of view. The Rann of Kutchch is divided into the following administrative subunits (Talukas) : Bhuj, Mandis, Mundra, Abadasa, Lakhpat, Nakhatrana, Rapar Bhachau and Anjar.

The Rann of Kutchch may be divided into three zones (Fig 1), *viz.*, Kutchch (Central part), Great Rann (Rann of Kutchch) and Little Rann. The mainland of Kutchch is fringed by Great Rann in the north and Little Rann in south-east. The Kutchch (Central part) forms the shape of a tortoise and its name has been derived from the Indian language version of this animal. The Banni formed by sediments deposited by north flowing rivers is a strip along the northern of the main Rann.

According to the geological records, this region was under the ocean during Pleistocene as it is evident from the highly fossiliferous soil conditions, *i.e.*, sandy strands, rock sandy strands and soft marsh black mud. The soils in Kutchch region can be classified into different textures. The sandy soil covers a vast area of the district, coastal alluvial soil in the coast of Mundra and Mandis talukas, the black soils in the central part of Kutchch, shallow and skeletal soil in the slopes of hilly areas of Anjar, Rapar, Mandis, Mundra, Bhuj and Nakhatrana talukas. The mud soil formed under the influence of seawater is found in the coastal belt. The dominant soil texture of Banni area is sandy loam. The upland areas have nonsaline soil while the low lying and flat lands along the two Ranns have silty loam and silty clay soil with huge salinity. The salt affected soils of the Kutchch area are highly variable in the salt contents (5.2-82.8 dsm-1). The pH varies from 7.4-8.7. The analysis of most of the surface soil indicates the trend of calcium, magnesium and sodium chloride type salinity. The dominant textures are clayey-loam and silty clay. These are uncultivated barren lands but suitable for salt tolerant grasses and shrubs.

The important rivers draining into Rann of Kutchch are the Luni, the Rakhari, the Bhukhi, the Banas, the Nachhu and the Demi. The Luni has a well defined delta which starts from Chitalwana. The Luni delta consists of a flooded plain from Chitalwana to Rathora, a distance of about 6.5 km, and a delta plain from Rathora to the Rann of Kutchch (about 44.8 km in length). All these rivers have their origin in the Aravalli Hills.

The district Kutchch has a human population of over 12.6 lakhs (1991 census) with an average density of 65 person per sq km, which is much higher than the other deserts in the world. The livestock population has also increased with rapid pace during the last four decades, *i.e.*, from 9.40 lakhs (48 animals per sq km) in 1962 to 14.13 lakhs (73 animals per sq km) in 1992. The herd structure consists of mainly cattle, buffaloes, sheep and goats, horses, donkeys, camels, pigs, etc.

2.1 Climate

Like other parts of the Indian desert, Rann of Kutchch also experiences extremes of weather conditions and has three distinct seasons, *i.e.*, winter, summer and monsoon. The winter season usually lasts from middle of November to the February. January is the coldest month when temperature may drop as low as 4.6°C. Summer starts from March and continues till late June with temperature ranging from 39°C to 45°C. The evaporation rate is also very high during this period.

The analysis of the rainfall data from 1972 reveals that district Kutchch receives an average rainfall of about 325 mm per annum. The distribution of this meagre rainfall was highly variable and erratic, sometimes leading to droughts. The magnitude of the droughts during the last three decades has varied from mild to moderate to severe, sometimes 3-6 years in continuation. As per records, this ecosystem has occasionally received surplus rainfall.

Fig. 2 : An Oasis in the Desert (*Courtsey* : P. L. Kankane)

3. BIOLOGICAL DIVERSITY

The Rann of Kutchch exhibits a spectacular biological diversity because of its evolutionary history, geographical location and ecological uniqueness of the salt desert. Unfortunately, this region of Indian desert remains significantly unexplored for biodiversity, especially eastern Kutchch. Because of the unique ecological conditions and habitats, some of the species are endemic to this region.

3.1 Flora

The analysis of literature reveals that there are about 700 species of flowering plants in Kutchch district, of which about 345 species are indigenous to Kutchch (Blatter, 1908). The natural vegetation of the district is scrubby and the dominant species are : *Euphorbia mivulia* in drier parts and *Acacia nilotica, A. sengal, Prosopis cinerana, Salvadora persica, S. oleoides, Commiphora wightii, Zizyphus spp., Suaeda fruticosa, Aeluropus logopoides, Dactyloctenium aegyptium, Sporobolus helvolus, Anstida funiculata*, etc. Approximately 73 plant species have been reported from the grasslands. Out of these, 61 speices were in non-saline areas, 33 species were accounted from saline areas while 21 species have been found common in both saline and non-saline soils. In Banni grassland, 31 species of grasses were reported but their number has now reduced to about a dozen species. More than 60 spp. of the medicinal plants have been reported from this region but with restricted distribution.

In 1960, the total forest cover was 474.6 sq km. Recently, due to the implementation of afforestation schemes by the State Forest Department, the total area has increased to 2852 sq km. However, the actual forest cover is very thin (about 1.45%) and the dense forest cover is hardly 187 sq km. The maximum forest area has been recorded in Abdasa taluka and the minimum in Anjar taluka.

Fig. 3 : An patch of Glaval land, a typical desert component in Kutchch (*Courtsey* : P. L. Kankane)

The Kutchch Coast of Arabian sea is about 338 km long, consisting of an area of about 2500 sq km, of which 709 sq km is covered with mangroves forest. Certain region of the coast is surrounded by a 10-13 km wide marshy zone. This swampy coast is dotted with about 27 species of the mangroves, especially in the Gulf of Kutchch area. These mangroves are scrubby type consisting of the following important species : *Avecennia marina*, *Avicennia marina* var. *acutissima A. officinalis*, *A. alba*, *Rhizophora mucronata*, *Ceriops tagal*, *Aegiceras corniculatum*, etc. Out of these, *Avecennia marina* is the most dominant species.

3.2 Fauna

The review of the zoological literature reveals that Rann of Kutchch has not been explored significantly for the invertebrate fauna while significant work has been done on the vertebrate groups except the fishes. If we exclude the marine and coastal fauna reported from the Gulf of Kutchch (which forms a separate ecosystem), our knowledge on terrestrial and freshwater fauna is meagre from this unique desert ecosystem.

In fact, the coast and Gulf of Kutchch are not only rich in biodiversity but also significantly explored for faunal resources. Several groups of marine invertebrates, *viz.*, Coelenterates (52 spp. of corals), Echiurans (11 spp.) Molluscs (72 spp.), Bryozoans (42 spp.) etc., have been reported from this area. Its vertebrate fauna includes a large number of marine fishes, reptiles and mammals (dolphins and whales).

In the hot desert of Rann of Kutchch, only a few species of the major phyla like Protozoa, Cnidara, Platyhelminthes, Nematoda have been reported till date. The members of the phylum Arthopoda constitute the largest and one of the most economically important groups of animals. They are represented by 23 species of Isoptera, 6 species of Diptera, 10 species of Coleoptera, 20 species of Lepidoptera, 6 species of Odonata, 9 species of Metastigmata (Acari), and a few others. The information on the distribution of scorpions, pseudoscorpions, ticks and spiders is almost nil from this region.

The vertebrate fauna of Rann of Kutchch, except the fishes, has drawn considerable attention of the Zoologists. In all, about 317 species of vertebrates are known from the Great Kutchch region. These include 20 species of fishes, 6 species of amphibians, 35 species of reptiles, 220 species of birds and 36 species of mammals. The commonly found species of these groups are mentioned below :

Fishes : *Cirrhinus mirgala, Labeo boggut, L. fimbriatus, L. potail, Punitus arulius, P. sarana, Mystus cavasius, Channa punctatus, etc.*

Amphibians : *Rana tigerina, R. cyanophlyctis, R. limnocharis, R. hexadactyla, Bufo andersoni, Microhyla ornata.*

Reptiles : Lizards : *Cyrtodactylus kachhensis, Hemidactylus brooki, H. leschenaulti, H. flaviviridis, Sitana ponticeriana, Calotes versicolor, Agama agilis, A. minor, Mabuya macularia, M. carinata, Ablepharus grayanus, Riopa punctata, Eumeces taeniolatus, Ophiomorus tridactylus, Acanthodactylus cantoris contoris, Ophisops jerdoni, O. microlepis, Varanus bengalensis, Chamaleo zeylanicus.*

Crocodiles : Not reported.

Turtles : *Lissemys punctata punctata.*

Snakes : *Typhlops brahminus, Eryx johni, E. conicus, Xenochrophis piscator, Psammophis leithi, P. condanarus, Bungarus caeruleus, Naja naja oxiana, Echis carinatus, Hydrophis cyanocinctus, Pelamis platurus.*

Birds : *Egretta intermedia intermedia, E. gularis schistacea, Ciconia nigra, Plegadis falcinellus, Phoenicopterus roseus, Phoenicopterus minor, Anser indicus, Dendrocygna javanica, Tadorna ferruginea, Anas falcata, Elanus caeruleus vociferous, Sarcogyps calvus, Circaetus gallicus gallicus, Perdicula asiatica asiatica, Grus grus, Grus antigone antigone, Anthropoides virgo, Pavo cristatus, Streptopelia senegalensis, S decaocta, Centropus sinensis, Corvus macrorhynchos, Columba livia, Psittacula krameri, Acridotheres tristis, Francolinus pondicerianus, Turdoides caudatus, T. striatus sindianus, Dicrurus adsimilis, Upupa epops, Pterocles exustus erlangeri, P. orientalis, P. indicus indicus, Cuculus c. canorus, Eudynamys s. scolopaca, Alaemon alaudipes doriae, Calandrella raytal adamsi, Lanius excubitor, Muscicapa parva, Saxicola macrorhyncha, Parvus muchalis, Nectarinia asiatica, Passer domesticus indicus, etc.*

Mammals : *Paraechinus micropus, Hemiechinus auritus, Suncus murinus sindensis, Rhinopoma hardwickei hardwickei, R. microphyllum, Taphozous*

Fig. 4 : Wild Ass–*Equus hemionus*

perforatus perforatus, Taphozous mudiventris kachhensis, Scotozous dormeri, Manis crassicaudata, Canis lupus pallipes, Vulpes cana, Tadarida aegyptiaca, Mellivora capensis, Herpestes auropunctatus, H. edwardsi, Hyaena hyaena, Felis silvestris ornata, F. libyca, F. chaus, Panthera pardus fusca, Equus h. khur, Gazella bennetti, Antilope cervicapra, Tatera indica indica, Meriones hurrianae, Millardia meltada, Rattus rattus, R. meltada pallidior, Mus saxicola, Dugong dugon, etc.

4. SPECIAL FEATURES

The Rann of Kutchch (Kutchch, Great and Little Ranns) supports a good number of threatened species of plants and animals because of its unique topography and ecology. One of the special features of Rann of Kutchch is the elevated islands which are called "Bets" The elevated islands in main marshy Rann are scattered intermittently. The salt is periodically leached from the elevated plains. A wide variety of plants grow on these Bets, specially the grasses. The size of these Bets may be up to 10 sq km. These Bets are inhabited by a number of xeric rodents, *i.e.*, species of *Gerbillus*, *Tatera* and *Meriones*. These small mammals are totally isolated from other populations present on distant Bets. Due to isolation, a wide diversity has been observed in various parameters of populations of the same species.

The coastal belt falling within the Gulf of Kutchch is also distinguished by the presence of living corals. The corals are often inhabited by pearl oysters. The sea also harbours a wide variety of marine life, *viz.*, hippocampus, sea turtles, dolphins, whales, etc. The coastal region is a favourite spot for the breeding of the following sea turtles : *Eretmochelys imbricata*, *Lepidochelys olivacea* and *Chelonia mydas*. This region has also vast resources of lobsters and prawns.

The Great Rann of Kutchch is an established nesting and breeding ground of Flamingos in India. These migratory birds are attracted to this region because of the availability of their food (algae), which is abundantly found in this saline-desert-marshy ecosystem. Due to huge concentration of Flamingos between Khadir and Pachham belts, this breeding place is called Flamingo City.

The subspecies of Wild Ass, *Equus hemionus khur*, is found only in Rann of Kutchch and thus this is endemic to this region. Hedgehogs are also seen in abundance in this area.

The following species in this region are endangered or vulnerable : Spring Tailed Lizard, Green Sea Turtle, Olive Ridley Turtle, Wild Ass,

Fig. 5 : Wasteland in Kutchch

Fig. 6 : Forest Reserve in Dayapar (*Courtsey* : P. L. Kankane)

Desert Cat, Caracal, Wolf, Chinkara Indian Pangolin, Dugong and Great Indian Bustard. All the corals, molluscs and lobsters are threatened or vulnerable in the Gulf of Kutchch. In the marine fauna of this region, dolphins and whales are also threatened animals. In fact, Rann of Kutchch sustains isolated populations of a good number of plants and animal species which are extremely important from evolutionary point of view. Gujarat Ecological Commission (1996) has recommended conservation status for 62 species of plants from Gujarat. Most of these species are found in Kutchch region.

5. VALUE

The mangroves in the coastal region of Rann of Kutchch are very important for the people of this region. Their leaf-litter is also a main source of nitrogen that makes the Gulf water highly productive, which supports various life forms. A number of plant species are used in the form of medicines by the tribals. The shells of molluscs are used in various commercial products, *viz.*, tooth powder, dental cream, talcum powder, indigenous medicines, etc. The molluscs are also used as a source of food and in jewellery, interior decoration, toys and curios. The crustaceans, fishes and a few other animals are a source of food for the human population. Besides, the scientific and ecological values of this ecosystem are considered to be of great significance.

6. THREATS

The rapid increase in human and livestock populations has put too much pressure on this extremely fragile ecosystem. In fact, the grazing load is now beyond the carrying capacity of salt marsh land.

Since the "salt desert" is considered as a unique and a fragile ecosystem, the slightest human interference may result in the fast depletion of the rare desert fauna and flora. A number of recently established industries are discharging effluents, which have adversely affected even the littoral fauna.

The depletion of the mangroves has resulted in the decline of fish catch. Only a few years ago, a fisherman could catch 50 kg of jumbo lobsters in a single trip but at present the average catch hardly exceeds 1 kg per trip. In recent years, the area under Rann of Kutchch mangrove forests has reduced drastically. The annual rate of degradation in percentage has been calculated at about 11% for the mangroves.

The number of pearl oysters in the Gulf of Kutchch has drastically dwindled along with the fast depleting population of other marine animals. The coral reefs are also being over exploited for various reasons. The destruction of corals is to be stopped immediately because they are considered to be important component of the marine biodiversity.

Fig. 7 : Salt industry in Little Rann

The subspecies of Indian Wild Ass *(Equus hemionus khur)* found in the Little Rann of Kutchch is one of the rarest mammals surviving now in this desert. Its habitat has reduced drastically. As a result, the population of Wild Ass has declined from 3000-5000 in 1946 to 500-700 in 1990s. The ever-multiplying number of salt pans in the Little Rann and increase in road traffic are also contributory factors to the decline of Wild Ass population. The excess growth of weeds in the natural habitat of the Wild Ass is also becoming a matter of concern.

Though the Wild Ass populations are not under threat from the poachers, the Maldharis (nomadic cattle grazers) are indeed

Fig. 8 : *Prosopis juliflora* threatening the habitat in Little Rann

a real threat to them. These tribals are gradually encroaching the Wild Ass habitat, especially on the Bets (grassy islands) inside the Rann of Kutchch.

7. CONSERVATION

Since the Rann of Kutchch is a forest-poor area, wildife is also limited. After realizing the importance of the rare and endangered species of animals in the area, Government of Gujarat has taken an effective step to preserve this unique ecosystem by declaring an area of 7506 sq km in the Great Rann of Kutchch as "Kutchch Desert Wildlife Sanctuary" in 1987. This is one of the largest sanctuaries in the country.

To save the Wild Ass, the Gujarat Government has declared an area of about 500 sq km in Little Rann and adjoining Wasteland as "Wild Ass Sanctuary" The sanctuary encompasses the districts of Surendernnagar. Mahesana, Banaskantha and Rajkot. The management of the sanctuary is done efficiently by the State Forest Department.

Narayan Sarovar Sanctuary has been declared specially for the conservation of Chinkara. This sanctuary occupying an area of about 30,754 ha also supports other important animals, *viz.*, Caracal, Desert Cat, Indian Wolf, Pangolin, Great Indian Bustard, Peafowl and a few other birds.

Since the people of Rann of Kutchch are generally vegetarian in their feeding habit, the hunting or poaching threat is limited and the animals rather feel protected.

Fig. 9 : On way to Bhuj sea water receded revealing exposed bed (*Courtsey* : P. L. Kankane)

8. FUTURE DIRECTION

- Since Rann of Kutchch is a poorly surveyed region for the faunal resources, the work on the identification and richness of animal species should be undertaken on priority basis. This is necessary so that we may know, what does exist/what is lost/how much we can use?
- There should be an adequate grazing policy and the local people should be asked to maintain useful and limited population of livestock.
- The excess growth of the weed *Prosopis juliflora*, popularly known as Mexican mesquite, in the Little Rann is fast replacing the natural plants. It is therefore essential to control the invasion of this weed.
- To conserve and save the remaining population of Wild Ass, which is endemic to this region, another home for them should be established as early as possible before their population is affected by any disease, as it happended in 1958.
- Indiscriminate use of corals from Gulf of Kutchch should be stopped immediately.
- The mangroves should also be afforested in the coastal zone on priority basis.
- The habitat of Flamingo city in the Great Rann of Kutchch is to be protected at all cost. It has recently been noticed that Flamingos are shifting their breeding place from Rann of Kutchch to Sambhar Lake (Salt Lake) in Rajasthan because of some disturbances or destruction of habitat in Kutchch area.

9. SELECTED REFERENCES

Ali, S. 1956. *The Birds of Gujarat.* Gujarat Research Society, Bombay.

Anonymous, 1987, *Mangroves in India-Status Report.* Ministry of Environment & Forests, New Delhi : 72 pp.

Anonymous, 1996. *Biological Diversity of Gujarat, Current Knowledge.* Gujarat Ecology Commission : 330 pp.

Anonymous, 2000. *State Fauna Series* No. 8. Fauna of Gujarat (Part-I) Vertebrates : 464 pp., *Zool. Surv. India.*

Blatter, E. J. 1908. On the Flora of Kutch. *J. Bombay nat. Hist.* **18** : 756-777.

Ghosh, A. K., Baqri Q. H. and Prakash, I. 1996 (Editors) *Faunal Diversity in the Thar Desert : Gaps in Research;* Scientific Publisher, Jodhpur : 410 pp.

Mc Cann, C. 1938. The Reptlies and Amphibians of Cutch State. *J. Bombay nat, Hist. Soc.,* **40** : 425-427.

Mc Cann, C. 1938. The Reptiles and Amphibians of Cutch State. *J. Bombay nat. Hist. Soc.,* **42** : 45-64.

Pandey, D. K. and Fursich, E. T. 1993. Contributions to the Jurassic of Kachchh, Western India. *Beringeria,* **8** : 3-69

Pillai, C. S. G. and Patel, M. L. 1988. The Coral Fauna of Gulf Kutch. *J. Mar. Biol. Assn.;* **30** : 54-64.

Pillai, C. S. G. and Patel, M. L. 1988. Scleractenian Corals from Gulf of Kutch. *J. Mar. Biol Assn.;* 64-74.

Singh, Y. D. 1996. *Process of Desertification in Kachcha and Banaskantha districts of Gujarat, India (1961-1991).* Gujarat Institute of Desert Ecology; Bhuj (Kachchh.) 83 pp.

Soman, P. W. 1960. A note on the Amphibian Fauna of Kutch. *J. Bombay nat. Hist. Soc.,* **57** : 226-227.

Stoliczka, F. 1872. Notes on the Reptilian and Amphibian Fauna of Kutch (Cutch). *Proc. Asiat. Soc. Bengal,* May, **71** : 65-85.

Forests

P. Venu and M. Sanjappa

ENVIS–*Zool. Surv. India*
Ecosystems of India : 123-147, 2001.

Forests

P. VENU AND M. SANJAPPA*

Botanical Survey of India
Southern Circle, P.O. Lawley Road, Coimbatore-641 003

1. INTRODUCTION

The word forest is derived from the Latin root *foris*, meaning out of doors, and etymologically, it is "a large uncultivated tract of land covered with trees and under wood" Willis (1951) defined forest as a closed assemblage of trees allowing no break in the overhead canopy, homogenous of one species, or diversified. The term woodland is frequently used by English ecologists for forest. According to Toumey and Korstian (1947) "forest vegetation is composed of plant communities of units of vegetation developed and arranged in accordance with definite biological laws and is not an aggregation of trees and other plants brought together by chance"

Champion's monograph on forest types (1936) is a landmark in forest ecology of India, besides a number of contribution by him. A number of others who contributed on this subject include Blasco (1975), Bourdillon (1908), Brandis (1874), Champion (1975), Mani (1974), Mathur (1960), Meher- Homji (1973), Mehra *et al.* (1983), Puri (1954, 1960), Puri *et al.* (1983), Raheja (1965), Ranganathan (1938), Rao (1974) and Talbot (1909).

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

Forests cover nearly 23.42 percent of the total geographical area of India. The recorded forest area in country is 7,65,210 sq km while forest cover analysed by the satellite is 6,39, 900 sq km (19.47 percent of the geographical area of the country) (ICFRE, 2000). The type of forest found in a given locality depends on the climate and the soil. Geographically India is a tropical country but the whole of Gangetic plains lies outside the tropics. The country has strong monsoonic climate and differs from other tropical regions of the world.

2.1 Climate in relation to forest types

Temperature and rainfall are the most obvious factors of climate. Temperature can be related to latitude giving a broader differentiation into four zones.

a) Tropical—very hot and winterless,

b) Subtropical—hot and with a cool winter,

c) Temperate—a warm summer with a pronounced winter and

d) Arctic—with a short summer and a long and pronounced winter.

For India, the mean annual temperature exceeds 24°C over the whole country with the exception of the hill areas and the extreme north-west. On the basis of mean annual temperature and that of January, the four zones mentioned above may be differentiated as presented in Table 1.

* Botanical Survey of India, Central National Herbourum, P.O. Botanic Garden, Howrah-711 103

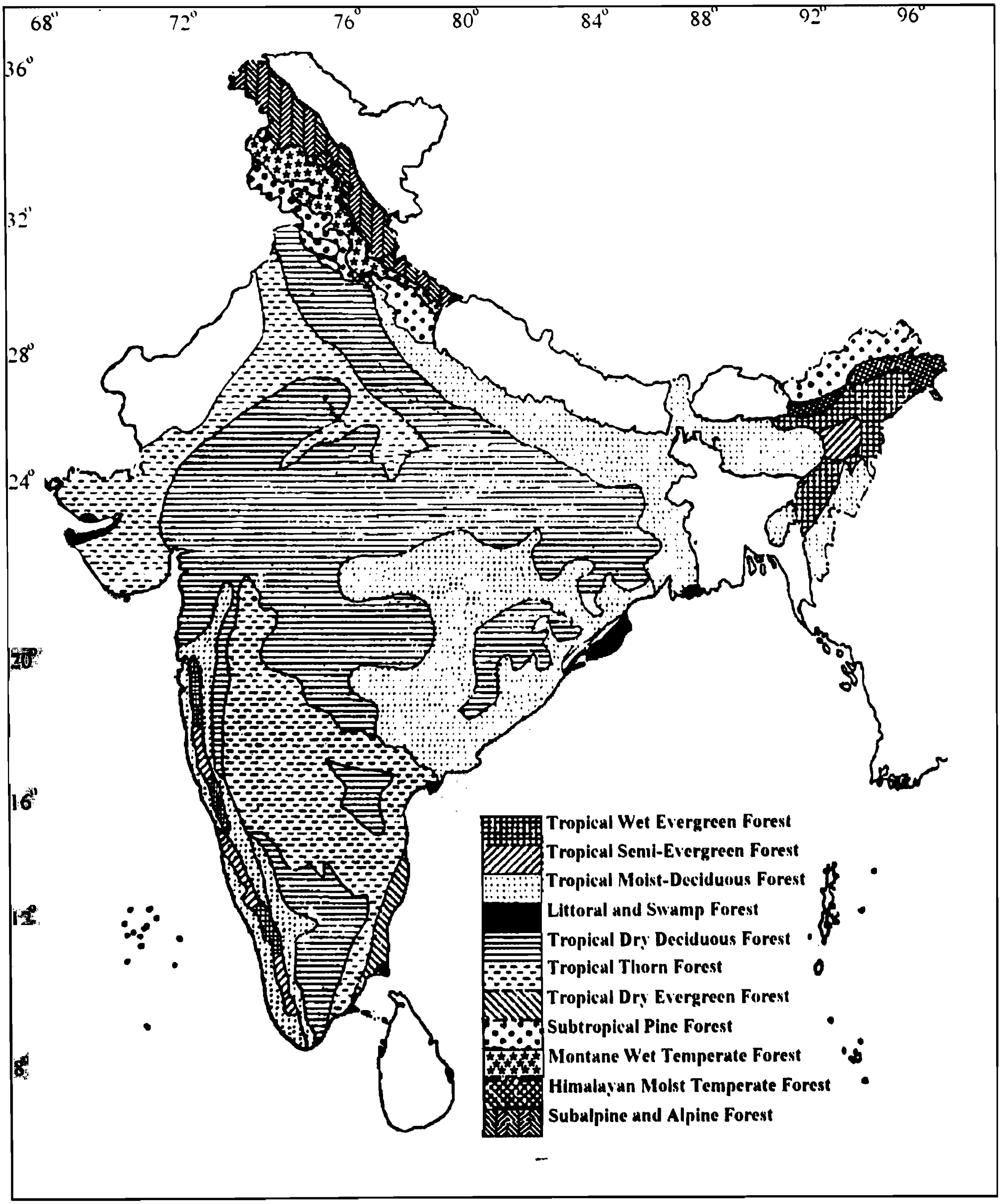


Fig. 1 : India—Forest Types

Table 1. Tentative Temperature - Vegetation zones of India (Puri *et al.* 1960)

Zone	Mean annual temperature	Mean January temperature	Winter
I. Tropical	Over 24°C	Over 18°C	None; no frost
II. Subtropical	17° - 24°C	10° - 18°C	Difinite but not more; frost rare
III. Temperate	7° - 17°C	1° - 10°C	Pronounced winter, frost and some snow
IV. Alpine	Under 7°C	Under 1°C	Severe and with much snow

Besides latitude, rainfall, distance of land from the sea, altitude, winds and ocean currents are important factors for the climate of a region. India exhibits wide range of rainfall, from less than 15 cm in the Thar desert to nearly 500 cm in specific areas in Assam and Meghalaya. Precipitation over 250 cm occurs in the Western Ghats, North Bengal and Assam and in some specific areas of Western Himalaya. Based on the annual rainfall four zones, namely, Wet zone, Intermediate zone, Dry zone and Arid zone may be broadly differentiated.

1. **Wet zone**: The annual rainfall in this zone is 200 cm and above. Wet zone comprises Western Ghats including western coastal part of Maharashtra, Goa, Karnataka and Kerala, and north-eastern India. Natural vegetation is normally of evergreen and semi-evergreen forests.

2. **Intermediate zone**: The annual rainfall in this zone ranges between 100 and 200 cm. This zone is represented by southwest Bengal, Bihar, Orissa, part of Madya Pradesh, east Uttar Pradesh, north-eastern Andhra Pradesh, eastern slopes of Western Ghats and east Tamil Nadu. Natural vegetation is of moist deciduous forests.

3. **Dry zone**: This zone receives annual rainfall between 50 and 100 cm and includes western Uttar Pradesh, North-eastern Punjab, Delhi, South-eastern Maharashtra, eastern Rajasthan and western Andhra Pradesh. Natural vegetation includes dry deciduous forests and scrub jungles.

4. **Arid zone**: This zone receives annual rainfall less than 50 mm and includes south-western Rajasthan, Punjab and Gujarat. Natural vegetation includes thorny scrubs and short-lived herbs.

There is a greater intergradation among different forest types depending on temperature and rainfall. Also, total annual rainfall and its seasonal distribution shows influence on vegetation. The rainy season varies in duration with a general increase from north-west to east and south-east. The upper Assam gets the shortest dry period and the north-west the longest. On the basis of rainfall Indian Metereological Department has adopted four seasons in India : (i) Cold weather season (from January to February), (ii) Hot weather season (from March to middle of June), (iii) Rainy season (from middle of June to middle of September) and (iv) Season of retreating monsoon (from middle of September to December)

3. BIOLOGICAL DIVERSITY

The biological diversity of forest ecosystems based on the classification adopted by Champion and Seth (1968) is discussed below.

3.1 Forest types of India

Sixteen important forest types are identified in India (Champion and Seth, 1968) as given in Table 2.

3.1.1 Tropical wet evergreen forests : In India these are found in regions receiving

Table 2. Forest types of India

Major Groups	Type and Groups	Area (milion ha)	% of forest area	Characteristics	Occurence in States / UTs of India
I. Tropical forests	1. Wet evergreen forests	4.5	5.8	Dense tall forests entirely evergreen or nearly so. Mean annual rainfall above 250 cm.	Arunachal Pradesh, Assam, Karnataka, Kerala, Mizoram, Manipur, Nagaland, Tamil Nadu, Sikkim, Andaman & Nicobar Islands and Goa.
	2. Semi-evergreen forests	1.9	2.5	Evergreens predominate. Dominants include deciduous species. Mean annual rainfall 200 - 250 cm.	Assam, Karnataka, Kerala, Maharashtra, Nagaland, Orissa, Tamil Nadu, Andaman & Nicobar Islands and Goa.
	3. Moist deciduous forests	23.3	30.3	Dominants mainly deciduous, but of lower storey largely evergreen. Top canopy rarely dense and even and over 25 m high. Mean annual rainfall 100 - 200 cm.	Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Tripura, Nagaland, Orissa, Tamil Nadu, Uttar Pradesh, West Bengal, Andaman & Nicobar Islands, Goa and Dadra & Nagar Havelli
	4. Littoral and swamp forests	0.7	0.9	These are essentially moist edaphic formations. Occur in moist and dry tropical and temperate regions. Mainly evergreen of varying density and height but always associated with wetness.	Andhra Pradesh, Gujarat, Maharashtra, Orissa, Tamil Nadu, West Bengal and Andaman & Nicobar Islands
	5. Dry deciduous forests	29.4	38.2	Entirely deciduous or nearly so. Top canopy broken and trees rarely over 25 m height, usually 8 - 20 m and with a grassy ground cover. Mean annual rainfall around 100 cm. Canes and palms absent.	Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Jammu & Kashmir, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh.
	6. Thorn forests	5.2	6.7	Deciduous low thorny trees and with broken canopy; trees under 10 m height and with general absence of grass. Mean annual rainfall below 50 cm and this type group is the result of biotic interference.	Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh.

Table 2. contd.

Major Groups	Type and Groups	Area (milion ha)	% of forest area	Characteristics	Occurence in States / UTs of India
	7. Dry evergreen forests	0.1	0.1	Hard leaved evergreen trees predominate and mixture of spiny and shrubby species; plenty of rainfall but with longer dry period; rank intermediate between moist evergreen woodlands and deserts under 20m height. (Result of secondary succession and biotic interference).	Andhra Pradesh and Tamil Nadu.
II. Sub-tropical forests	8. Sub-tropical broad leaved hill forests	0.3	0.4	Broad leaved largely evergreen forests of South Indian hills without conifers but with *Eugenia*, *Randia*, *Gymnosporia* and *Memecylon* communities.	Assam and Meghalaya.
	9. Sub-tropical pine forests	3.7	5.0	Pine association predominates and chiefly occur in western and eastern Himalaya and north-eastern India between 1000 and 2500 m.	Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Nagaland, Sikkim, Haryana, Uttar Pradesh and Punjab.
	10. Sub-tropical dry evergreen forests	0.2	0.2	Low xerophytic forests and scrubs and occur in foot hill zone of Himalaya.	Himachal Pradesh and Jammu & Kashmir.
III. Temperate forests	11. Montane wet temperate forests	1.6	2.0	Evergreen forests without conifers. Trees attain a height of 20 m; confined to South Indian hills and Eastern Himalaya above 1500 m altitude, rainfall above 150 cm. Sholas are significant ecosystems.	Arunachal Pradesh, Karnataka, Manipur, Nagaland, Sikkim and Tamil Nadu.
	12. Himalayan moist temperate forests	2.6	3.4	Evergreen forests mainly of selerophyllus oaks and conifers, occur above 1500 m, rainfall 100 - 150 cm mixed variously with deciduous dicotyledonous species. Undergrowth consists of *Berberis*, *Spiraea* and *Cotoneaster*	Himachal Pradesh, Jammu & Kashmir and Uttar Pradesh.

Table 2. contd.

Major Groups	Type and Groups	Area (milion ha)	% of forest area	Characteristics	Occurence in States / UTs of India
	13. Himalayan dry temperate forests	0.2	0.2	Open coniferous forests with sparse xerophytic under growth; rainfall below 100 cm. Occur in Western Himalaya and dominated by Rhododendrons, oaks and conifers.	Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh and Sikkim.
IV. Sub-alpine and Alpine forests	14. Sub-alpine forests	3.3	4.3	Occur between 4500 - 6000 m in Himalaya. Stunted deciduous or evergreen forests usually in close formation with or without conifers	Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh and Sikkim.
	15. Moist alpine scrub			Occur above 3000 m in Himalaya. Low but often dense scrub	
	16. Dry alpine scrub			Xerophytic scrubs in open formation	Himachal Pradesh, Jammu & Kasmir and Uttar Pradesh
Total		77.0	100		

Source : Champion and Seth (1968), ICFRE, (2000)

Fig. 2 : Shola in Mukurthy National Park (one km after upper Bhavani Dam)

Fig. 3 : Indira Gandhi Wild Life Sanctuary—Evergreen Forests (Courtsey : P. S. Sivaprasad)

above 250 cm mean annual rainfall. The forests are with lofty trees of 45 m height. The dominant genus is *Dipterocarpus* (*D. indicus* on West coast, *D. tuberculatus* and *D. alatus* in Andamans, *D. macrocarpus* and *D. turbinatus* in Assam) followed by *Palaquium, Cullenia, Shorea (S. assamica)* and *Mesua ferrea* as sub-dominants. Shrubs, lianas and epiphytes are abundant. The trees are buttressed and grasses are generally absent.

Sub group A–Southern tropical wet evergreen forests : These forests occur in Western Ghats from Bombay southwards up to Tirunelveli and are distributed in Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala. The top canopy consists of genera like *Artocarpus, Calophyllum, Dipterocarpus, Dysoxylum* and *Hopea* while the second storey with *Cyclostemon, Diospyros, Elaeocarpus, Hydnocarpus, Palaquium* and *Syzygium*. Epiphytes, specially aroides, ferns, mosses and orchids are numerous. In the undergrowth, *Alpinia malaccensis, Amomum cannaecarpum* and *Zingiber montanum* are seen while *Bauhinia phoenicea, Beaumontia jerdoniana, Chonemorpha fragrans, Entada rheedii, Gnetum ula* and *Moullava spicata* are some of the woody climbers. With increase in altitude, the composition of the evergreen forests gradually changes and *Bischofia javanica, Canarium strictum, Mesua ferrea, Myristica dactyloides, Palaquium ellipticum* and *Poeciloneuron indicum* constitute the canopy trees.

Sub group B–Northern tropical wet evergreen forests : These forests are found in the north-eastern parts of the country particularly in West Bengal, Assam and Orissa and beyond Bombay in western India in patches. The top canopy consists of *Anthocephalus, Artocarpus, Dipterocarpus, Dysoxylum, Hydnocarpus, Mesua* and *Shorea*. The common shrubs belong to genera *Clerodendrum, Garcinia, Ixora, Miliusa* and *Pandanus*. Canes, palms and ferns also occur. The shrubby layer consists of *Allophyllus cobbe, Clerodendrum kaempferi, Costus speciosus, Desmodium pulchellum, Flemingia macrophylla, Leea alata, L. compactiflora, L. indica* and *Micromelum integerrimum*. Scandent shrubs include *Aspidopterys, Bauhinia, Bridelia, Combretum, Entada, Hiptage, Spatholobus* and *Tinospora*. The undergrowth of these forests varies from place to place and is dominated by genera like *Desmodium, Impatiens, Licuala, Oxalis, Phlogacanthus, etc.*

3.1.2 Tropical moist semi-evergreen forests: These forests occur where there is adequate moisture but not enough for an evergreen climax. These forests are found along the Western Ghats, eastern Orissa and upper Assam where annual rainfall is between 200 and 250 cm. They are characterised by admixture of luxuriantly growing evergreen and deciduous elements.

Sub group A–Southern tropical moist semi-evergreen forests : The forests of this category are found in Western Ghats, in few patches in Central India and Andamans. These occur sometimes in association with evergreen forests. To illustrate the tree composition, forests of this type are described hereunder from south-eastern parts of Madhya Pradesh and adjoining Orissa In these forests canopy reaches a height of about 25-35 m formed by species, such as, *Dalbergia paniculata, Hymenodictyon orixense, Pterocarpus marsupium, Shorea robusta, Stereospermum chelonoides, Terminalia alata* and *Tetrameles nudiflora* and, the often planted *Tectona grandis*. The next storey is formed of smaller mostly evergreen trees and shrubs like *Antidesma acidum, Ardisia solanacea, Artocarpus lakoocha, Berberis asiatica, B. lycium, Bridelia squamosa, Celtis tetrandra, Chloroxylon swietenia, Dillenia aurea, D. indica, D. pentagyna, Diospyros malabarica, D. montana, Eriolaena candollei, Ficus hispida, F. heterophylla, F. semicordata, Glochidion* spp., *Gmelina arborea, Haldina cordifolia, Leea crispa, L. macrophylla, Litsea monopetala, Michelia champaca, Ochna obtusa, Phoebe lanceolata, Pittosporum napaulense, Rhus paniculata, Schrebera swietenioides, Vitex peduncularis* and *V. leucoxylon*. Important Bamboo species are *Bambusa arundinaceae, B. vulgaris, Cephalostachyum pergracile* and *Gigantochloa hasskarliana* while among canes are *calamus tenuis* and *C. viminalis*. Among the lianas mention may be made of *Gnetum ula* and *Entada rheedei* which are confined to the well protected forests. Other woody climbers are *Acacia torta, Argyreia involucrata, Bauhinia vahlii, Combretum album, Dalbergia volubilis, Erycibe paniculata, Hemidemus indicus, Ichnocarpus frutescens, I. setosa, Ipomoea sinuata, Millettia extensa, Olax scandens, Smilax zeylanica* and *Vallaris solanacea*. There are several species of ground orchids like *Eulophia explanata, E. flava, E. graminea, E. herbacea, E. nuda, Geodorum densiflorum, Goodyera procera, Habenaria commelinifolia, H. digitata, H. foliosa, H. plantaginea, Liparis bituberculata, Microstylis congesta, Peristylus constrictus* and *Pecteilis gigantea*. The common epiphytic orchids are *Aerides multiflora, Dendrobium macrostachyum, D. moschatum, Luisia trichorhiza, Oberonia falconeri, Rhynchostylis retusa, Sarcanthus insectifer, Thunia venosa, Vanda tessellata* and *V. testacea*.

Ferns and fern allies are other important constituents of these Central Indian semi-evergreen forests. These are represented here by about 70 80 species, including the tree ferns *Cyathea gigantea* and *C. spinolusa* in the valleys and gorges. Some of the other species growing in the humid rock crevices or epiphytes are *Actiniopteris radiata, Adiantum incisum, A. philippense, Ampelopteris prolifera, Asplenium cheilosorum, A. indicum, A. laciniatum, Blechnum orientale, Botrychium daucifolium, B. lanuginosum, Ceratopteris thalictroides, Cheilanthes anceps, Christella dentata, C. parasitica, Drynaria quercifolia, D. cochleata, Equisetum debile, E. diffusum, Huperzia hamiltonii, Isoetes coromandelia, Leptochilus axillaris, Lygodium flexuosum, L. microphyllum, Microsorum membranaceum, Nephrolepis cordifolia, N. exaltata, Ophioglossum costatum, O. gramineum, O. reticulatum, Osmunda regalis, Psilotum nudum, Pteris biaurita, P. vittata, Selaginella bryopteris, S. ciliaris, S. repanda, S. rupestris* and *Tectaria polymorpha. Azolla pinnata* with its small pinkish fronds and *Marsilea minuta* are commonly seen floating in pools and slow moving shallow streams (Verma, 1996).

Sub group B–Northern tropical moist semi-evergreen forests : These forests occur in heavy to moderately heavy rainfall areas in West Bengal, Orissa, Assam and other north-eastern states typically up to the elevation of 1200 m. The typical floral composition of semi-evergreen forests of north-eastern states is presented here. The canopy in these forests is formed by *Artocarpus, Dysoxylum, Elaeocarpus, Mangifera, Michelia, Phoeba, Terminalia, Tetrameles*, etc. The underwood consists of *Amoora, Ilex, Mallotus, Phoeba*, etc. Bamboos occur in these forests. Besides the upper storey, the other zonations of trees can easily be demarcated. *Callicarpa arborea, Careya arborea, Dillenia pentagyna, Garcinia lancifolia, Rhus acuminata* are deciduous elements and shed leaves during dry season. The undergrowth is not as dense as seen in evergreen forests. The lianas are scarce in these forests. *Entada rheedii* and *Mucuna macrocarpa* are seen occasionally. The tree trunks are covered by epiphytic flora of poor diversity due to seasonally dry period. Besides, hemiparasites, *viz.*, *Helixanthera parasitica*, *Loranthus scurrula* and *Taxillus* spp. are common (Chauhan, 1996).

3.1.3 Tropical moist deciduous forests: These forests cover extensive areas of the country receiving rainfall between 100 and 200 cm and the rainfall distribution spreads over most of the year. The dry periods are of short duration. Many species show leaf fall in hot summer. The undergrowth has bamboo and canes on wet ground. In shady places epiphytes are present. The number and size of climbers are large. These forests in southern India are dominated by *Dalbergia latifolia*, *Grewia tiliaefolia*, *Haldina cordifolia*, *Lagerstroemia parviflora*, *Tectona grandis* (Teak), *Terminalia bellirica* and *T. paniculata*. In north, they are dominated by *Boswellia* spp., *Dillenia* spp., *Eugenia* spp., *Mallotus philippensis*, *Shorea robusta*, (Sal), *Terminalia tomentosa*. These forests produce valuable timber. Grasses consitute important components of this type.

Sub group A–Southern tropical moist deciduous forests : This is subdivided into very moist, moist and slightly moist teak forests. The very moist forests may contain only 10 percent of teak, the moist ones 10 25 percent while the slightly moist ones contain 25 65 percent. These are distributed

Fig. 4 : Indira Gandhi Wild Life Sanctuary, Tamil Nadu—Moist deciduous forest (Courtsey : P. S. Sivaprasad)

in the wet western side of Deccan plateau, on the west coast in Kanara, Coorg, Wynanad, Nelumbore, parts of Karnataka, Kerala, parts of Madhya Pradesh and in Andamans in drier regions (Puri, 1960).

In the leeward side of Western Ghats these forests are composed of *Butea monosperma, Careya arborea, Toona ciliata, Radermachera xylocarpa* and *Schleichera oleosa* constituting canopy. *Cordia macleodii* and *Erinocarpus nimmonii* are also seen in the northern portion. The shrubs include *Ardisia solanacea, Argyreia pilosa, Holarrhena antidysenterica,* and *Ligustrum gamblei. Holostemma annulare* and *Jasminum malabaricum* are some of the common climbers found in the region. Epiphytic orchids include *Aerides crispum, Dendrobium barbatulum, D. natans* and *Rhynchostylis retusa.* The undergrowth during rainy season consists of aroids like *Amorphophallus paeoniifolius, Arisaema leschenaultii, A. tortuosum* and orchids like *Liparis nervosa* and *Nervelia aragoana* (Henry et al., 1996).

In the Maharashtra Plateau these forests are found on the slopes of the hilly uplands. Teak is the dominant species and associated with *Acacia chundra, Anogeissus latifolia, Bombax ceiba, Haldina cordifolia, Lagerstroemia parviflora, Mitragyna parviflora, Terminalia bellirica, T. crenulata, Wrightia tinctoria,* etc., forming the top storey. Lofty trees of *Haldina cordifolia, Mitragyna parvifolia* and *Tectona grandis* are seen in the Alapalli forests in Chandrapur district. The second storey consists of *Albizia procera, Bauhinia racemosa, Butea monosperma, Careya arborea, Cassia fistula, Diospyros melanoxylon, Holoptelea integrifolia, Kydia calycina, Mangifera indica, Miliusa tomentosa* and *Sterculia urens.* The shrubs include *Carissa congesta, Carvia callosa, Casearia graveolens, Helicteres isora, Meyna laxiflora, Woodfordia fruticosa* and *Ziziphus caracutta. Cuscuta reflexa, Dendrophthoe falcata, Scurrula cordifolia, Vanda tesellata, Viscum articulatum,* etc., are the common parasites and epiphytes. *Rhynchostylis retusa* is a rare epiphytic orchid found in this area Fern and its allies are common in this area and represented by *Actinopteris dichotoma, Adianthum caudatum, Marsilea minuta* and *Ophioglossum gramineum* (Henry et al. 1996).

Sub group B–North Indian tropical moist deciduous forests : This subgroup of economically important forests occurs in Uttar Pradesh, Bihar, Orissa, Madhya Pradesh, Assam and other north-eastern states. The annual rainfall varies from 100 to 200 cm. *Shorea robusta* is the most important species in this sub group. In general, the associated species of sal are *Albizia odoratissima, Bombax ceiba, Chukrasia tabularis, Gmelina arborea, Haldina cordifolia, Lagerstroemia parviflora, Schima wallichii, Stereospermum personatum,* etc. In Gangetic plains the dominant species include *Alangium salvifolium, Casearia tomentosa, Phyllanthus emblica, Garuga pinnata, Hymenodictyon orixense, Kydia calycina, Lagerstroemia parviflora, Mallotus philippensis, Mitragyna parviflora, Pterocarpus marsupium, Stereospermum scaveolens, Sterculia* spp., *etc.* (Roy, 1996). Species of *Desmodium, Licuala, Phlogacanthus, Impatiens, Oxalis,* etc. form dominant undergrowth. In open and disturbed areas, species of *Eupatorium, Lantana* and *Mikania* grow profusely without any competition. Lianas are fewer but species of scandent shrubs, such as, *Aspidopteris, Bauhinia, Bridelia, Combretum, Entada, Hiptage, Mussaenda, Spatholobus, Tinospora* grow.

3.1.4 Littoral and swamp forests : There are moist edaphic formations and in this group excepting littoral forests, all others are subject to immersion or water logged situations. These are evergreen forests on wet sites and constitute 0.9 percent of total forest area. These are sub-divided into littoral forests, fresh water swamp forests and tidal swamp forests.

Typical species of many littoral forests are *Casuarina equisetifolia, Calophyllum inophyllum, Manilkara littoralis* and *Syzygium cumini.* On fringes of water courses *Terminalia arjuna, Mangifera indica* and *Lagerstroemia speciosa* are the characteristic species. Swampy forests occur

Fig. 5 : Coastal vegetation

in water logged situations in Indo-Gangetic plains. Here species composition varies with degree of water logging. Characteristic species are *Syzygium cumini, Trewia nudiflora, Drypetes roxburghii, Ficus glomerata, Bischofia javanica, Terminalia arjuna, Celtis tetrandra, Litsaea polyantha* and *Trema orientalis*. *Myristica* swamps are important ecologically and are found at an altitude of 200 m along the sides of sluggish streams in the flat valleys of Anachal, Kulathapuzha and Shenduruni ranges in south India. Prominant trees are members of Myristicaceae family giving the name *Myristica* swamps. *Carallia brachiata, Gymnacranthera farquhariana, Lagerstroemia regine, Lophopetalum wightianum, Myristica dactyloides, M. fatua* var. *magnifica* and *M. malabarica* are the chief elements. On the edges of the swamps *Hopea* spp., *Humboldtia vahliania, Persea macrantha* and *Vateria indica* occur (Vajravelu & Vivekananthan, 1996).

Mangrove forests of Sundarbans are typically evergreen forests with trees of moderate height on tidal muddy flats which are permanently wet with salt water submergence from every tide. Common species found in Sundarbans are *Avicennia alba, Bruguiera gymnorrhiza, Ceriops tagal, C. decandra, Heritiera fomes, Kandelia candel, Lumnitzera racemosa, Rhizophora* spp., *Sonneratia apetala, Xylocarpus granatum*, etc. (Roy, 1996). In Kodaikkadu (Point calimer) the forests are dominated by *Aegiceras corniculatum, Avicennia officinalis, Excoecaria agallocha* and *Tamarix troupii*. In the Coringa tidal estuary of the Godavari in Andhra Pradesh, *Avicennia alba, Rhizophora apiculata, R. mucronata. Avicennia officinalis, Bruguiera gymnorrhiza, Excoecaria agallocha, Sonneratia apetala* and *Xylocarpus granatum* are the dominant species. The climbers include *Caesalpinia crista, Dalbergia spinosa* and *Derris trifoliata*.

In the Vellar estuary, in the tidal mangrove zone, plants like *Aegiceras corniculatum, Avicennia officinalis, Ceriops decandra, Rhizophora apiculata* and *R. mucronata* usually form the forests. In the prohaline zone, *Bruguiera cylindrica, Dalbergia spinosa, Derris trifoliata, Lumnitzera racemosa, Sonneratia apetala* and *Xylocarpus granatum* are the most prominent taxa.

Fig. 6 : *Rhizophoral mucronata* in—Mangrove Forest, Picavaram

Mangrove forests of Andaman and Nicobar Islands possess high floristic richness with 15 percent of the total area covered. The most common trees are *Bruguiera gymnorrhiza, B. parviflora, Rhizophora apiculata, R. mucronata, R. stylosa* and *Xylocarpus granatum.* Climbers and epiphytes are *Derris trifoliolata, Hoya parasitica* and several ferns and a few orchids. The mangrove palm *Nypa fruticans* is also common especially in tidal creeks where fresh and salt water mixes. Very often it forms pure stands with a closed canopy without any undergrowth (Balakrishnan, 1996).

3.1.5 Tropical dry deciduous forests : These are distributed in the areas where annual rainfall is usually low ranging between 70 and 100 cm. The largest area of the country's forest land is occupied by this type. Punjab, Uttar Pradesh, Bihar, Orissa, Madhya Pradesh and large part of Indian peninsula are occupied by these forests. The dry season is long and most of the trees remain leafless during this season. The forest trees are not dense, 10 to 15 m in height, and undergrowth is abundant. The trees here are generally drought resistant and have greater adaptability and attain no appreciable girth. In north, the forests are dominated by sal (*Shorea robusta*) and in south by teak (*Tectona grandis*). Bamboos are poor and confined to restricted areas.

Sub group A–Southern tropical dry deciduous forests : These forests occur in Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra and Madhya Pradesh.

In the Karnataka plateau, besides *Tectona grandis* the other characteristic species are *Acacia chundra, Anogeissus latifolia, Boswellia serrata, Cochlospermum religiosum, Hardwickia binata, Pterocarpus marsupium, Sterculia urens* and *Terminalia alata* and these are reported only from the southern half. The other common tree species are *Acacia leucophloea, Aegle marmelos, Albizia lebbeck, A. amara, Bauhinia racemosa, Buchanania lanzan, Chloroxylon sweitenia, Dalbergia latifolia, D. paniculata, Diospyros melanoxylon, Givotia rottleriformis, Grewia pilosa, Ixora arborea, Lagerstroemia parviflora, Lannea coromandelica, Madhuca longifolia* var. *latifolia, Soymida febrifuga, Terminalia paniculata, T. bellirica, Wrightia tinctoria* and *Semecarpus anacardium. Ficus amplissima, Mallotus philippensis* and *Morinda tomentosa* are occasionally met

Fig. 7 : A view of dry deciduous mixed forest of Mara, Sidhi in Madhya Pradesh

with. *Apluda mutica, Heteropogon contortus* and *Perotis indica* are the grasses seen throughout the area. Other grasses with sporadic presence are *Cymbopogon fulvus, C. martinii, Eragrostis unioloides, Eulalia phaeothrix* and *Hackelochloa granularis*. Orchids are relatively rare and epiphytic orchids, *Aerides crispum, A. ringens* and terrestrials like *Habenaria grandifloriformis, H. longicorniculata, H. marginata, H. plantaginea* and *Geodorum densiflorum* are often seen. Ferns are represented by *Actinopteris australis, Cheilanthes mysorensis, Hemionitis arifolia* and *Selaginella wightii.*

In the Telangana plateau (includes Adilabad, Nizamabad, Karim Nagar, Warangal and Medak) the upper canopy is formed by *Aegle marmelos, Albizia procera, Anogeissus latifolia* and *Boswellia serrata* which occur almost as a pure stand on shallow soils and hilltops. *Bridelia montana, Diospyros melanoxylon, Holoptelea integrifolia, Madhuca longifolia* var. *latifolia, Polyalthia cerasoides, Pterocarpus marsupium, Soymida febrifuga, Sterculia urens, S. villosa, Terminalia bellirica, T. chebula* and *T. pallida* also occur. Species with lower frequencies include *Acacia chundra, Buchanania axillaris, B. lanzan, Casearia tomentosa, C. graveolens, Cassia fistula, Cleistanthus collinus, Diospyros montana, D. sylvatica, Erythroxylum monogynum, Gardenia gummifera, G. latifolia, Gmelina arborea, Holarrhena antidyenterica, Ixora pavetta, Manilkara hexandra, Tamilnadia uliginosa, Wrightia arborea* and *W. tinctoria.* The common herbs including grasses are *Aerva lanata, Andrographis paniculata, Apluda mutica, Aristida setacea, Cajanus scarabaeoides, Dipteracanthus prostratus, Enicostema axillare, Eragrostis atrovirens, Eulaliopsis binata, Indigofera glandulosa, I. astragalina, Tephrosia purpurea* and *Saccharum spontaneum.*

Rayalseema uplands comprise Anantapur, Chitoor, Kurnool and Cuddapah districts of Andhra Pradesh. The dominant tree species are *Albizia amara, Anogeissus latifolia, Bauhinia racemosa, Cassia fistula, Chloroxylon swietenia, Cleistanthus collinus, Cochlospermum religiosum, Commiphora caudata, Dalbergia latifolia, Diospyros chloroxylon, Erythroxylum monogynum, Gardenia gummifera, Gyrocarpus asiaticus, Hardwickia binata, Pterocarpus marsupium, Terminalia arjuna, T. alata, T. bellirica, T. chebula* and *T. pallida*. The other tree species with lower frequencies include *Aegle marmelos, Buchanania axillaris, Lagerstroemia parviflora, Phyllanthus emblica, Soymida febrifuga, Vitex altissima* and *Wrightia tinctoria*. *Santalum album* is sparsely distributed in this area. The dominant grasses are *Aristida adscenscionis, A. setacea, Brachiaria ramosa, Chrysopogon asper, Eragrostis atrovirens, Oplismenus compositus, Panicum notatum* and *Sporobolus wallichii* (Henry et al. 1996).

Sub group B–Northern tropical dry deciduous forests : These forests occur in the drier parts of northern Madhya Pradesh, Orissa, Bihar, West Bengal, Uttar Pradesh and Haryana. The mean maximum temperature lies between 29° and 33°C with maximum temperature touching 48°C during summer. The mean minimum ranges between 15° and 21°C, but during some nights temperature may go below the freezing point. The mean annual rainfall in the area ranges between 75 and 120 cm.

The dry deciduous forests are generally found in the northern, western and central regions of Madhya Pradesh, in southern Uttar Pradesh and in the Aravalli hill ranges in eastern Rajasthan. Sometimes due to degradation, patches of dry deciduous forests are also found in other regions receiving higher rainfall like in parts of Raipur, Bastar, Surguja, Balaghat, Seoni and Mandla. The common constituents of these forests are *Acacia nilotica* ssp. *indica, A. leucophloea, Albizia lebbeck, A. odoratissima, A. procera, Aegle marmelos, Anogeissus latifolia, A. pendula, Bauhinia malabarica, B. purpurea, B. racemosa, Bombax ceiba, Boswellia serrata, Bridelia squamosa, Buchanania lanzan, Butea monosperma, Carissa opaca, Cochlospermum religiosum, Cordia obliqua, Diospyros melanoxylon, Phyllanthus emblica, Garuga pinnata, Hardwickia binata, Madhuca longifolia* var. *latifolia, Lagerstroemia parviflora, Lannea coromandelica, Pterocarpus marsupium, Phoenix sylvestris, Sterculia urens, S. villosa, Tectona grandis, Terminalia elliptica, T. bellirica, T. chebula*. The less dominants include *Acacia catechu, Adhatoda vasica, Alangium lamarkii, Annona squamosa, Capparis zeylanica, Casearia elliptica, Flacourtia indica, Gardenia gummifera, G. latifolia, G. resinifera, G. turgida, Grewia tiliefolia, G. hirsuta, G. rothii, G. serrulata, Helicteres isora, Holarrhena antidysenterica, Kirganella reticulata, Mimosa himalayana, Nyctanthes arbor-tristis, Securinega virosa, Woodfordia fruticosa, Wrightia arborea, W. tinctoria, Xeromphis spinosa, X. uliginosa, Ziziphus mauritiana* and *Z. xylopyrus*. The common central Indian bamboo, *Dendrocalamus strictus*, is found in drier form with thinner and shorter culms than those in the moist deciduous forests.

There are several species of slender climbers on smaller trees and shrubs, sometimes twining and inter-woven among their branches, only a few rather woody and attain a more gregarious habit. The common climbers are *Abrus precatorius, Ampelocissus latifolia, A. tomentosa, Cajanus scarabaeoides, Cayratia trifolia, Coccinia indica, Cocculus hirsutus, Cissampelos pareira, Cryptolepis buchananii, Dioscorea hispida* var. *daemona, D. pentaphylla, Diplocyclos palmatus, Dregia volubilis, Gymnema sylvestre, Hemidesmus indicus, Ichnocarpus frutescens, Ipomoea eriocarpa, I. hedericifolia, I. nil, I. obscura, Marsdenia tenacissima, Merremia hederacea, M. tridentata, Mucuna pruriens, Mukia maderaspatana, Momordica dioica, Pergularia daemia, Rhynchosia minima, Tinospora cordifolia, Ventilago denticulata* and *Ziziphus oenoplia*. *Cuscuta reflexa* with its yellow wiry twining stems is a common parasitic climber. Epiphytes are poorly represented and are *Dendrophthoe falcata, Scurrula parasitica, Viscum nepalense* and *V. orientale*. During monsoon and in postmonsoon period, between August and November, grasses form large patches represented by species of *Aristida, Apluda, Chloris, Cynodon, Dichanthium, Digitaria, Eragrostis, Imperata, Themeda, Vetiveria* and *Sporobolus*.

3.1.6 Tropical thorn forests : These forests occur in the areas where annual rainfall is between 20 and 90 cm, dry season is hot and very long. The vegetation is of open type consisting of small trees with 8 to 10 m high and thorny or spiny shrubs of stunted growth. There is luxuriant growth of ephemeral herbs and grasses during the rainy season.

Sub group A–Southern tropical thorn forests : These forests occur in the dry areas of Andhra Pradesh, Karnataka , Tamil Nadu, Madhya Pradesh, and Maharashtra. The mean annual temperature varies from 24° to 28°C and mean annual rainfall ranges between 45 and 95 cm with the number of dry months varying from four to nine but generally seven or eight.

In Telangana region of Andhra Pradesh, the vegetation is composed of *Acacia chundra, Albizia amara, Bauhinia racemosa, Cassine glauca, Canthium dicoccum, Dichrostachys cinerea, Ehretia aspera, Gardenia latifolia, Glycosmis pentaphylla, Hugonia mystax, Ixora pavetta, Jatropha gossypifolia, Prosopis chilensis, Tarenna asiatica* and *Ziziphus xylopyrus*. In the Maharashtra plateau, the forests are blank and with shallow soils. The grasses are stunted due to poor soil. The forests being scattered and surrounded by cultivation on all sides, are subjected to heavy grazing and illicit felling. In the areas of rivulets and streams there are savannah formations composed of open grasslands with few scattered shrubs and trees. Trees, like *Acacia chundra, A. nilotica* ssp. *indica, Anogeissus latifolia, Terminalia crenulata* and *Ziziphus mauritiana* frequent this area. However, the typical members of scrub forests are shrubs like *Canthium parviflorum, Carissa congesta, Senna auriculata, Dichrostachys cinerea, Maytenus emarginatus, Mimosa hamata, Rhus mysorensis, Ziziphus oenoplia* and *Z. nummularia*. The common climbers are *Aspidopterys cordata, Cardiospermum helicacabum, Cocculus hirsuta, Mukia maderaspatana, Rivea hypocrateriformis* and *Wattakaka volubilis*.

Sub Group B–Northern tropical thorn forests : These forests occur in semi-arid regions of Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan and Gujarat. The average annual rainfall varies from 20 to 70 cm with 15 to 40 rainy days. These are drier forests dominated by low thorny hard leaved evergreen trees and xerophytes on generally very shallow and poor soil. The trees and bushes are widely scattered forming a broken canopy which is under 10 m height. Climbers are scarce, and those found are mostly slender and annual. Epiphytes are represented by members of the family Loranthaceae. Large woody climbers, orchids and ferns are almost absent.

The common trees in these forests are *Acacia nilotica* ssp. *indica, A. leucophloea, A. catechu, A. farnesiana, A. torta, Aegle marmelos, Albizia lebbeck, A. procera, A. odoratissima, Anogeissus latifolia, A. pendula, Bombax ceiba, Boswellia serrata, Balanites aegyptiaca, Cordia obliqua, Crateva adansonii* ssp. *odora, Dalbergia sissoo, Gardenia spinosa, G. turgida, Hardwickia binata, Prosopis cineraria, Sterculia urens, S. villosa* and *Ziziphus mauritiana* The intermixed shrubs are usually *Capparis decidua, Dichrostachys cinerea, Flacourtia indica, F. jangomas, Grewia rothii, G. serrulata, G. tenax, Gymnosporia spinosa, Mimosa hamata, Ziziphus mauritiana* var. *fruticosa* and *Z. nummularia*. The climbers are few and generally with slender wiry twining branches entangled with shrubs and bushes. Some of the common species are *Abrus precatorius, Cajanus scarabaeoides, Cissampelos pareira, Cocculus hirsutus, Dioscorea hispida* var. *daemona, Ipomoea eriocarpa, I. nil, I. obscura, Coccinia indica, Cuscuta reflexa, Diplocyclos palmatus, Gymnema sylvestre, Gymnosporia spinosa, Momordica dioica, Mukia maderaspatana, Rhynchosia minima, Dendrophthoe falcata, Viscum nepalense* and *V. orientale*. All partly parasitic profusely branched perennials with bushy habit, are the only epiphytes commonly sighted in these forests.

3.1.7 Tropical dry evergreen forests : These forests are found in the areas where rainfall is in plenty but dry season is comparatively longer. The trees are dense, evergreen and short (under 20 m). These forests are found both in east and west coasts. The leaves are coriaceous and the crowns are spreading. The common woody plants are *Atalantia monophylla, Breynia vitisidaea, Calophyllum inophyllum, Canthium parviflorum, Carissa spinarum, Diospyros ferraea, Drypetes sepiaria, Ehretia aspera, E. microphylla, Erythroxylum monogynum, Lannea coromandelica, Manilkara hexandra, Mimusops elengi, Murraya paniculata, Pleurostylia opposita* and *Pterolobium hexapetalum*. Species of *Maba, Calotropis, Pavetta, Feronia, Canthium, Ziziphus, Randia* are also present. Bamboos are absent but grasses are common.

In Deccan, this type of forests occurs in gorges, ravines and valleys. The chief components are *Albizia amara, Atalantia monophylla, Cassine glauca, Catunaregam spinosum, Diospyros ferrea, Drypetes sepiaria, Manilkara hexandra, Memecylon umbellatum, Santalum album* and *Syzygium cumini*. In Sriharikota island on the east coast, this forest on sandy soils is dominated by *Calotropis gigantea, Feronia elephanta, Garcinia spicata, Glycosmis pentaphylla, Memecylon edule, Maba buxifolia, Strychnos nux-vomica, Ochna squarrosa, Pavetta indica, etc.*

3.1.8 Sub-tropical broad leaved hill Forests: These forests are found between 1,000 m and 1,700 m altitude in south India and about 1,000 m in central India. These forests are essentially without conifers.

Sub Group A–Southern sub-tropical broad leaved forests : The sub-types recognised are Nilgiri sub-tropical, Western sub-tropical (Mahabaleshwar) and Central Indian sub-tropical (Madhya Pradesh—Panchmarhi, Rajasthan— Mount Abu) forests. In Kerala at a height between 1,200 and 1,500 m these forests are dominated by *Calophyllum elatum, Cinnamomum sulphuratum, Eugenia wightiana* and *Ficus arnottiana*. In the Nilgiris between 1,100 and 1,700 m, *Dalbergia latifolia, Phyllanthus emblica, Olea dioica* and *Phoenix humilis* occur. In Mahabaleshwar, *Actinodaphne hookeri, Memecylon umbellatum, Pouteria tomentosa, Terminala chebula* and *Syzygium cumini* dominate. In Pachmarhi (Madhya Pradesh) *Manilkara hexandra, Mangifera indica, Syzygium cumini* dominate.

Sub Group B–Northern sub-tropical broad leaved hill forests : These forests occur on slopes of eastern Himalayas from 1,000 to 2,000 m. The important genera are *Castanopsis* spp., *Schima, Michelia, Quercus, etc.* In these forests, trees may attain a height of 50 m. with a middle storey of medium sized evergreen undershrubs. In West Bengal, *Alnus nepalesis, Bauhinia purpurea, Betula, Castanopsis* spp., *Eugenia* spp., *Michelia champaca, Quercus* spp., *Prunus* spp., *Schima wallichii* and *Terminalia bellirica* occur. In Assam and Khasi hills species of *Schima* and *Castanopsis* dominate.

3.1.9 Sub-tropical pine forests: Such forests occur throughout western, central and eastern Himalaya, from Jammu and Kashmir to Nagaland and Manipur between 600 and 2,000 m altitude. The mean annual temperature varies from 15° to 20°C with mean annual maximum ranges from 20° to 26°C and mean annual minimum from 10° to 15°C. The average annual rainfall ranges between 100 and 300 cm with number of rainy days varying between 75 and 125. These forests are economically important, dominant species being *Pinus roxburghii* in the Western and Central Himalaya, and *Pinus insularis* in Khasi, Naga and Manipur hills. Apart from *Pinus roxburghii*, the trees present are *Mallotus philippensis, Pyrus pashia, Albizia chinensis* and in moist localities *Acer oblongum, Betula alnoides, Castanopsis* spp., *Myrica nagi, Quercus glauca, Q. griffithii, Q. serrata, Rhododendron arboreum,* etc.

3.1.10 Sub-tropical dry evergreen forests : These forests occur in Siwalik hills and foothills of Western Himalaya generally up to 1,000 m altitude. The important species are *Olea cuspidata* and *Acacia modesta*, its degraded stage being *Dodonea* scrub.

3.1.11 Wet temperate forests : These are found in Himalaya with altitudes ranging from 1,800 to 3,000 m as well as in some parts of South India (Nilgiris).

Sub Group A–Southern Montane wet temperate forests : These forests occur in Kerala and Tamil Nadu on the Nilgiri, Anamalai, Palani and Tirunelveli hills from about 1,000 m upwards. These forests in south are evergreen and are called sholas. The forests are mostly confined to moist and sheltered valleys in Anamalais, Nilgiris and Pulneys. The trees found are evergreen, usually short boled and of less than 12 m height with dense round crowns, coriaceous leaves and branches covered with epiphytes, mosses and lichens. Woody climbers are also frequent. In the margins of these forests, light demadning trees and shrubs are common and they do not penetrate the shola proper. The principal trees of sholas are *Ilex denticulata, I. wightiana, Michelia nilagirica, Microtropis* spp., *Syzygium* spp., *Vaccinium leschnaultii, V. nilgherrense* and *Viburnum punctatum*. Trees found generally on the fringes of the sholas are *Eurya nitida, Photinia integrifolia, Rhododendron arboreum* ssp. *nilagiricum, Rhodomyrtus tomentosa, Symplocos cochinchinensis* ssp. *laurina* and *Ternstroemia japonica*. These are light loving species. Other plants found are species of *Berberis, Disporum, Gaultheria, Mahonia, Moonia, Valeriana, etc.* The undergrowth consists of *Abelmoschus angulosus* and species of *Arundinaria, Elatostema, Impatiens, Lasianthus, Psychotria* and *Strobilanthes*. The common pteridophytes are *Asplenium aethiopicum, A. laciniatum, Polystichum* spp. and *Osmunda regalis*. Among the climbers mention may be made of *Rubia cordifolia* and *Tylophora pauciflora*. Orchids include *Aerides ringens, Coelogyne mossiae, C. nervosa, Dendrobium nanum, Eria dalzellii, E. pauciflora, etc.* (Nair and Henry, 1983).

Sub-group B–Northern Montane wet temperate forests : These forests occur in the hills of West Bengal, Sikkim, Assam and Nagaland between 1,800 and 3,000 m. The main species are *Acer* spp., *Alnus nepalensis, Carpinus viminea, Cinnamomum obtusifolium, Machilus edulis, Michelia* spp., *Quercus lamellosa, Q. pachphylla, etc.*

Important plants constituting the vegetation in Eastern Himalaya are species of Conifers, *viz., Artocarpus, Balanocarpus, Elaeocarpus, Hopea, Myristica, Pterocarpus* and *Salmelia*. Members of families Asteraceae, Rubiaceae, Acanthaceae and Fabaceae form the undergrowth.

3.1.12 Himalayan moist temperate forests : These forests develop in the areas of lesser rainfall. These are important forests of Western and Eastern Himalaya, from 1500 to 3300 m in the States of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, West Bengal, Sikkim, Assam and Arunachal Pradesh. The mean annual temperature of the area is about 13.5°C with annual mean maximum and annual mean minimum being about 18° and 9°C respectively. Quite a good amount of precipitation is received in the form of snowfall. Average annual rainfall varies from 100 to 150 cm. The trees are tall up to 45 m height. The dominant trees are oak and conifers. Undergrowth is shrubby and consists of species of *Berberis, Cotaneaster, Spiraea, etc.*

3.1.13 Himalayan dry temperate forests : These forests occur in the inner Himalaya where the annual rainfall is below 100 cm, usually above 2,700 m, distributed in Ladakh (Jammu and Kashmir), Lahul and Spiti, Kinnur and Pangi (Himachal Pradesh), Inner Garhwal (Uttar Pradesh) and Sikkim. Here due to several biotic factors like overgrazing, lopping of trees, etc., the original forests have turned into scrub forests, where species of *Berberis, Rosa, Hippophae rhamnoides, Salix* spp., and *Juinperus* spp. dominate over others. *Cedrus deodara* forms pure stands (north of Shimla, Khajar, in Himachal Pradesh) and *Pinus gerardiana* (only in Himachal Pradesh, and

Jammu and Kashmir) appears to be gregarious in relatively drier slopes. In some places *P. gerardiana* occurs in association with *Betula utilis, Ilex, Quercus, Rhododendron campanulatum* (Hajra and Vohra, 1996). Shrub layer in these forests consists of *Daphne oleoides, Desmodium floribundum* and *Indigofera heteranta.* In the ground layer are mainly *Artemisia vulgaris, Lespedeza floribunda, Plectranthus rugosus, Polygonatum verticillatum* and *Quercus* seedlings in a grassy growth.

3.1.14 Sub-alpine forests : These forests generally occur bertween 3,000 and 4,000 m in the Himalaya. The total precipitation usually is below 100 cm, most of it being in the form of snow. At lower level, alpine forests consist of dwarf trees with or without conifers and at higher level, only scattered xerophytic shrubs are left to merge with alpine meadows. Trees are essentially stunted and either deciduous or evergreen. Some important species in the west are *Abies spectabilis* and *Picea smithiana,* while the Eastern Himalaya commonly have *Abies densa* and *Betula utilis.* Rhododendrons are mainly found as understorey along with species of *Astragalus, Berberis, Cassiope, Cotoneaster, Daphniphyllum, Juniperus, Lonicera, Polygonum, Salix, Tsuga, Taxus, etc.,* (Chauhan, 1996).

3.1.15 Moist alpine scrub: These are low dense scrubs. This type occurs above the timberline up to 5,500 m. The species of *Rhododendrons* and *Junipers* are common. *Juniperus wallichiana, J. communis* and *J. recurva* are the dominants. Alpine pastures include mesophytic herbs.

Fig. 8 : Alpine forest

3.1.16 Dry alpine scrub: These are open xerophytic formations spreading in the states of Uttar Pradesh, Himachal Pradesh, Punjab, Jammu and Kashmir. It is widespread in the inner ranges behind the main Himalayan axis where dwarf shrubs dominate. *Juniperus, Caragana* and *Eurotia* with *Salix, Myricaria, Hippophe* along streams are the main genera. Species of *Artemisia, Juniperus, Kochia, Potentilla* predominate and generally develop on limestone rock.

The tropical forests of Champion are divided into 4 sub-types, namely, wet evergreen forest, semi-evergreen forest, moist deciduous forest and dry deciduous forests. Of these, the dry deciduous forests cannot be called truly climatic, but appear to be degraded forms of the moist deciduous type due to biotic interference. The thorn forest and dry evergreen types are not only confined to tropical regions but also occur as degraded forms of subtropical and temperate regions. The differences in the floristic composition in north and south forms of the above subtypes of the tropical forests are largely not due to climate but to biotic and edaphic features. Champion divides the sub-tropical forests into 3 sub-types, namely, (1) sub-tropical wet hill forest, (2) sub-tropical moist hill forest and (3) sub-tropical dry evergreen forest. Among these, the first one is divided into northern and southern forms though not justified. The second type seems to be an edaphic association since in its stable stage, pine community is confined to quartzite formation. The third type is also not truly climatic. Among the temperate types, 3 sub types include (1) wet temperate forest (2) Himalayan moist temperate forest and (3) Himalayan dry temperate forest. The south and north types of wet temperate forests are very different and so the classification is justified. While the moist and dry temperate forests are confined to the Himalaya, the second and third types are greatly disturbed due also to biotic interference. Among the alpine types, the first one (sub-alpine forests) is influenced by geological conditions and the other two (moist alpine scrub and dry alpine scrub) are partly influenced by sheep grazing in high altitudes.

It would be seen that by far, bulk of the forest area falls among the tropical dry deciduous and tropical moist deciduous types, these being 29.4 and 23.3 mi ha respectively. Tropical thorn forests, tropical wet evergreen forests and sub-tropical pine forests constitute 5.2, 4.5 and 3.7 mi ha respectively. The area under the tropical semi-evergreen type is 1.9 mi ha while the Himalayan moist temperate and sub-alpine and alpine forests account for 2.6 and 1.8 mi ha respectively (Fig.1 & Table 2). The factual position of various types of forests based on actual forest stock maps and aerial photographs need to be determined. This is a priority activity of Forest survey of India and State and Central working plan organisations.

3.2 Fauna

Forests are the store-house of very rich and varied faunal diversity. The vegetation type is one of the most important factors which determines the faunal characteristics of a region. It is expected that each vegetation type supports a particular faunal composition. However, the fauna of a particular type of forest varies widely from one geographical area to the other depending on the geographic and altitudinal aspects as well as human interference. Again, the distribution of animal life, as we know it today, is based to a great extent upon the changes that have taken place on the surface of earth through the long ages of its geological and biogeographical history. It has been found that quite a number of species are adopted to different situations and found in more than one type of forests. Thus, the following account of fauna in different forest types provides a general faunistic composition of a particular forest type, and the same may not be totally applicable for that type of forest in all the geographical locations.

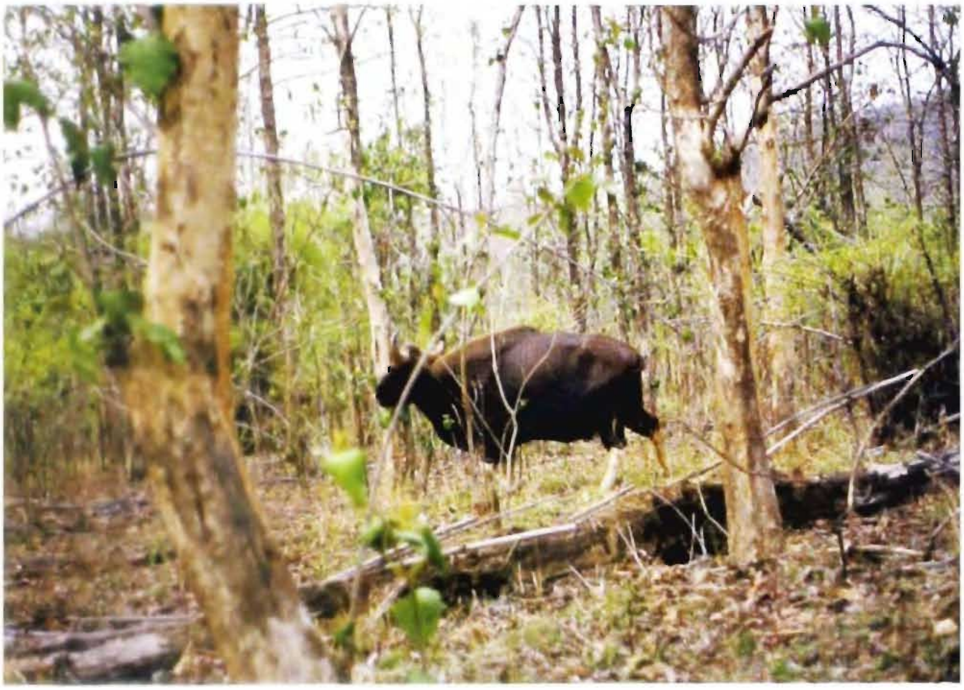


Fig. 9 : Gaur—*Bos frontalis* in forest habitat

In the evergreen forests, life at ground level is virtually suppressed by the blanket of rank and rotting vegetation, and ground animals other than reptilies and amphibians find movement difficult. Important mammalian species are elephant—*Elephus maximus,* Gaur—*Bos frontalis,* Sambar—*Cervus unicolor,* Hoolock Gibbon—*Hylobates hoolock,* Pig-tailed Monkey—*Macaca nemestrina,* Phyre's Leaf Monkey—*Trachypithecus phayrei,* Slow Loris—*Nycticebus coucang,* Slender Loris—*Loris tardigradus,* Malayan Sun bear—*Helarctos malayanus,* Tiger—*Panthera tigris,* Panther—*P. pardus,* Giant squirrels—*Ratufa* sp., Brush-tailed Porcupine—*Atherura macrourus,* Flying squirrels—*(Petaurista* sp., *Hylobetes* sp., *Belomys* sp.), Mole—*Talpa* sp., Tree shrew—*Tupaia* sp. and many species and subspecies of bats and rats. There is a good assemblage of avian species with different diets—seeds, fruits, buds, nector, insects. Some threatened bird species of evergreen forests are White-winged Wood Duck—*Cairina scutulata,* Black Crested Baza—*Aviceda leuphotes,* Bhyth's Tragopan—*Tragopan blythii,* Painted Bush Quail—*Pardicular manipurensis,* Bamboo Patridge—*Bambusicola flytchii,* Burmese Pea Fowl—*Pavo muticus,* Hornbills—*(Rhyticeros* sp., *Buceros* sp.), *etc.* Many other species of birds, *viz.,* Tickell's babbler—*Trichastoma tickelli,* Red-breasted Flycatcher—*Muscicapa pava,* Black-breasted Sunbird —*Aethopyga satura,* Warblers *(Seicarcus* sp., *Abroscopus* sp.) are the common inhabitant of this type of forest. A very rich reptilian and amphibian fauna are also met with, such as, Indian Python—*Python reticulatus,* Banded Krait—*Bungarus fusciatus,* Common Cobra—*Naja naja* King Cobra—*Ophiphagus hannah,* Blind Snake—*Typhlops diardi,* Indian Monitor—*Varanus bengalensis,* Blue-throated Lizard—*Ptyctolaemus gularis,* Tree Frogs—*Rhacophorus* sp., different species of Caecilians, Microhylids and Pelobatids.

Since the sunlight is able to filter through to the forest floor in semi-evergreen type, dense tangled undergrowth flourishes. Among the arboreal mammals different species of bats (*Pteropus* sp., *Cynopterus* sp., *Rousettus* sp., *Hipposideros* sp., *Rhinolophus* sp., *etc.),* Tree shrew *(Tupaia* sp.), Squirrels *(Collosciurus* sp., *Dremomys* sp., *Tamiops* sp., *Petaurista* sp., *etc.),* Monkeys *(Macaca assamensis, M. mulatta, M. arctoides),* Langurs (*Trachypitheues johnii, T. pileatus, T. geei)* are common. Among the ground forms, different species of rodents *(Rattus* sp., *Cannonys* sp., *Hystrix* sp.), deer (*Muntiacus* sp., *Axis* sp., *Cervus* sp.), Elephant—*Elephus maximus,* Wild Boar—*Sus scrofa,* Gaur—*Bos frontalis,* Tiger—*Panthera tigris,* Panther—*P. pardus,* Black Bear—*Melursus ursinus,* Otters (*Lutra* sp. *Lutrogele* sp.,) Civets *(Viverricula* sp., *Vivera* sp., *Paradoxurus* sp., *Paguma* sp.) Clouded Leopard—*Neofelis nebulona,* Leopard Cat—*Prionailurs bengalensis,* Hare—*Lepus* sp., etc., are frequently met with. Pangolins—*Manis* sp. are also occasionally found. Amphibian, reptilian and avian fauna are very rich and by and large species composition is not strikingly different from that of evergreen forest.

Tropical deciduous forest harbours a large number of small to medium sized carnivores, *viz.*, Hyaena—*Hyaena* sp., Jackal—*Canis aureus*, Wolf—*Canis lupus*, Fox—*Vulpes* sp., Mongooses—*Herpestes* sp., Civet—*Viverricula* sp. and also tiger and leopard. Small herds of elephants are also found in some of the deciduous forests. Deer species are mostly common with that of semi-evergreen type. Four-horned Antelope—*Tetracerus quadricornis*, Nilgai—*Boselaphus tragocamelu* are found in relatively drier parts of the country. A very rich species composition of rodents and chiropteran mammals is found everywhere. Another characteristic mammalian species is the Tree-shrew—*Anathana ellioti*, Among the birds, nightjars, pigeons, doves, orioles, koels, kingfishers, woodpeckers, myna, lapwings, owls, rollers, hoopoe, bee eaters, barbets, Tree-pies bulbuls, *etc.*, exhibit abundance and species richness. One of the most threatened species of bird Jerdon's Courser—*Cursorius bitorquatus* has been recorded from Andhra Pradesh. Among the reptilian species *Calotes* sp., *Hemidactylus* sp., *Gekko* sp.,*Varanus* sp., *Calodactylodes* sp., *Psammophilus* sp., *Mabuya* sp. *Chamaeleon* sp., *Python molurus*, *Naja naja*, *Ophiophagus hannah*, *Ptyas mucosus* are very common. Amphibians are mainly represented by different species of Bufonidae and Ranidae.

Fauna of temperate and alpine forest is somewhat distinct from the the earlier described ones. Snow Leopard—*Panthera uncia*, Emuine—*Mustela erminea*, Pallas's cat—*Otocolobus manul*, Brown Bear—*Ursus arctos*, Panda—*Ailurus fulgens*, Musk Deer—*Moschus monchiferus*, Himalayan Tahr—*Hemitragus jemlahicus*, Tibetan Gazelle—*Procapra picticaudata*, Tibetan Antelope—*Pantholops hodgsoni*, Ibex—*Capra ibex*, Nayan—*Ovis ammon*, Yak—*Bos grunniensis*, Kiang—*Equus kiang*, voles (*Pitymys* sp., *Alticola* sp.), Flying Squirrel—*Eupetaurus cinerenus*, Pika—*Ochotona* sp., *etc.*, are the mamalian species confined to these regions. Many of the threatened avian species like Tibetan Snow Cock—*Tetraogallus tibetanus*, Tibetan Blood Pheaset—*Ithaginis cruentus*, Western Trogopan—*Tragopan melanocephalus*, Crimson Horned Tragopan—*T. satyra*, Himalayan Monal Pheasant—*Lophophorus impejanus*, *etc.*, are the characteristics of alpine and temperate forests. Number of reptilian and amphibian species are not too many, but most of them have restricted distriution, such as, Himalayan Rock Lizard—*Agama tuberculata*, Toad-headed Agama—*Phrynocephalus theobaldi*, Mountain Agamids—*Japalura* sp. Mole Skink—*Eumesces taeniolatus*, Himalayan Newt—*Tylototriton verrucsus*, Green Toad—*Bufo viridis*, Himalayan Frog—*Rana liebigii*, Caecilian—*Ichthyophis sikkimensis*, *etc.*

Grassland and thorn forest also hold some characteristic fauna. Some of the threatened species of mammals, *viz.*, One-horned Rhinoceros—*Rhinoceros unicornis*, Hispid Hare—*Caprolagus hispidus*, Pygmy Hog—*Sun salvanius*, Nilgiri Tahr—*Hemitragus hylocrius* are mainly restricted to grassland, while Indian Wild Ass—*Equus onager* is found in desert or thorn forest of Gujarat.

4. INTRODUCED BIODIVERSTY

The following indigenous and exotic species have been introduced in the form of plantations : (i) Sal and Teak; (ii) Chir Pine and Blue pine; (iii) Deodar, Fir and Spruce, (iv) *Cryptomeria japonica*, (v) *Casurina equisetifolia*, (vi) Khair and Sisham and (vii) Poplars.

These species have been planted over large areas which were devoid of tree cover for a very long period. Such lands are mainly marginal lands, wastelands and strips along roads, railway lines, canals and even agricultural and pasture lands. The plantations are mainly of one or two species.

5. VALUE

Values of forest ecosystems are immense. Forests were the part and parcel of ancient people. Even today, they are the source of material progress and basis of spiritual and moral inspiration of human being.

(i) **Ethical** : Forests are intricately connected with Indian religion and culture. In ancient India most form of education were imparted within the surrounds of forests. The major incidents described in both the great Indian epics, the Ramayana and the Mahabharata also happened inside the forests.

(ii) **Ecological** : Forests play a very significant role in soil and water conservation, regulation of water yield and rate of siltation of reservoir. These ecosystems of India are the store house of innumerable varieties and variabilities of plants, animals and micro-organisms. They also play a major role in controlling floods, droughts, desertification and environmental pollution.

(iii) **Economical** : The forests contribute about 1.7 percent of the GDP of the country. A large part of the forest production consists of fuel, timber, fooder, medicine and food.

Forests meet the increasing demand of timber. As per ICFRE estimate, the current demand of timber is around 30 million cu m, out of which 8.3 million cu m is required for paper, pulp and pannel and 15.4 cu m for saw milling for the purpose of housing, packaging, furniture, *etc.*

Forest produce about 30 percent of the fuel wood. They also contribute 30 percent of the fodder requirement of the country.

The non-wood forest products play a very important role in modern economy. Such products include wild edible products, Sal, Mohua, Neem or other seeds, Sal oil, Mahua oil and some essential oils, gums, resins, turpentines, tans, dyes, bamboo, fibres, grasses, Bidi and Tendu leaves, *etc.* These products form the basic raw material of the industries of phyto-pharmaceutical, phyto-chemicals, dyes, tanins, seed oil, amora, resins, *etc.* In fact, over 50% of the revenue earned by the Forest Departments comes from non-wooded forest products.

(iv) **Social** : Forests provide ample opportunities for self employment to the forest dwellers. One hectre of forest plantation from rising of nurseries to harvesting stage creates nearly 630 man days as per ILO estimate. In the remotest areas forestry may be the only source of employment and income. Through participatory forest management forest dwellers are also benefited to some extent.

6. THREATS

Most of the forest ecosystems in India are under acute form of degradation mainly due to following factors although each ecosystem is having specific problems.

- Loss of forest land due to agriculture, industries and human settlement.
- Loss of forest land due to multipurpose projects, construction of roads, erection of transmission lines, quarrying, shifting cultivation, *etc.*
- Degradation due to illicit felling, lopping for fodder and fuel wood, overgrazing, forest litter removal, forest fires, over felling, conversion to monoclure, mining, army operations, introduction of exotics, fire and pollution.
- Human and cattle population explosion around forest land.

The other causes of degradation of this ecosystem are poverty, landlessness, derivation of livelihood from forests, lack of land use planning, biotic interferences and lack of restrictive covenants and punitive legislations.

7. CONSERVATION

Some effective steps have already been taken for conserving forest ecosystems of India.

- Enactment of the Indian Forest Act, 1927, Wildlife (Protection) Act, 1972 and Wildlife (Protection) Amendment Act, 1991, Forest (Conservation) Act, 1980, CITES, adoption of National Wildlife Action plan, 1983, Environment (Protection) Act, 1986.

- Approximately 4.65 percent of the total geographical area of the country has been earmarked for extensive *in-situ* conservation of habitats and ecosystems. A protected area network of 89 National Parks and 482 Wildlife sanctuaries has been created, majority of which are within the forest ecosystems.
- Indian Council of Forestry Research and Education (ICFRE) has identified 309 forest preservation plots of representative forest types for conservation of viable and representative areas of biodiversity, covering a total area of 8,500 hectares. Out of these, 187 plots are in natural forests and 112 are in plantations. There are 2,554 sample plots wherein regular monitoring studies are being done for the plant growth, regeneration, mortality and plant succession.
- Twelve biodiversity rich areas of the country, covering about 1 percent of the total geographical area have been desigated as Biosphere Reserves for coserving representative ecosystems.
- For *ex-situ* conservation of rare and endangered species germ plasm banks have been created. For conserving genetic variability clonal banks, multiplication gardens, clonal and seedling seed orchards, seed bank and tissue culture laboratories have also been set up.
- Various management systems including Participatory Forest Management are being practiced at present for conservation of forest ecosystems. A programme entitled "Ecodevelopment" has been initiated in recent years to integrate the ecological and economic parameters for sustained conservation of ecosystems, involving the local communities surrounding the protected areas.

Irrespective of all these, forest degradation is being continued as discussed earlier. For effective conservation of this ecosystem ICFRE has recently formulated National Forestry Research Plan.

8. REFERENCES

Balakrishnan, N.P. and J.L. Ellis. 1996. Andaman and Nicobar Islands. In: *Flora of India, Introductory Volume part I* (ed. P.K. Hajra *et al.*) : 523-538. Deep Printers, New Delhi.

Blasco, F. 1975. Mangroves of the deltas of Godavari & Krishna. In: *The Mangroves of India,* Institute Francais de Pondicherry.

Brandis, D. 1874. *The Forest Flora of North-West and Central India.* London.

Champion, H.G. 1936. A preliminary survey of the forest types of India and Burma. *Ind. For. Rec.* (n.s.) *Silv.* **1** : 1-286.

Champion, H.G. and S.K. Seth. 1968. *A revised survey of forest types of India.* New Delhi.

Chapman, V.J. 1975. *Mangrove vegetation*, Cramer, Lehre.

Chauhan, A.S. 1996. North-Eastern India and North Bengal. In: *Flora of India, Introductory Volume part I* (ed. P.K. Hajra *et al.*) : 251-294. Deep Printers, New Delhi.

Hajra, P.K. and J.N. Vohra. 1996. North West Himalayas: *Flora of India. Introductory 'Volume part I.* (ed. P.K. Hajra *et al.*) : 205-219. Deep Printers, New Delhi.

Henry, A.N., N.C.Rathakrishnan, and T. Ravishankar. 1996. Deccan. In: *Flora of India, Introductory Volume Part I.* (ed. P.K. Hajra *et al.*) : 456-476. Deep Printers, New Delhi.

Karthikeyan, S. 1996. Northern Western Ghats and Northern West Coast. In: *Flora of India, Introductory Volume part I.* (ed. P.K. Hajra *et al.*) : 375-390. Deep Printers, New Delhi.

Mani, M.S. 1974. *Ecology and Biogeography of India.* W. Junk Publishers. The Hague.

Mathur, C. M. 1960. Forest types of Rajasthan. *Indian Forester,* **86** : 734-739.

Meher- Homji, V.M. 1973. Phytogeography of the Indian Subcontinent. Progress of Plant Ecology **1** : 9-88.

Mehra, R.N., K.S.Bawa, P.K. Khosla and A. S. Hans. 1983. Floristic account of some forest types of the Eastern Himalayas. *Bull. Bot.Surv. India,* **25** : 1-18.

Nair, N.C. and A.N. Henry (eds.) 1983. *Flora of Tamil Nadu, India-Series I Analysis.* Coimbatore

Puri, G.S. 1954. Forest types studies in India. *J. Ind. Bot. Soc.,* **33** : 19-27.

Puri, G.S. 1960. *Indian Forest Ecology.* Oxford, New Delhi.

Puri, G.S., V.M. Meher-Homji, R.K. Gupta, and S. Puri. 1983. *Forest Ecology,* Vol. I. New Delhi.

Raheja, P. C. 1965. Influence of climatic changes on the vegetation of arid zone in India. *Ann. Arid Zone* **4** : 64-73.

Ranganathan, C.R. 1938. Studies in the ecology of Shola grassland vegetation of Nilgiri plateau. *Indian Forester,* **64** : 523-540.

Rao, A.S. 1974. Vegetation and Phytogeography of Assam-Burma. In: *Ecology and Biogeography in India* (ed. M.S. Mani) : 204-246. The Hague.

Roy, G.P. 1996. Indo.Gangetic plains. In: *Flora of India, Introductory Volume part I.* (ed. P.K. Hajra *et al.*) 220-224. Deep Printers, New Delhi.

Toumey, J.W. and C.F. Korstian 1947. *Foundations of Silviculture upon ecological basis.* London.

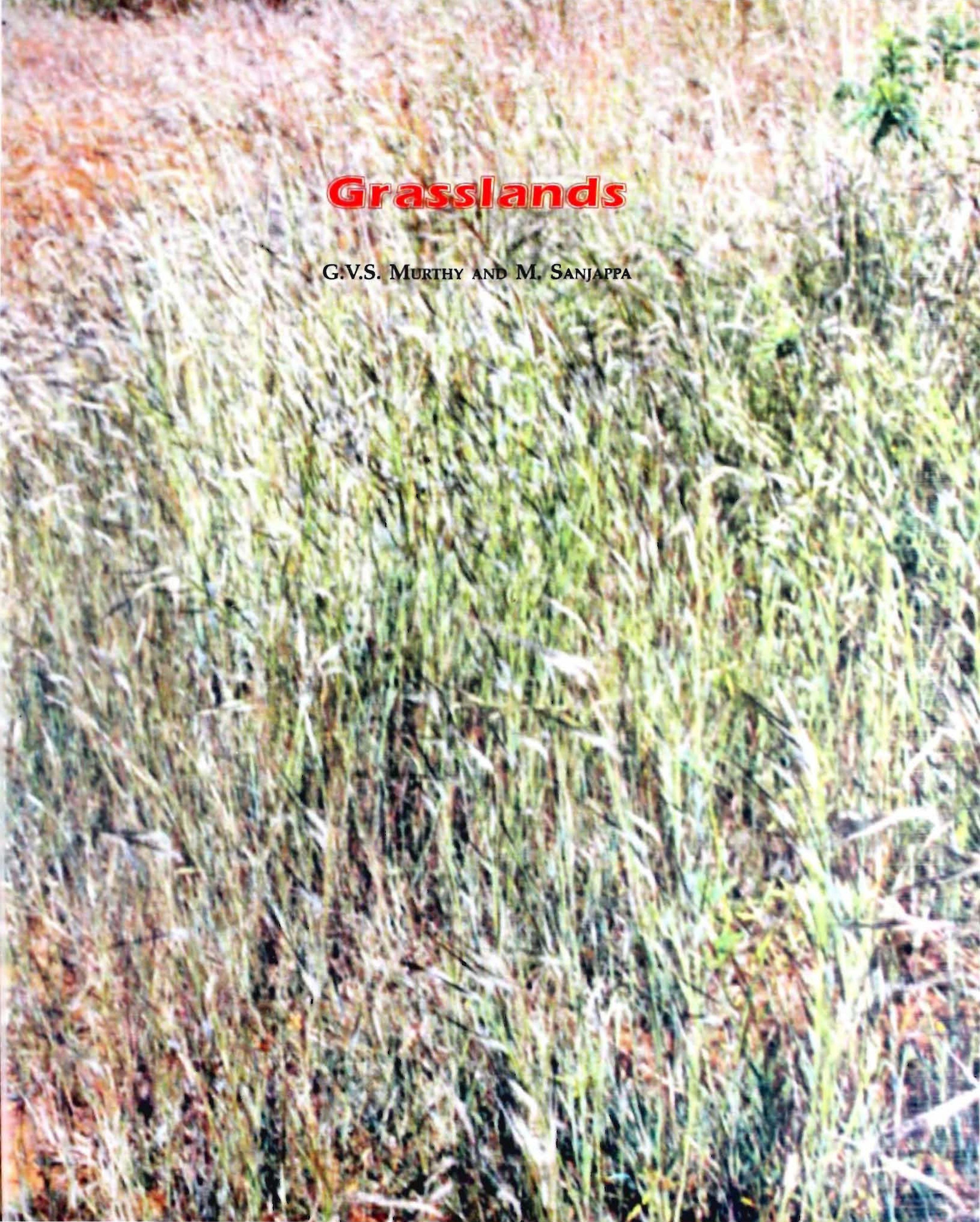
Vajravelu, E. and K. Vivekananthan. 1996. Southern Western Ghats South of Goa. In : *Flora of India, Introductory Volume part I.* (ed. P.K. Hajra *et al.*) : 391-445. Deep Printers, New Delhi.

Verma, D.M. 1996. Central India. In: *Flora of India, Introductory Volume part I.* (ed. P.K. Hajra *et al.*) : 295-326. Deep Printers, New Delhi.

Willis, J.C. 1951. *A Dictionary of the flowering plants.*(6th ed.). Cambridge Univ. Press, Cambridge.

Grasslands

G.V.S. Murthy and M. Sanjappa



ENVIS–*Zool. Surv. India*
Ecosystems of India : 149-163, 2001.

Grasslands

G.V.S. MURTHY AND M. SANJAPPA*

Botanical Survey of India
Southern Circle, TNAU Campus, P.O. Lawley Road, Coimbatore-641 003

1. INTRODUCTION

Grassland means a landscape in which the grasses are the dominant plants. Grasslands are found in regions where climatic and edaphic conditions are such as to prohibit growth of trees. Lesser rainfall and frequent light showers keep the upper layers of soil moist so that grass continues to grow. Grasslands occupy about 20% of the earth's land surface.

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

A natural grassland is a plant community in which the dominant species are perennial grasses, with few or no shrubs and trees absent. Usually grasslands are composed of grasses and a variety of other herbaceous plants, both annual and perennial types which give a characteristic aspect to the plant community (Moore, 1964). Where water is more abundant, sedges (Cyperaceae) grow side by side with true grasses. A large number of Compositae (Asteraceae) and Leguminosae (Fabaceae) plants grow in meadows and lawns and these plants out number grasses in highland pastures.

Grassland is one of a number of seral phases of vegetation. The vegetation structure is dynamic, one ecological association follows another in an orderly sequence, known as the "Sere" If the enviornmental conditions are not favourable the development of the sere may be arrested and end at a sub-climax. Because of their seral nature, grassland communities change their composition when grazing or burning pressure is relaxed. The interaction of local variations in climate and topography with grazing intensity results in a myraid of communities. Individual species of such communities often interact with each other and show varied pattern of interspecific association.

According to one estimate 3.9% of the total area of our country is occupied by grasslands. The grasslands of India are of great diversity. These include semi-arid and arid grasslands of Deccan Peninsula and Rajasthan, water-logged grasslands of Terrai belt, the rolling shola-grasslands of hill tops of Western Ghats and the high altitude temperate-alpine grasslands of Himalaya. The grasslands in India, except for those occurring in the alpine regions, are seral in nature and are maintained at various successional stages by grazing and burning. According to Champion (1936) there is no climatic climax of a grassland in India except the high Himalayan meadows. According to Whyte (1974) these monsoon grasslands, occurring in a forest climate, may be called teritiary communities.

* Botanical Survey of India, Central National Herbourium, P.O. Botanic Garden, Howrah-711 103

2.1 Climate and Soils

India situated between 8°-37° north latitudes is entirely tropical except for the high altitude mountains—the Himalaya and the Nilgiris—which have temperate and arctic climates. The Indo-Gangetic plain though lying geographically in the subtropical region remains tropical in effect, on account of the high Himalaya shielding it from the northern cold winds and holding the monsoon and the southern warm winds within the country. India's climate is affected by two seasonal winds, the south-west monsoon and the north-east monsoon. The heaviest rain falls along the Western Ghats in the coastal plains of Kerala and Karnataka, in the foot hills of the eastern and central Himalaya (Fig. 1). As one proceeds from the east to the west in northern India, from Manipur to Rajasthan, the annual rainfall decreases from 3000 mm to 300 mm or less with the number of months of the dry season increasing from 3 to 9. The forests accordingly phase out in the east-west sequence of wet evergreen, moist mixed, moist deciduous, dry deciduous and dry evergreen types. The diversity, height and density of the trees also fall along this gradient, but the grass undergrowth follows a reverse trend.

The soils of India have been broadly classified into eight categories: alluvial soils, black soils, red soils, laterites, mountain and hill soils, arid and desert soils, saline and alkaline soils and peat soils (Raychaudhary, 1966). The alluvial soils are the most fertile soils and occur in Gangetic-Barhmaputra plains. The black soils are pre-dominant in Central India, while red soils are derived from weathered metamorphic rocks of the Deccan plateau. Laterites are well-developed on the hills in the Deccan trap. The arid and desert soils are pre-dominantly sandy and mostly occur in Rajasthan and parts of Haryana and Punjab. Saline and alkaline soils occur in many parts of arid and semi-arid areas of the country. Peat soils occur in humid regions and are often water-logged.

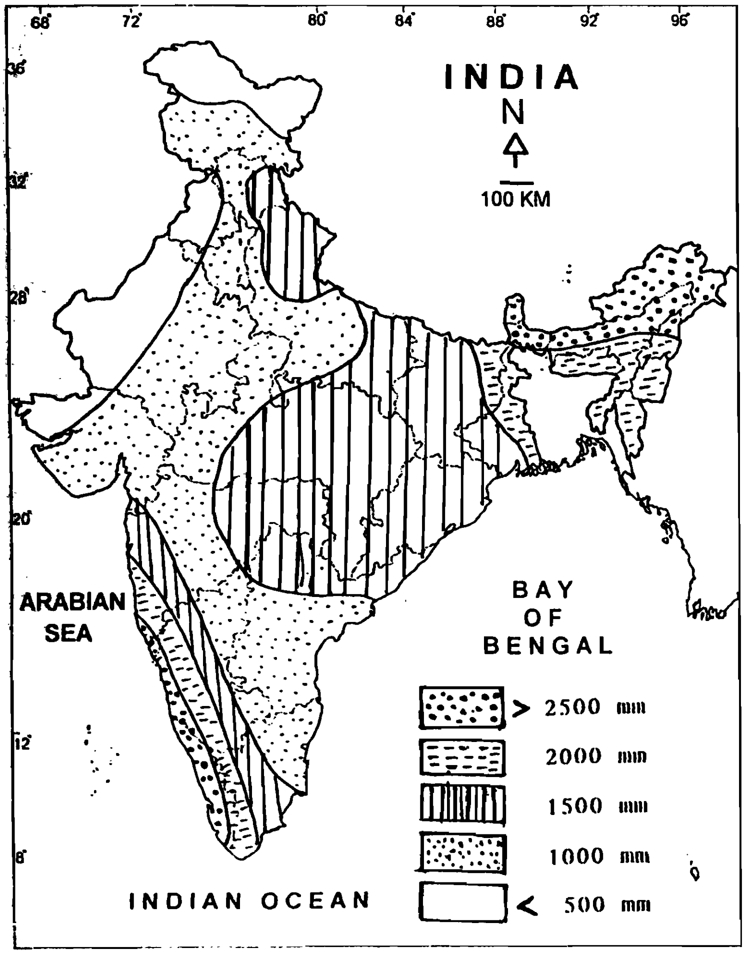


Fig. 1 Annual Rainfall in India

Fig. 1 : Annual Rainfall in India

3. GRASSLAND TYPE AND COMMUNITIES

In India grasslands range from village grazing grounds and extensive low pastures of dry regions to alpine Himalaya. The grasslands of India have been variously classified by different workers using different parameters. The Indian Council of

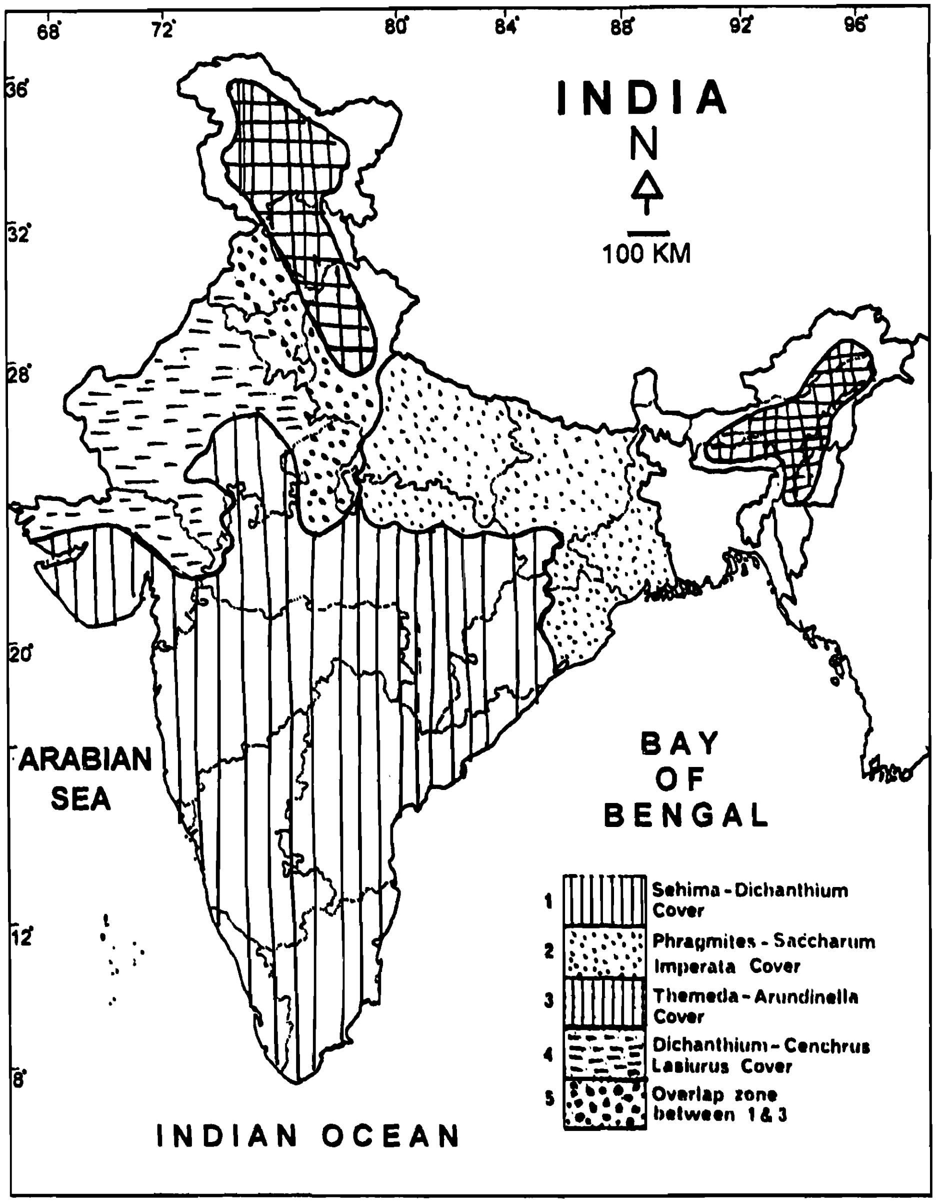


Fig. 2 : Grass covers of India (after Dabadghao and Shankaranarayan, 1973)

Agricultural Research carried out a survey of grasslands in India. Whyte, Venkataraman and Dabadghao (1954) distinguished eight grassland types in the country. Puri (1960) has classified the grasslands on the basis of moisture as Xerophilous, Mesophilous and Hygrophilous grassalnds. According to Whyte (1968) the distribution of grass covers is governed by climatic factors and particularly by latitude. Thus *Sehima-Dichanthium* cover is tropical, the *Dichanthium-Cenchrus-Lasiurus*, *Phragmites-Saccharum-Imperata* and *Themeda-Arundinella* covers are sub-tropical. The temperate-alpine covers are different. The altitude separates *Phragmites-Saccharum-Imperata* and *Dichanthium-Cenhrus-Lasiurus* types of plains from that of *Themeda-Arundinella* type confined to northern hills.

Yadava and Singh (1977) have given a good review on grassland communities in India. Some of the important studies on grasslands from different regions of India include: Rajasthan (Shah, 1957; Prakash, 1958; Puri, 1960; Vyas, 1964; Gupta and Saxena, 1966, 1972), Uttar Pradesh (Ramam, 1966; Misra, 1959 and Shankara-narayan and Dabadghao, 1970), Madhya Pradesh (Pandeya, 1964 and Singh, 1972), West Bengal (Chaudhuri, 1959), Assam (Bor, 1940, 1942), Himalaya (Mohan, 1955; Raina, 1959; Agarwal, 1959 and, Gupta and Nanda, 1970), Deccan (Burns and Kulkarni, 1921, 1927, 1928) and Western Ghats (Fischer, 1921; Ranganathan, 1938; Bharucha and Shankaranarayan, 1958; Meher-Homji, 1965; Whyte, 1968 and Blasco, 1971).

Dabadghao and Shankaranarayan (1973) have recognised five main/broad grass cover types in India (Fig.2) and discussed their distribution in relation to climate, topography and soil factors A myraid of distinct or transitional communities have been recognised by others within each of the major grassland types.

3.1 Sehima-Dichanthium type

The largest of the five grass zones of India, covers the Peninsular India, including the Central Indian Plateau, the Chota Nagpur Plateau and the Aravalli ranges, comprising the states of Gujarat, Maharashtra, Madhya Pradesh, Orissa, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, South-West Bengal, Southern Bihar, Southern Uttar Pradesh and Rajasthan. The topography is undulating to hilly and the elevation ranges between 300 and 1200 m. The rainfall is monsoonal and varies from 300 mm (Kutchch) to 6450 mm (Western Ghats) annually. Soils are gneissic or basaltic in origin and colour ranges from pale brown to dark grey. The floristic list includes 24 perennial grasses, and 129 other herbaceous species of which 56 are legumes. The principal grasses are *Sehima, Dichanthium, Iseilema, Ischaemum, Chrysopogon, Bothriochloa, Heteropogon* and *Themeda*. These communities have a common growth pattern. Growth starts with arrival of the monsoon in June/July and attains a peak in September. The grasses mature by November and remain dormant during the eight month dry period. The thorny bushes and trees of the savannah are *Acacia catechu, Mimosa rubicaulis, Zizyphus* sp. and sometimes fleshy *Euphorbia, Anogeissus latifolia, Soymida febrifuga* and other deciduous species.

The *Sehima* community is more prevalent on gravel soils as in the states of Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Kerala. The cover of *Sehima* may be 87%. The *Dichanthium* community flourishes on level flat soils and may cover 80% of the ground.

Pandeya (1964) has recognised eight different grassland associations at Sagar (Madhya Pradesh) under the *Sehima-Dichanthium* cover. They are: *Aristida-Melanocenchris, Heteropogon-Andropogon, Cymbopogon-Eulalia, Themeda, Coix-Ischaemum, Bothrichloa-Dichanthium, Sehima-Chrysopogon-Tripogon* and *Cynodon-Bothriochloa-Dichanthium*. Similarly V.P. Singh (1972) recognised nine grassland communities at Ujjain (Madhya Pradesh). The Vindhyan uplands possess *Saccharum-Vetiveria* grassland along river banks and flood plains, while *Heteropogon* grassland prevails in dry areas (Ramam, 1966).

Fig. 3 : Grassland near Kolhapur, Maharastra

Six grassland associations are recognised from Western Ghats by Bharucha and Shankara-narayan (1958). These associations are: *Themeda triandra-Burmannia pusilla, Eragrostis unioloides- Alloteropsis cimicina, Arthraxon meeboldii-Alysicarpus belgaumensis, Blumea eriantha-Eriocaulon minutum, Themeda quadrivalvis-Habenaria longecalcarata* and *Gracilea royleana-Lophopogon tridentatus*.

3.2 Dichanthium-Cenchrus-Lasiurus type

It occurs in the semi-arid zone covering the northern portion of Gujarat, Rajasthan (excluding

Aravallis), western Uttar Pradesh, Delhi and Punjab. The topography is broken by hill spurs and sand dunes. The annual rainfall ranges between 200 and about 700 mm on the eastern boundary. There are high summer temperatures, relatively severe winters and frosts being frequent in December and January. Alluvial soils, sandy to sandy loam in texture. The floristic list includes 11 perennial species of grasses and 45 other herbaceous species, of which 19 are legumes. The most important species are *Dichanthium annulatum, Cenchrus ciliaris, C. setigerus, Lasiurus hirsutus, Ocththochloa compressa, Cynodon dactylon, Sporobolus marginatus, S. pallidus, Panicum turgidum, Heteropogon contortus* and *Dactyloctenium sindicum*. To this list may be added scattered shrubby growth of *Acacia senegal, Calotropis gigantea, Senna auriculata, Prosopis spicigera, Salvadora oleoides* and *Zizyphus nummularia* which make the grassland (Savannah) look like scrub forest from a distance.

In this cover the dominant species are *Dichanthium annulatum, Cenchrus ciliaris* and *Lasiurus sindicus*. *Dichanthium annulatum* shows the highest expression in grasslands developed in low-lying areas. *Cenchrus setigerus* and *Cenchrus ciliaris* show good growth where soil moisture conditions are medium but not too dry. On the drier places as in the western Rajasthan, with a rainfall varying from 90 300 mm on loose sandy soils, *Lasiurus* community is favoured, with *L. sindicus* as the dominant species. *Cenchrus ciliaris, Cynodon dactylon, Dichanthium annulatum* and *Lasiurus sindicus* are preferred by the grazing animals.

3.3 Phragmites-Saccharum-Imperata type

This type occurs in the moist subhumid zone, covering the Ganga alluvial plain (Uttar Pradesh, Bihar and West Bengal), Brahmaputra valley (Assam, Manipur and Tripura) and extends westwards into the plains of the Punjab and Delhi. The topography is level, low-lying and ill-drained. The rainfall may range from 1000 to 2000 mm. The floristic list includes 19 principal grass species and 56 other herbaceous species including 16 legumes. In the transitional zone between this and *Sehima-Dicanthium* cover type, *Bothriochloa pertusa, Cynodon dactylon* and *Dichanthium annulatum* are found. *Narenga porphyrocoma* occurs in sal forest.

In low rainfall region only six perennial species, *viz., Desmostachya bipinnata, Imperata cylindrica, Phragmites karka, Saccharum arundinaceum, S. bengalensis* and *S. spontaneum* seem to be represented as compared to a more diverse vegetation found in the high rainfall region. The tree and shrub species commonly associated with these grasslands are *Acacia nilotica* ssp. *indica, Anogeissus latifolia, Butea monosperma, Phoenix sylvestris* and *Zizyphus nummularia* on the palm savannah near the Sundarbans.

3.4 Themeda-Arundinella type

This grass cover extends to the humid montane regions and moist subhumid areas of Manipur, Assam, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh and Jammu and Kashmir. It is found around the altitude of 350 m above sea level, the upper limit being 2,100 m. The tract between 1,800 and 2,100 m altitude is considered as transitional zone. The rainfall varies from about 1,000 mm in the western region to over 2,000 mm in the east. Snowfalls are quite common in winter. The soils are shallow and gravelly with a pH of 6.2.

The dominant perennial grasses are *Arundinella bengalensis, A. nepalensis, Bothriochloa intermedia, B. pertusa, Chrysopogon fulvus, C. gryllus, Cymbopogon jwarencusa, C. olivieri, C. stracheyi, Cynodon dactylon, Dimeria fuscesens, Eragrostiella leioptera, Eulaliopsis binata, Heteropogon contortus, Ischaemum barbatum* and *Themeda anathera*. Out of 34 herbaceous species associated with this type, 9 are legumes. *Themeda anathera* grows luxuriently when the grassland is subjected to light disturbance as cutting or grazing. Sometimes it may cover up to 80% (in Kashmir). The savannah type is derived from the humid forests on account of shifting cultivation and sheep grazing. The tree and shrub elements are varied and numerous as given by Champion and Seth (1968).

3.5 Temperate - Alpine Type

This type occurs on the Himalayan mountains above 2,100 m in the west and above 1,500 m in the east covering parts of Jammu and Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, West Bengal and Assam. Snow fall is a common feature during winter season. The dominant perennial grass species of this cover are *Agropyron canaliculatum, Agrostis canina, A. filipes, A. munroana, A. myriantha, Andropogon tristis, Calamagrostis epigejos, Chrysopogon gryllus, Dactylis glomerata, Danthonia jacquemontia, Koeleria cristata, Phleum alpinum, Poa pratensis* and *Stipa concinna*. About 35 perennial grass species are associated with this cover type. In all 68 herbaceous species have been reported, of which 6 are legumes.

Temperate alpine grasslands form a distinct and important group in Kashmir, locally known as "Margs" From western Himalaya, Gupta and Nanda (1970) have described 11 grassland types. These are grouped under three categories, namely, alpine and subalpine, temperate and, tropical and subtropical according to the altitudinal zones of occurrence. The first two categories are described here, whereas the last category falls under *Arundinella* cover.

3.5.1 Alpine Subalpine Grasslands : These grasslands occur on steep slopes forming alpine meadows above 4,200 m, where the climate is too cold and not favourable for tree growth. The ground remains covered with snow for more than 6 months in a year and precipitation is low. Large herds of cattle, sheep and goats visit these areas during summer season. The following types occur in this zone.

(i) Agrostis type : This grassland occurs between 4,000 m and 5,200 m altitudes. The common grasses are *Agrostis canina, A. munroana, Calamagrostis epigejos, Festuca valesiaca, Hierochloe laxa, Poa annua, P. pagophila, P. stewartiana, P. pratensis, Polypogon fugax, Stipa concinna, S. sibirica, Trisetum aeneum, T. clarkeii, T. flavescens, T. spicatum* and *Andropogon tristis*.

(ii) Danthonia type : It occurs between 3,200 m and 4,200 m altitudes and forms large patches in forest gaps caused by fires and landslips. The common grasses are *Danthonia jacquemontii, D. cachemeriana, Koeleria cristata, Calamagrostis emodensis, C. epigejos, Festuca lucida, Poa annua, P. pratensis, Brachypodium sylvaticum, Stipa sibirica* and *Trisetum clarkeii*.

(iii) Puccinellia type : The prominent grasses are *Puccinellia kashmiriana, Trisetum spicatum, Poa alpinia, P. pratensis, P. annua* and *Heirochloe laxa*. This grassland type is confined to the eroded slopes.

Fig. 4 : Alpine gıass meadows mixed with scrub at Jongri (*C.* 4200 m altitude)

(iv) Pheum alpinum type : The dominant species of this grassland are *Phleum alpinum, Agropyrum semicostatum, A. canaliculatum, Poa pogophilla, P. jaunsarensis, P. alpina, P. annua, Calamagrostis littorea, C. epigejos, Agrostis munroana, Festuca ovina, F. kashmiriana, Deschampsia caespitosa* and *Deyeuxia scabrescens.* This type occurs on well-drained slopes and flat meadows with more soil moisture.

The grass cover of Punjab Himalaya was described by Mohan (1955). The dominant grasses are *Agrostis stolonifera, Agropyron longearistatum, A. semicostatum, Brachypodium sylvaticum, Bromus asper, Calamagrostis emodensis, Dactylis glomerata, Festuca kashmiriana, Koeleria cristata, Milium effusum, Pennisetum flaccidum* and *Poa* spp.

The alpine grasslands of Garhwal Himalaya are dominated by *Festuca rubra, F. bromoides, F. sibirica, Agropyron semicostatum, Agrostis* spp., *Arthraxon* spp., *Avena* spp. and *Bromus* spp. (Agarwal, 1959).

3.5.2 Temperate Grasslands : These grasslands are characteristic of the oak-conifer forest region. The soils are deep and moist. During winter animals graze in these grasslands. The following major types are reported from Western Himalayas (Gupta and Nanda, 1970).

(i) Chrysopogon gryllus type : *Chrysopogon gryllus* is the dominant grass associated with *Heteropogon contortus, Themeda anathera, Koeleria cristata, Bothriochloa pertusa, Eragrostis anathera, Polypogon fugax, Rottboellia exaltata, Agrostis canina* and *Festuca* spp.

(ii) Poa pratense type : This type occurs mostly between 2,500 m and 2,800 m altitudes. The dominant grasses are *Poa pratensis, P. annua* and *P. stewartiana.*

(iii) Themeda anathera type : This type occurs between 1,700 m and 2,200 m. The major grasses are *Themeda anathera, Arundinella setosa, A. nepalensis, Polypogon fugax, Melium effusum, Bothriochloa intermedia, Oryzopsis aequiglumis, Cynodon dactylon, Festuca gigantea, Phalaris arundinacea, Bromus ramosus* and *Eragrostis minor*. In the Garhwal Himalayas *Themeda anathera* and *Arundinella setosa* dominate the grass lands.

The following grass associations are enumerated from the temperate zone of Punjab Himalayas (Mohan, 1955) and Himachal Pradesh (Raina, 1959).

Upper Oak-Conifer forest (2,500 to 3,000 m) : *Agropyron longearistatum, A. semicostatum, Agrostis canina, Brachypodium sylvaticum, Bromus asper, B. japonicus, Calamagrostis pseudophragmites, Dactylis glomerata, Digitaria ischaemum, Festuca kashmiriana, Milium effusum, Oplismenus undulatifolius, Oryzopsis aequiglumis, Pennisetum flaccidum, Poa annua* and *P. himalayana.*

Middle Oak-Conifer forest (2,250 to 2,500 m) : Grasses as in Upper Oak-Conifer forest but *Stipa sibirica* and *Vulpia myuros* are additions.

Lower Oak-Conifer forest (1,700 2,300 m) : In addition to the above, *Arundinella napalensis, Coenotheca lappacea, Cymbopogon distans, Panicum psilopodium* and *Tripogon filiformis* also occur.

Grasslands of South Indian Hills : The montane grasslands of the south Indian hills occurring at the higher altitudes of Nilgiris, Palni and Anamalai are classified as southern montane wet grasslands by Champion and Seth (1968) and Shola-grassland by Meher-Homji (1965). This type of vegetation is composed of grasses, herbs and shrubs and mixed in varying proportions, covering large areas on the mountain tops. The grasses found in general are *Agrostis peninsularis, Arundinella purpurea, A. vaginata, Bromus ramosus, Chrysopogon zeylanicus, Dichanthium polyptycum, Indochloa oligantha, Isachne bourneorum* and *Tripogon bromoides.*

In many places these high level grasslands lie in close juxtaposition with sholas. As a result, the ecological status of shola-grassland formation has always been a subject of debate. Ranganathan (1938) opined that both Shola and grasslands are climatic climax types, because of their origin due to frost, which prevents their seral growth. While others consider them as a sub-climax, resulting from destruction of forests (sholas) and are maintained by frost and fire (Meher-Homji, 1965).

For the sake of description these grasslands have been described as follows:

(a) **Nilgiri hills** : Southern montane wet temperate forests popularly known as "Sholas" interspersed with southern montane wet grasslands (Shrub Savannah) are the main type occurring above 1,600 m altitude mostly in and around Kundah, Naduvattam, Nilgiri Peak, Parson Valley, Porthmund and Pykara.

The southern montane wet grasslands (shrub savannah or high altitude grasslands) are extensive and include a complex of grasses, herbs, undershrubs and few shrubs/ treelets. *Chrysopogon zeylanicus* *Arundinella* spp. type of savannah occur on the Wenlock and Mukurtti region (Blasco, 1971). *Andropogon polyptychus* *Eulalia phaeothrix* type of grassland occurs above 1,800 m altitude. *Andropogon lividus, Arundinella purpurea, A. setosa, Bothriochloa insculpta, Eragrostis nigra, Ischaemum indicum* and *Tripogon bromoides* are the main species. A large number of ligneous and herbaceous plants like *Anaphalis neelgerryana, Heracleum hookerianum, Leucas rosmarifolia, Pleocaulis sessilis* and *Senecio polycephalus, Anemone rivularis, Frageria nilgerrensis, Habenaria* spp., *Impatiens* spp. occur in this area.

In the upper Bhavani area dominant grasses are *Themeda triandra* and *Isachne* spp. Herbs/shrubs associated are *Anaphalis neelgerryana, A. wightiana, Andrographis lawsonii, Leucas suffruticosa, Phlebophyllum lawsonii* and *Teucrium wightii, Rhododendron arboreum* ssp. *nilgiricum, Ligustrum perrottetii* and *Syzygium calophyllifolium* occur in a stunted form.

The presence of temperate species like *Alchemilla, Anemone, Gaultheria, Geranium, Lysimacha, Mahonia, Rhododendron, Thalicturum* and *Vaccinium* on these high altitude grasslands and margins of sholas is interesting and many theories have been proposed.

(b) **Palni Hills** : Meher-Homji (1965) has recognised two kinds of vegetation types: Shrub-Savannah and grasslands in the warm temperate montane climate of Kodaikanal (Palni hills).

(i) **Shrub Savannah type** : Main grasses are *Andropogon lividus, Anthistira ciliata, Arundinella mesophylla, A. metzii, A. purpurea, A. setosa, A. villosa, Bothriochloa foulkesii, B. pertusa, Bromus ramosus, Capilipedium parviflorum, Chrysopogon orientalis, Coelanche pulchella, Cymbopogon coloratus, C. confertiflorus, C. polyneuros, Eragrostis nigra, Eulalia phaeothrix, E. quadrinervis, Heteropogon contortus, Ischaemum aristatum, I. indicum, I. pilosum, Isachne kunthiana, I. globosa, Themeda cymbaria, T. triandra, Tripogon bromoides* and *Zenkeria elegans.* Shrubs associated are *Berberis tinctoria, Hypericum mysurense, Hedyotis stylosa, Gaultheria fragrantissima, Uraria rufescens, Rubus fairholmianus* and *Osbeckia aspera.*

(ii) **Grassland type :** These grasslands are dominated by *Heteropogon contortus.* Other grasses are *Apluda mutica, Arundinella mesophylla, A. purpurea, A. setosa, Bothriochloa pertusa, Chrysopogon orientalis, C. zeylanicus, Eulalia phaeothrix, E. quadrinervis, Ischaemum aristatum* and *Themeda triandra.*

(c) **Anamalai Hills** : Fischer (1921) recognised two vegetation types above 1,000 m altitude.

(i) **Lower grassland type** : The vegetation of high plateau of Anamalai, Anaimudi and Eravikulam consist of shrub savannah at 1,000 m and above. The shrub savannah are extensive and include complex of grasses, herbs and undershrubs. The dominant grasses are *Dichanthium polyptychum* and *Eulalia phaeothrix.* Other associates are *Arundinella purpurea.*

(ii) **Upper grassland type :** This cover occurs above 2,000 m and the dominant grasses are *Andropogon lividus, Arundinella purpurea, A. vaginata, Bromus ramosus, Chrysopogon zeylanicus, Indochloa oligantha, Isachne bourneorum, I. indicum* and *Tripogon bromoides.* Other orchids and herbs associated are *Habenaria heyneana, H. perrottetiana, Malaxis*

Fig. 5 : Shrub-Savannah in Anamalai Hills

densiflora, Satyrium nepalense and *Spiranthes sinensis*.

In marshy areas *Burmannia pusilla, Eriocaulon nilgirense, E. collium, Fimbristylis kingii, Lobelia heyneana, Parnassia mysorensis, Utricularia graminifolia, U. roseo-purpurea* and *Xyris capensis* are encountered.

Grasslands of the Deccan : The Deccan grasslands are broadly divided into two types depending upon the rainfall (Puri, 1960).

(i) **High rainfall grasslands:** These grasslands are found on the Western Ghats, usually above the height of 600 m and in areas with average rainfall above 5,000 mm. The dominant grass species are *Andropogon pumilus* (between 3,720 4,250 mm), *Heteropogon contortus, Sporobolus* ssp. and *Eragrostis amabilis* (above 5,000 mm). Depending upon the soil type, soil moisture, their origin and biotic disturbances, these grasslands are again categorised into three subtypes: (i) *Andropogon pumilus* community associated with *Leucas stelligera, Cyathocline lutea, Linum mysorense, Crotolaria orixensis* and *Glossocordia linearifolia*; (ii) *Heteropogon contortus* community associated with *Leucas stelligera, senecio grahami, Isachne elegans, Memecylon umbellatum* and *Randia dumetorum* and (iii) *Sporobolus* spp., *Eragrostis amabilis* community associated with *Arundinella tenella, Isachne australis, I. elegans, Paspalum compactum* and *P. flavidum*.

In depressions where water collects, patches of *Dypsophylla stellata*, either pure or mixed with *Arundinella tenella* form a conspicuous feature. *Ischaemum semisagittatum* and *I. aristatum* are also found in these depressions.

(ii) **Low rainfall grasslands** : These grasslands are found to the east of the Western Ghats in the rain shadow area where the annual rainfall ranges from 250 1250 mm and the altitude of the land is below 600 m. These grasslands have originated due to destruction of the forests and the erosion of the soil. Dominant grass species found in these grasslands are *Lophopogon tridentatus, Apluda varia, Aristida funiculata* and *Heteropogon contortus. Cymbopogon* spp. and *Themeda triandra* are common associates and other herbs are *Crotalaria orixensis, Indigofera cordifolia, Crotalania haebecarpa, Commelina* spp. and on deeper soils *Bothriochloa* spp. is sometimes seen.

4. GRASSLAND FAUNA

Grassland primarily supports a large number of herbivore species from minute insects to the largest land animal—the elephant. This in turn makes grasslands happy hunting grounds of various carnivorous species of different sizes. Most of the grasslands have some common mammalian species, such as, Tiger (*Panthera tigris*), Elephant (*Elephas maximus*), Deer (*Axis* sp., *Cervus* sp.), Hare (*Lepus* sp.), Rats and Mice (*Rattus* sp. *Bandicoota* sp., *Mus* sp.) and bird species, such as, Grass Warbler (*Prinia* sp.), Patridge (*Francolinus* sp.), Munia (*Lonchura* sp.), Streaked Baya (*Ploceus* sp.) and many others. However, depending upon the geographical locations, ecological set up and management practices, many of the grasslands possess some characteristic faunal elements.

Endemic mammalian species, Nilgiri Thar—*Hemitragus hylocrius* provides uniqueness to the grasslands of the Western Ghats. Among the other mammalian species, Elephant—*Elephas maximus*, Gaur—*Bor frontalis*, Mouse Deer—*Moschiola memina*, Spotted Deer—*Axis axis*, Sambar—*Cervus unicolor*, Wild Boar—*Sus scrofa*, Tiger—*Panthera tigris*, Mongooses—*Herpestes* sp., Fishing cat—*Prionailurus bengalensis, etc.* are also found to take shelter in the grasslands. Large number of avian species, such as, Patridges (*Francolinus* sp.) Quails (*Turnix* sp., *Coturnix* sp.), Lapwing (*Vanellus* sp.) Smal Skylark—*Alauda gulgula* and many others are found foraging in this habitat. The largest Indian butterfly, Birdwing—*Trides helena* could also be seen flying over the grasslands.

One-horned Rhinoceros—*Rhinoceros unicornis*, Pygmy Hog—*Sus salvanius*, Hispid Hare—*Caprolagus hispidus* make the grasslands of North East India most significant from the conservation point of view. Among the other threatened species, North Indian Swamp Deer, *Cervus duvauceli* Wild buffalo—*Bubalus bubalis*, Elephant—*Elephas maximus*, Tiger—*Panthera tigris*, Leopard—*P. pardus*, Ferret Badgers, (*Melogale* sp.) Bengal Florican—*Eupodotis bengalenis*, Burmese peafowl —*Pavo muticus*, Bamboo patridge—*Bambusicola fytchii, etc.*,

Fig. 7 : Indian Elephants—Elephas maximus in the grassland habitat of Corbett National Park, Uttaranchal (*Courtsey* : H. Nandi)

find shelter in the grassland of the Nort-East. Besides these, many common mammals, birds and reptiles, such as, fox, jackal, civets, shrikes, drongo, myna, varieties of lizards visit the grassland particularly in search of prey.

Grasslands along with thorny bushes particularly in the drier parts exhibit a characteristic species composition. Among the mammals, Indian Black buck—*Antilope cervicapra,* Chinkara—*Gazella bennettii,* Nilgai—*Boselophus tragocamelus,* Indian Wild Ass—*Equus onager,* Desert Cat—*Felis silvestris,* Caracal—*Caracal caracal,* among birds Great Indian Bustard—*Ardeotis nigriceps,* Indian peafowl—*Pavo cristatus, etc.,* are conservation dependent. Apart from these, huge populations of Hare (*Lepus* sp.), Gerbils (*Tatera* sp., *Meriones* sp., *Gerbillus* sp.), Hedgehogs (*Hemiechinus* sp.), Babbler (*Dumetia* sp., *Turdoides* sp.), Sandgrouse—*Pterocles exustus* frequent the grasslands of arid and semiarid region. Among the reptilian species, spriny tailed Lizard—*Uromastix hardwieki,* Indian Fringe—Toed Lizard—*Acanthodactylus contoris,* Desert Monitor—*Varanus griseus,* Red Sand Boa—*Eryx johni* deserve special mention.

Grassy glades in the temperate to alpine zone support the greatest diversity of hoofed mammals, some of which are Yak—*Bos gruniens,* Tibetan Antelope—*Pantholops hodgsonii,* Himalayan Tahr—*Hemiragus jemlahieus,* Markhor—*Capra falconeri,* Ibex—*C. ibex,* Bharal—*Pseudois nayaur,* Musk Deer—*Moschus moschiferus,* Goral—*Nemorhedus goral* and Kiang—*Equus kiang*. Besides, carnivore species, Snow Leopard—*Panthera uncia,* Ermine—*Mustella erminea,* Red Panda—*Ailurgus fulgens,* Himalayan Brown Bear—*Ursus arctos,* along with different species of Hare (*Lepus* sp.), Pika (*Ochotona* sp.), Voles (*Pitymys.* sp., *Alticola* sp.), *etc,* are the other characteristic mammalian fauna. Quite a number of threatened avian species, such as, Tibetan Snowcock—*Tetraogallus tibetanus,* Tibetan Blood Pheasant—*Ithaginis melanocephalus,* Elwes's Eared Pheasant—*Crossoptilon crossoptilon,* Himalayan Moral Pheasant—*Lophophorus impejanus* and few others are often seen foraging in the grassy glades.

5. VALUE

Grasslands are of considerable economic value. Whether natural or man-made these are used vastly for production of milk, meat, wool and hides. Temperate grasslands are the granaries of the world, producing wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), oats (*Aevna sativa*) and rye (*Secale cereale*) in the cooler regions and rice (*Oryza sativa*)and millets (*Pennisetum typhoides, Setaria italica, Sorghum* spp., *Zea mays, Panicum miliaceum, Elesine coracana*) in the warmer regions. The alpine grasslands provide pastures to the cattle of the mountain regions. Many grasses, such as, *Dicanthium annulatum, Cenchrus ciliaris, C. setigerus, Lasiurus hirsutus, Themeda anathera, etc.,* are well known for their fodder value. Grasses like *Phragmites, Saccharum* and *Imperata* are used for thatching, rope making, *etc.,* in rural areas.

A good strand of grasses and legumes on the soil checks erosion, prevents the loss of nutrients by leaching, improves the physical properties of soil and maintains a well balanced water regime. Species of *Panicum, Lasiurus, Cenchrus, etc.,* are good sand binders. Grasses make very good turf and lawns.

Legumes like clover (*Trifolium* spp.) are of great economical value and provide better food for the stock animals than the grasses. Herbaceous plants of the lily family are also abundant and their bulbs serve as food to the rodents inhabiting the regions. Grasslands also provide nesting habitat to the birds. These grasslands are the house of many ungulates, deer, lions and along the rivers they harbour crocodiles.

A number of species belonging to the genera *Cymbopogon, Vetiveria, Bothriochloa* and a few others produce aromatic oils and can be extracted by steam distillation. Bor (1960) has listed the following species as the source of aromatic oils: *Cymbopogon nardus, C. winterianus, C. schoenanthus, C. caessus, C. clandestinus, C. polyneuros, C. virgatus, C. nervatus, C. martinii, C. flexuosus, C. pendulus, C. coloratus, C. travancorensis, C. citratus, Bothriochloa intermedia, B. kuntzeana, B. odorata, B. woodrowii, B. compressa; Capillipedium huegelii* var. *foetidium, Vetiveria zizanioides, Anthoxanthium* sp., *Indochloa oligantha*. The species of *Cymbopogon* and *Vetiveria* are commercially exploited.

The grass species, such as, *Saccharum spontaneum, S. benghalense, Narenga porphyrocoma, Arundo donax, Phragmites karka, Themeda arundinacea, T. villosa,* and *Heteropogon contortus* are used in paper industry.

Some grasses are of medicinal value. The extract from rhizome of *Agropyron repens* is used for the treatment of catarrhal disease of the genito-urinary tract, as bladder sedative and as antiseptic; *Cymbopogon schoenanthus* is used in stomachic and its oil is used in rheumatism (Bor, 1960). *Cymbopogon jwarancusa, C. nardus, C. citratus, Vetiveria zizanioides, Desmostachya bipinnata, Thysanophaena maxima, Setaria italica, Saccharum officinarum* and *Pragmites karka* are also used as medicine (Bor, 1960).

6. THREATS AND CONSERVATION

Natural calamities like forest fires, floods, etc., overgrazing and various socio-economic developmental activities are the factors threatening grasslands. Severe destruction was caused to the natural vegetation in north-east India due to "Jhum" (shifting) cultivation. Due to population explosion the intervals of jhuming cycles has been reduced to 4 5 years from 10 years. Many swamps have been reclaimed for agriculture and typical swamp. As a result grasses like *Phragmites australis, Saccharum griffithii, Vetiveria zizanoides* have started getting depleted in their natural habitats. The *Phragmites Saccharum Imperata* cover type is subjected to cutting and burning, which expose the habitat to the process of desiccation. With the gradual dryness of the swampy habitat, *Phragmites karka* disappears giving place to *Saccharum, Imperata* and *Sclerostachya*.

Most of the grasslands remain under severe grazing pressure throughout the year. The high altitude pastures and the arid and semi-arid grasslands in Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, Rajasthan and Gujarat suffer from severe seasonal grazing stress by migratory livestock. According to 1971 estimates by Chakravarty, 7.4 million cattle, 5.6 million sheep, 3.38 million goats and 0.5 other livestock graze in an area of one million hectares in arid and semi-arid regions. Over-grazing lead to the deterioration of the vegetation and triggered soil erosion by wind and rain.

Dabadghao and Shankaranarayan (1973) have discussed the effect of grazing on different grass covers. For example, when the *Sehima-Dicanthium* cover is subjected to grazing, this is replaced by *Chrysopogon* and *Bothriochloa* communities, by further grazing these communities are replaced by *Heteropogon* and *Eremopogon* communities, which by over-grazing may change to *Aristida, Eragrostis* and *Melanocenchris* communities. While in *Dicanthium-Cenchrus-Lasiurus* cover type, the most palatable species *Dicanthium annulatum* disappears first and is replaced by *Cenchrus* and *Lasiurus sindicus*. Later on *Cenchrus-Lasiurus* community is replaced by *Cynodon dactylon* in low-lying areas and *Eleusine compressa* on drier soils.

Bor (1960) observed that over-grazing in moist climate of Assam reduced the tall grassland to an impoverish tuft of *Chrysopogon aciculatus* and *Imperata cylindrica*, while in West Bengal it leads to replacement of grassland by *Careya herbacea*, an unpalatable shrub/herb.

Grasses exhibit a fairly good degree of endemism in India. There are about 18 genera endemic to India. *Bhidea, Cyathopus, Chandrasekharania, Danthonidium, Glyphochloa,* *Hubbardia, Indochloa, Indopoa, Ischnochloa, Limnopoa, Lophopogon, Normanboria, Pogonachne, Pseudodanthonia, Pseudodichanthium, Silentivalleya, Trilobachne* and *Triplopogon*. Thirteen of them are restricted to Peninsular India. According to Jain (1986) about 350 taxa of grasses are endemic to India and of these 172 occur in Peninsular India, 56 in the north-east, 30 in north-west, 12 in the lower Gangetic plain, 5 in the western and arid regions, 4 in Andaman and Nicobar islands and 50 occur in more than one region. Nearly, 120 endemic grass species are rare and most of them are known only by their type collections. Therefore there is a need for conservation of the grassland ecosystem and native species.

7. REFERENCES

Agarwal, S.C. 1959. Grasslands of Chakrata forest division, district Dehra Dun. *Indian For.* **85** : 659-662.

Barucha, F.R. and K.A. Shankaranarayan. 1958. Studies on the grasslands of the Western Ghats, India. *J. Ecol.* **46** : 681-705.

Blasco, F. 1971. Montagnes du Sud de l' Inde: Forêts, Savanes, Ecologie. Inst. Fr. Pondicherry. Trav. Sect. Sci. Tech. **10** : 1-436.

Bor, N.L. 1940. A list of grasses of Assam. *Ind. For. Rec. (Bot. N.S.)* **1** : 47-102.

Bor, N.L. 1942. The relict vegetation of the Shillong Plateau Assam. *Ind. For. Rec.* **3** : 152-195.

Bor, N.L. 1960. Grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, London. 767 pp.

Burns, W. and G.M. Chakradeo. 1921. An ecological study of Deccan grasslands. *J. Indian Bot. Soc.* **2** : 84-91.

Burns, W. and L.B. Kulkarni. 1927. A line survey of grasslands with reference mainly to rainfall. *J. Indian Bot. Soc.* **16** : 103-108.

Burns, W. and L.B. Kulkarni. 1928. A study of some Indian grasses and grasslands. Mem. Dept. Agric. I.d. Bot. Ser. **16** : 101-143.

Chakravarty, A.K. 1971. Pasture production and its use in the arid and semi-arid areas of Rajasthan (India) and Kazakhstan (USSR). *Ann. Arid Zone* **8** : 251-256.

Champion, H.G. 1936. A preliminary survey of the forest types of India and Burma. *Indian For. Rec.* (N.S.) **1** : 1-286.

Champion, H.G. and Seth, S.K. 1968. The Forest Types of India: A Revised Survey. Manager of Publications, New Delhi, 404 pp.

Chaudhuri, A.B. 1959. Grasses and grassland types of the Central Forest Division, West Bengal. *Indian For.* **85** : 603-606.

Dabadghao, P.M. and K.A. Shankaranarayan. 1973. The grass cover of India. Indian Council of Agricultural Research, New Delhi. 713 pp.

Fischer, C.E.C. 1921. A Survey of the flora of the Anamalai hills in the Coimbatore district, Madras Presidency. *Rec. Bot. Surv. Ind.* **9** : 1-218.

Gupta, R.K. 1971. Ecology of pastoral areas in the arid zone of Rajasthan. *Ann. Arid Zone* **10** : 136-157.

Gupta, R.K. and P.C. Nanda. 1970. Grassland types and their succession in the Western Himalayas. pp. 10-13. In: *Proc. of the XI International Grassland Congress*. University of Queensland Press.

Gupta, R.K. and S.K. Saxena. 1966. Habitat, grassland types and forage potential of Jalore district in Western Rajasthan. *Ann. Arid Zone* **5** : 189-203.

Gupta, R.K. and S.K. Saxena. 1972. Potential grassland types and their ecological succession in Rajasthan desert. *Ann. Arid Zone* **11** : 198-218.

Jain, S.K. 1986. On the status of endemism of some grasses in India. *J. Indian Bot. Soc.* **66** : 237-247.

Meher-Homji, V.M. 1965. Ecological status of the montane grasslands of the south Indian hills: A phytogeographic reassessment. *Indian For.* **91** : 210-215.

Misra, R. 1959. The status of the plant community in the upper Gangetic plain. *J. Indian Bot. Soc.* **38** : 1-7.

Mohan, N.P. 1955. Grasses of the Punjab according to forest types. *Indian For.* **81** : 179-184.

Moore, C.W.E. 1964. Distribution of grasslands. In: Bernard, C. (ed.), Grasses and grasslands. London, Macmillan.

Pandey, S.C. 1964. Ecology of grasslands of Sagar, Madhya Pradesh II A. Composition of the fenced grassland associations. *J. Indian Bot. Soc.* **43** : 557-605.

Prakash, M. 1958. Treelands or grasslands in Rajputana desert. *Indian For.* **84** : 384.

Puri, G.S. 1960. Indian Forest Ecology, Vol. I. Oxford Book & Stationery Co., New Delhi.

Raina, V. 1959. A Preliminary survey of grasses of Himachal Pradesh. *Indian For.* **85** : 119-125.

Ramam, S.S. 1963. Ecological perspective on grasslands. *Proc. Natl. Acad. Sci. India* **33** B : 227-234.

Ramam, S.S. 1966. Organisation of grass communities on Western and Vidhyan uplands of Varanasi district. *J. Indian Bot. Soc.* **45** : 266-276.

Ranganathan, C.R. 1938. Studies in the ecology of the Shola grassland vegetation of the Nilgiri Plateau. *Indian For.* **64** : 523-541.

Raychaudhary, S.P. 1966. Land and Soil. National Book Trust, New Delhi. 171 pp.

Shah, S.A. 1957. Treelands or grasslands in Rajaputana desert. *Indian For.* **83** : 488-491.

Shankaranarayan, K.A. and P.M. Dabadghao. 1970. Ecological studies on the grasslands of Jhansi, U.P. *Ann. Arid Zone* **9** : 54-63.

Singh, V.P. 1972. Edaphic factors in the distribution of grasslands of Ujjain (M.P.). **5** : 1-11.

Vyas, L.N. 1964. Studies on the grassland communities of Alwar. *J. Indian Bot. Soc.* **43** : 490-494.

Whyte, R.O. 1964. Grassland and Fodder Resources of India. Scientific Monograph No. 22. Indian Council of Agricultural Research, New Delhi. 553 pp.

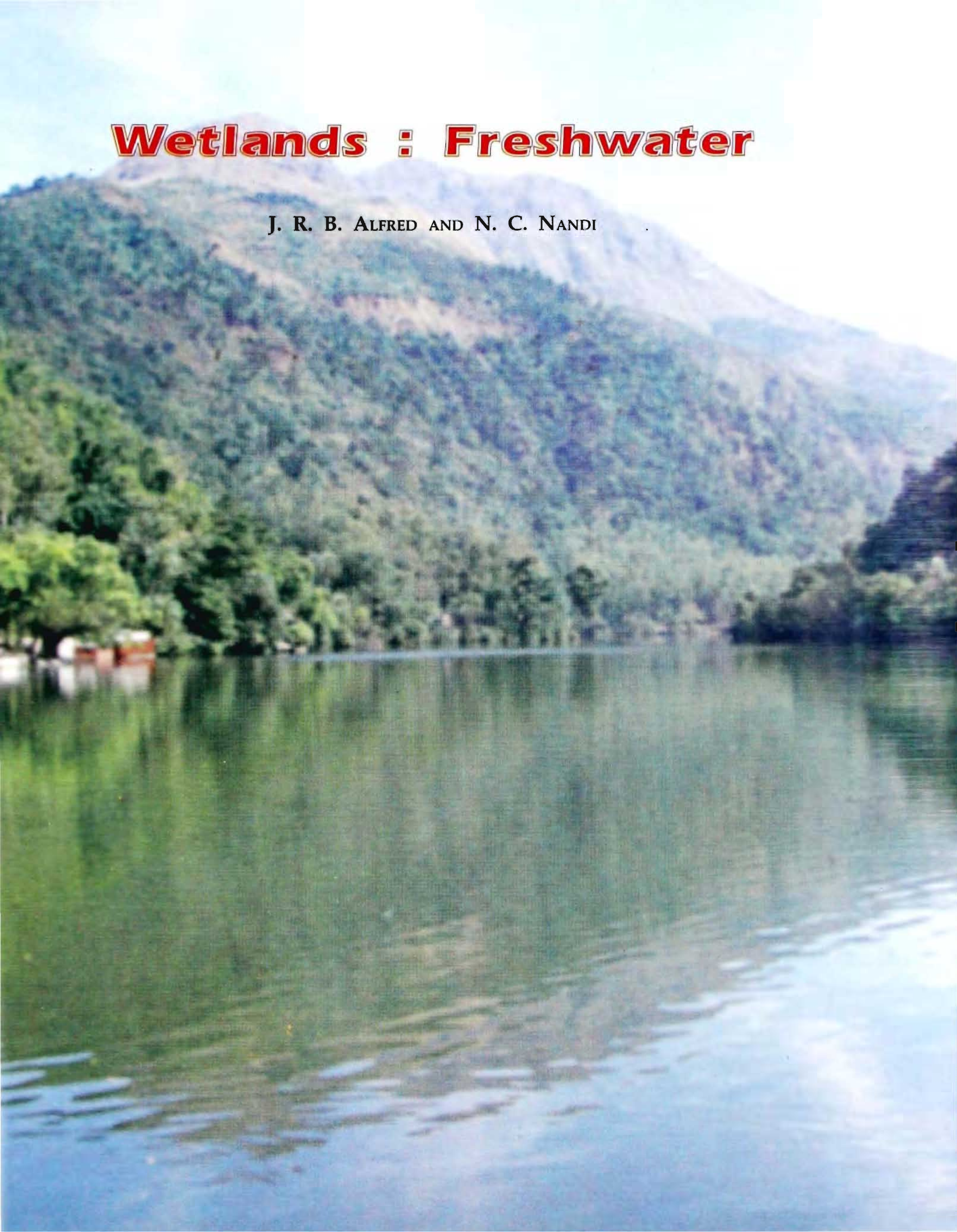
Whyte, R.O. 1968. Grasslands of the monsoon. Faber and Faber, London.

Whyte, R.O. 1974. Grasses and grasslands. pp. 239-262. In: Natural Resources of Humid Tropical Asia. UNESCO, Paris.

Yadava, P.S. and Singh, J.S. 1977. Grassland Vegetation. In: R. Misra, B. Gopal, K.P. Singh and J.S. Singh (eds.), *Progress in Ecology*, 2. Today and Tomorrow, New Delhi. pp. 132.

Wetlands : Freshwater

J. R. B. Alfred and N. C. Nandi



ENVIS–Zool. Surv. India
Ecosystems of India : 165-193, 2001.

Wetlands : Freshwater

J. R. B. Alfred and N. C. Nandi

Zoological Survey of India
'M' Block, New Alipore, Kolkata-700 053

1. INTRODUCTION

Wetlands have been defined by more than fifty different ways to include a wide spectrum of habitats. The 1971 Ramsar Convention has defined wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."

The above IUCN definition, however, fails to specify parameters in case of inland waters. To classify these inland waterboides the following definition of Cowardin *et al.* (1979) of U.S. Fish and Wildlife Service is useful.

"The wetlands are lands transitional between terrestrial and aquatic systems where water table is usually at or near the surface or the land is covered by shallow water."

The term wetlands include a wide range of inland, coastal and marine habitats which should have the following three essential attributes :

- An area which is permanently or periodically inundated for at least seven successive days during growing season.
- An area which supports hydrophytic vegetation at least for some part of the year.
- An area which has predominantly hydric soils that are saturated for a sufficiently long period to become anaerobic (lacking in oxygen) in their upper layers.

Classification of Wetlands

There is a wide range of classification for wetlands. The classification made by Scott (1989), modified by Dugan (1990) and adopted as Ramsar classification is widely followed. Based on their biological and physical characteristics, a total of 39 categories of wetlands, 30 natural and 9 man-made, have been recognised (Table 1). These landscape units do not necessarily occur in individual pattern ; rather, often a wetland contains a combination of several such units (Dugan, 1990).

2. GENERAL DESCRIPTION

Wetlands are broadly classified into freshwater and saltwater wetlands defined by salinity. The freshwater wetlands include both standing water habitats, such as, small or large ponds, tanks, lakes and reserviors, as well as running water habitats like rivers, streams, canals and drainage channels. These aquatic habitats are regarded as a special type of aquatic ecosystem spatially sandwiched between a very wide spectrum of habitats ranging from temporary ponds to shallow lakes, shallow marginal areas (littoral zones) of large lakes to extensive floodplains of large rivers, and a variety of marshes and swamps. These various kinds of wetland units can be

Fig. 1 : A wetland in Godda district of Bihar (*Courtsey :* Y. N. P. Sinha, ZSI)

topographically grouped into inland wetlands and marine wetlands. The inland wetlands include both freshwater and brackishwater wetlands, while the marine wetlands encompasses sea bays, straits, marine meadows and coral reefs. Amongst the inland wetlands, the freshwater wetlands include river systems, streams, irrigation canals, floodplains as well as freshwater reservoirs, hydrodams, lakes, ponds and marshes including rice fields (Table 1).

The various wetland habitats of the world include 22 wetland types (IUCN, 1989) and in India they can be categorised by region into ten predominant wetlands types (Alfred and Nandi, 2000), of which five belong to freshwater categories as follows :

- Tanks, Reservoirs and other waterbodies of Deccan peninsula ;
- Freshwater Lakes and Reservoirs from Gujarat, Rajasthan and Madhya Pradesh, representing arid and semi-arid regions;
- Marshes, Jheels, Terrai swamps and Chaur lands of the Gangetic plains ;
- Floodplains of the Brahmaputra and the Marshes and Swamps in the hills of Northeast India ;
- Lakes and Rivers of the Himalayan montane regions mostly in Jammu & Kashmir, Uttar Pradesh and Himachal Pradesh.

2.1 Geographical distribution

The extent of total wetlands area in India excluding rivers, canals and channels as shown in the Directory of Asian Wetlands (IUCN, 1989) are 58.2 million ha (Table 2). The Ministry of Environment and Forests,

Table 1. Classification of Wetlands

1. Salt Water		
1.1. Marine	*1. Subtidal*	i) Permanent unvegetated shallow waters less than 6 m depth at low tide, including sea bays, straits.
		ii) Subtidal aquatic vegetation, including kelp beds, sea grasses, tropical marine meadows.
		iii) Coral reefs.
	2. Intertidal	i) Rocky marine shores, including cliffs and rocky shores.
		ii) Shores of mobile stones and shingle.
		iii) Intertidal mobile unvegetated mud, sand or salt flats.
		iv) Intertidal vegetated sediments, including salt marshes and mangroves on sheltered coasts.
1.2. Estuarine	*1. Subtidal*	i) Estuarine waters, permanent waters of estuaries and estuarine systems of deltas.
	2. Intertidal	i) Intertidal mud, sand or salt flats, with limited vegetation.
		ii) Intertidal marshes, including salt-marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes.
		iii) Intertidal forested wetlands including mangrove swamp, Nypa swamp, tidal freshwater swamp forest.
1.3. Lagoonar		i) Brackish to saline lagoons with one or more relatively narrow connections with the sea.
1.4. Salt lake		i) Permanent and seasonal, brackish, saline or alkaline lakes, flats and marshes.
2. Freshwater		
2.1. Riverine	*Perennial*	i) Permanent rivers and streams, including waterfalls.
		ii) Inland deltas.
	Temporary	i) Seasonal and irregular rivers and streams.
		ii) Riverine floodplains, including river flats, flooded river basins, seasonally flooded grassland.
2.2. Lacustrine	*Permanent*	i) Permanent freshwater lakes (>8 ha), including shores subject to seasonal or irregular inundation.
		ii) Permanent freshwater ponds (<8 ha).
	Seasonal	i) Seasonal freshwater lakes (>8 ha), including floodplain lakes.
2.3. Palustrine	*Emergent*	i) Permanent freshwater marshes and swamps on inorganic soils, with emergent vegetation whose bases lie below the water table for at least most of the growing season.
		ii) Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by *Papyrus* or *Typha*.
		iii) Seasonal freshwater marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes, and dambos.
		iv) Peatlands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub vegetation, and fens of all types.
		v) Alpine and polar wetlands, including seasonally flooded meadows moistened by temporary waters from snowmelt.
		vi) Freshwater springs and oases with surrounding vegetation.
		vii) Volcanic fumaroles continually moistened by emerging and condensing water vapour.
	Forested	i) Shrub swamps, including shrub-dominated freshwater marsh, shrub carr and thickets, on inorganic soils.

Table 1. contd.

	ii) Freshwater swamp forest, including seasonally flooded forest, wooded swamps on inorganic soils. iii) Forested peatlands, including peat swamp forest.
3. Man-Made Wetlands	
3.1. Aquaculture/Mariculture	i) Aquaculture ponds, including fish ponds and shrimp ponds.
3.2. Agriculture	i) Ponds, including farm ponds, stock ponds, small tanks. ii) Irrigated land and irrigation channels, including rice fields, canals and ditches. iii) Seasonally flooded arable land.
3.3. Salt Exploitation	i) Salt pans and salines.
3.4. Urban/Industrial	i) Excavations, including gravel pits, borrow pits and mining pools. ii) Wastewater treatment areas, including sewage farms, settling ponds and oxidation basins.
3.5. Water-storage areas	i) Reservoirs holding water for irrigation and/or human consumption with a pattern of gradual, seasonal, draw down of water level. ii) Hydro-dams with regular fluctuations in water level on a weekly or monthly basis.

Source : Scott (1989); Dugan (1990)

Government of India (1990), estimates that India possesses about 4.1 million ha of wetlands (excluding paddy fields and mangroves), of which 1.5 million ha are natural and 2.6 million ha man-made. According to a recent estimate of the Space Application Centre (ISRO), Ahmedabad (1998), using space borne remotely sensed data from IRS 1A/1B, the total Indian wetland areas extend about 7.6 million ha (excluding paddy fields, rivers and canals), out of which 3.6 million ha are inland and 4 million ha are coastal. Besides 40.9 million ha area under paddy cultivation (Table 2), the inland freshwater resources in India encompass about 2.05 million ha of reservoirs, 2.85 million ha of tanks and ponds, nearly 0.8 million ha of beels, ox-bow lakes and derelict water bodies (Anonymous, 1996). The state-wise distribution of these freshwater wetlands along with rivers and canals is shown in Table 3, while the details regrading river basin profile, reservoir fishery resources and the distribution of floodplain lakes in India are presented in Tables 4-6. The state-wise distribution of reservoirs reveals that Madhya Pradesh has the highest area of reservoirs (0.29 million ha) followed by Maharashtra (0.28 million ha), Orissa (0.25 million ha), Gujarat (0.24 million ha) and Andhra Pradesh (0.23 million ha). The highest representation of freshwater wetland area under tanks and ponds is available in Tamil Nadu (0.69 million ha), followed by Andhra Pradesh (0.51 million ha) and Karnataka (0.41 million ha). Mention may be made that Assam has the greatest area of floodplain lakes in India (Table 6). The geographical location of important reservoirs in India is shown in Table 7. It is evdient that the Gandhisagar reservoir on Chambal river in Madhya Pradesh has the largest area (64,750 ha) followed by Ukai reservoir (51,282 ha) of Gujarat and Rihand reservoir (46,620 ha) of Uttar Pradesh.

The territory of India consists of no less than ten biogeographical provinces including the archipelagos of the Lakshadweep and Minicoy Islands lying in the Arabian Sea and the Andaman and Nicobar Islands lying in the Bay of Bengal. Thus the Indian landmass presents a remarkable diversity in physical features. It contains long and wide mountain ranges, high and low plateaus, extensive plains and swamps. There are densely forested

Fig. 2 : Renuka Lake in Lesser Himalaya (*Courtsey* : J. M. Julka & H.S. Mehta, ZSI)

Table 2. Extent of various wetlands in India

Wetland habitat types	Area (in million ha)
Area under paddy cultivation	40.9
Area suitable for fish culture	3.6
(i) Freshwater — 1.6 million ha	
(ii) Brackishwater — 2.0 million ha	
Area under capture fisheries	2.9
Mangroves	0.4
Estuaries	3.9
Backwaters	3.5
Man-made impoundments	3.0
Rivers including main tributaries	(28,000 km)
Canals and irrigation channels	(113,00 km)
Total area of wetlands (excluding rivers, canals and channels)	58.2

Source : IUCN (1989)

regions and river valleys as well as arid and semi-arid tracts where practically nothing grows. Some areas especially in the northeast boast of the world's highest rainfall, while there are areas in the western Rajasthan where hardly a rain-drop falls. All these give the region a diverse, multi-climate character which can even be revealed from five basic regions dominated by freshwater wetlands (Table 8) representing Deccan peninsula, central highland, deserts and semideserts, Gangetic plains, North-eastern hills and Brahmhaputra valley and Mountain region.

3. BIOLOGICAL DIVERSITY

Though freshwater systems *viz.*, lakes, reservoirs and rivers account for a small amount of about 2% of total water on the Earth, they are of great importance to all organisms including human beings. A considerable number of the total diversity of these organisms, particularly finfish and

Table 3. Inland freshwater resources in India as in 1995

Sl No.	State/UTs	Length of rivers canals (kms)	Area of reservoirs (Lakh ha)	Area under tanks and ponds (Lakh ha)	Beels, oxbow and derelict water (Lakh ha)
1.	Andhra Pradesh	11514	2.34	5.17	—
2.	Assam	4820	0.02	0.23	1.10
3.	Bihar	3200	0.60	0.95	0.05
4.	Goa	250	0.03	0.03	—
5.	Gujarat	3865	2.43	0.71	0.12
6.	Haryana	5000	—	0.10	0.10
7.	Himachal Pradesh	3000	0.42	0.01	—
8.	Jammu & Kashmir	27781	0.07	0.17	0.6
9.	Karnataka	9000	2.20	4.14	—
10.	Kerala	3092	0.30	0.30	2.43
11.	Madhya Pradesh	20661	2.94	1.19	—
12.	Maharashtra	1600	2.79	0.50	—
13.	Manipur	3360	0.01	0.05	0.40
14.	Meghalaya	5600	0.08	0.02	—
15.	Nagaland	1600	0.17	0.50	—
16.	Orissa	4500	2.56	1.14	1.80
17.	Punjab	15270	—	0.07	—
18.	Rajasthan	NA	1.20	1.80	—
19.	Sikkim	900	—	—	0.03
20.	Tamil Nadu	7420	0.52	6.92	NA
21.	Tripura	1200	0.05	0.12	—
22.	Uttar Pradesh	31200	1.50	1.62	1.33
23.	West Bengal (P)	2526	0.17	2.76	0.42
24.	Arunachal Pradesh	2000	—	2.76	0.42
25.	Mizoram	1395	—	0.02	0.42
26.	Andaman & Nicobar	115	0.01	0.03	—
27.	Chandigarh	2	—	—	—
28.	Delhi	150	0.04	—	—
29.	Lakshadweep	—	—	—	—
30.	Pondicherry	247	—	—	0.01
31.	Dadra & Nagar Haveli	54	0.05	—	—
32.	Daman & Diu	12	—	—	—
	Total	**171334**	**20.50**	**28.55**	**7.88**

Abbraviation : NA = Not available ; (P) = Provisional
Source : Anonymous (1996). Handbook of Fish Catch Statistics 1996. MoA, New Delhi—110 001

Table 4. River basin profile of India

Particulars of river basins	Major rivers	Medium, minor and desert rivers
1. Catchment area (in million sq. km)	2.58	0.54
2. Total area (in %)	83%	17%
3. Run off (in 1000 million cu. m.)	1,406	239
4. Run off (in %)	85%	15%
5. Cultivable area (in 1000 ha)	1,49,733	1,93,594
6. Gross sown area (,,)	1,30,824	1,61,418
7. Gross irrigated area (,,)	37,949	43,275
8. Population in the basins (in %)	80%	20%

Source : Rao (1979)

Table 5. Reservoir fishery resources of India

Category	Number	Area
1. Small (< 1000 ha)	19134	1,485,557
2. Medium (1000 — 5000 ha)	180	527,541
3. Large (> 5000 ha)	56	1,140,268
Total	**19,370**	**3,153,366**

Source : Sugunan (1995)

Table 6. Distribution of floodplain lakes in India

State	River basins	Area (ha)
Arunachal Pradesh	Kameng, Subansiri, Siang, Dibang, Lohit, Dihing and Tirap	2,500
Assam	Brahmaputra and Barak	1,00,000
Bihar	Gandak and Kosi (Ganga)	40,000
Manipur	Iral, Imphal and Thoubal	16,500
Meghalaya	Someswari and Jinjiram	375
Tripura	Gomti, Manu and Khowai	500
West Bengal	Hooghly and Matlah (Ganga)	42,500
Total		**2,02, 375**

Source : Central Inland Capture Fisheries Reserch Institute, Barrackpore, West Bengal

shellfish species, are exploited commercially, while many other freshwater animals (swans, cranes, turtles, crocodiles) and plants (lotus, reeds, cattails, etc.) are associated with social and cultural life of people all over the world. Although studies on freshwater ecology assume greater biological dimension in Europe and America (Hutchinson, 1957, 1967, 1975, Edmondson, 1959; Pennak, 1978 ; Cook, 1990), in India too, a large number of limmological studies have been made during the past few decades in almost all kinds of aquatic habitats (Tonapi, 1980 ; Gopal and Asthana, 1991 ; ILEC, 1996 ; NIE, 1999). It is impossible to get a coverage of all the important freshwater wetlands studied in India.

Fig. 3 : An upcoming wetland, in abandoned Bhatti Mine Area, in Arawall range, South Delhi (*Courtsey :* Anun Kumar, ZSI)

3.1. Ecosystem/Habitat diversity

Freshwater wetlands conceptually mean different things to different people. To the wetland ecologists, they are complex ecosystems and generally represent extremely important resources which change markedly and rapidly in response to fluctuations in climate and precipitation. As per Ramsar classification (Dugan, 1990) there are 25 categories of freshwater wetlands of which 17 are natural and 8 man-made (Table 1). Only a few of these categories received adequate attention from scientists in India. However, some representative freshwater wetlands, *viz.*, Dal lake, Kolleru lake, Loktak lake and Rabindra sarovar are referred herein along with reservoirs and floodplain wetlands in a general way. In the present paper attempts will be made to highlight the freshwater wetlands and their biodiversity with special reference to the following wetland types :

1. **Freshwater lakes** : Naturally formed deeper waterbodies

Table 7. State-wise list of important reservoirs in India

States and Reservoirs	River on which reservoirs are situated	Location (District)	Area (ha)
Andhra Pradesh			
1. Osmansagar Dam	Musi	Medan	4,200.980
2. Himayatsagar Dam	Issi	Medan	3,807.000
3. Nagarjunsagar Dam	Krishna	Nalagonda	30,303.000
4. Nizamsagar Dam	Mowgina	Nizamabad	14,636.090
5. Mopad Dam	Mammore	Nellore	1,693.860
6. Other reservoirs	—	—	78,326.780
			132,968.010
Bihar			
1. Panchet Dam	Damodar	Santhal Parganas	7,511.000
2. Maithon Dam	Barakar	Santhal Parganas	11,491.830
3. Konar Dam	Konar	Santhal Parganas	2,792.020
4. Tilaiya Dam	Barakar	Hazari Bagh	6,475.000
5. Mayurakshi Dam	—	—	6,734.000
6. Other reservoirs	—	—	2,245.530
			37,249.380
Gujarat			
1. Mahi stage II	—	—	16,576.000
2. Ukai	—	—	51,282.000
3. Other reservoirs	—	—	15,081.570
			82,939.570
Jammu and Kashmir			
1. Lidder Project	—	—	116.550
			116.550
Kerala			
1. Periyar Barrage	Periyar	Kottayam	606.000
2. Neyyar Dam	Neyyar	Trivandrum	9,065.000
3. Other reservoirs	—	—	9,755.624
			19,426.624

Table 7. contd.

States and Reservoirs	River on which reservoirs are situated	Location (District)	Area (ha)
Madhya Pradesh			
1. Tawa Multipurpose project	Tawa	Hoshangabad	29,533.770
2. Gandhisagar	Chambal	Mandsaur	64,750.000
3. Barodia	—	Shajapur	6,879.040
4. Other reservoirs	—	—	50,883.930
			152,046.740
Tamil Nadu			
1. Bhavanisagar	Bhavani	Coimbatore	7,861.840
2. Stanley reservoir	Cauvery	Salem	15,343.750
3. Poondi reservoir	Koraliyar	Chingelpet	3,263.400
4. Other reservoirs	—	—	23,408.163
			49,877.153
Maharashtra			
1. Shivajisagar	Koyna	Satara	12,100.480
2. Darwa Dam	Darwa	Nasik	3,367.000
3. Other reservoirs	—	—	135,647.230
			151,114.710
Karnataka			
1. Tungabhadra	Tungabhadra	Hospet	37,814.000
2. Vanivilasagar	Vedavathi	Chitradurga	7,252.000
3. Linganamakki	Sharavathi	Shimoga	38,850.000
4. Krishnarajasagar	Cauvery	Mysore	12,924.000
5. Other reservoirs	—	—	55,932.100
			152,772.100
Orissa			
1. Hirakud	Mahanadi	Sambalpur	74,592.000
2. Other reservoirs	—	—	5,275.830
			79,867.830
Punjab & Himachal Pradesh			
1. Beas Dam	Beas	Kangra	26,418.000
2. Govindsagar	Sutlej	Kangra	16,838.720
3. Other reservoirs	—	—	111.370
			43,368.090
Rajasthan			
1. Rana Protapsagar	—	—	20,720.000
2. Bajajsagar	—	—	12,950.000
3. Other reservoirs	—	—	10,250.430
			43,920.430
Uttar Pradesh			
1. Sardasagar Dam	Chukasanda	Nainital	7,303.800
2. Nanaksagar	Desha	Nainital	4,662.000
3. Matatila	—	—	20,720.000
4. Rihand	Rend (a tributary of Son river)	Mirzapur	46,620.000
5. Other reservoirs	—	—	46,419.749
			125,725.549
West Bengal			
1. Kangsabati	—	—	11,396.000
2. D. V. C. Konar Dam	—	—	2,331.000
3. Other reservoirs	—	—	9,840.880
			23,567.880
		Grand Total :	**1,094,960.616 ha**

Source : Jhingran (1977)

2. **Freshwater floodplains** : Natural areas that undergo periodic flooding as a river channel overflows with flood water, *i.e.*, shallow and seasonal waterbodies.

3. **Freshwater reservoirs** : Man-made areas holding water for irrigation and/or human consumption.

The ecological diversities of these three wetland types, *viz.*, lakes, floodplains and reservoirs from different parts of India with reference to water quality and soil characteristics as well as hydrobiological features are depicted in Tables 9-11 as follows. The chemical characters of water of a reservoir vary with its age. Sreenivasan (1969)

Table 8. Some general information and physiographical features of five basic regions dominated by freshwater wetlands in India

General/Physiographic features	Five basic regions of freshwater wetlands				
	Deccan peninsula	Central highlands, deserts and semi deserts	Gangetic plains	North-eastern hills and Brahmhaputra valley	Mountain region
	(1)	(2)	(3)	(4)	(5)
Location					
Latitude	22—32°N	22—29°N	22—30°N	22—29°N	30—35°N
Longitude	75—88°E	72—82°E	75—82°E	88—91°E	73—80°E
States	Parts of Maharashtra, Karanataka, Madhya Pradesh, Andhra Pradesh, Tamil Nadu & Orissa	Gujarat Rajasthan, Madhya Pradesh	Haryana, Uttar Pradesh, West Bengal, Bihar	North eastern States	Jammu & Kashmir, Laddakh
Cimatic conditions					
Overall climate	Tropical monsoon	Dry tropical monsoon	Subtropical monsoon	Humid tropical monsoon	Arid Tibetan montane
Summer temperature	38°—42°C	40—45°C	35—39°C	28—32°C	18—20°C
Winter temperature	8—14°C	10—20°C	10—18°C	6—10°C	-40 to 5°C
Humidity	Medium	Low	High	High	Low
Rainfall	Medium (50—200 cm)	Low (20—80 cm)	Fairly heavy (150—200 cm)	Heavy (above 250 cm)	Low (Below 50 cm)
Landscape type	Plateau-peninsula	Highlands, deserts, semi-deserts	Riverine plains	Hills and river valley	Montane valley
Altitude	1350—1650 m	15 —360 m	5—250 m	50—4580 m	1500-4530 m
Soil type	Red, Black, Laterilte, etc.	Red, Black, Desert, saline, etc.	Riverine, alluvial, etc.	Mountain, alluvial, laterite, red, etc.	Mountain
Vegetation type	Low trees, bushy thorn, scrub and grass	Thorn, scrub	Trees, weeds, grasses	Evergreen trees, swamps, grasses	Oak, Pine, thorny bushes, grasses
Forest type	Monsoon & dry deciduous	Xerophytic & semi-xerophytic	Monsoon deciduous	Tropical rain forest	Mountain coniferous

reported that in soft-water reservoirs like Amravathy, Bhavanisagar, Stanely, Aliyar and Sandynulla, free carbon dioxide and methyl orange alkalinity increased, while carbonates and pH decreased with depth. In hardwater reservoirs, such as, Sathanur and Krishnagiri, a wide changes occur in carbonates and bicarbonates, but the pH value does not show marked variations. Surface water often develops a high pH due to photosynthesis, while waters below the zone of effective light penetration show low pH values. Sreenivasan (1969) found nitrates and phosphates either lacking or occurring in traces in South Indian reservoirs. David *et al.* (1969), however, recorded phosphate values of Tungabhadra reservoir generally in traces (0.02-0.03 ppm) and occasionally as high as 3.3 ppm. The chracteristic soil and water qualities play a prominent role and determine the productivity of lakes. The size and shape of reservoirs often influence their productivity (Rawson, 1952 ; Sreenivasan, 1969). No uniform and intelligible patterns of productivity are discernible. Obviously a wide variety of features influence productivity. Among deeper reservoirs, Sreenivasan (1969) recorded low productivity in Hope Lake, Manimuthar and Pechiparai reservoirs of Tamil Nadu, while Stanely (Mettur Dam) and Bhavanisagar had high primary production and high nanoplankton. The freshwater floodplains are mostly seasonally productive. However, the freshwater reservoirs are known to pass through three trophic phases, such as, (i) initial fertility, (ii) trophic depression and (iii) low fertility after trophic depression. But very little work has been done in India to track the extent and duration of these three stages of evolution of lacustrine ecology with respect to Indian reservoirs.

3.2. Species diversity

The freshwater wetlands in India support a significant proportion of the total diversity

Table 9. Water characteristics of four representative freshwater lakes in India

	Representative freshwater lakes in India			
Parameters	**Dal Lake**	**Loktak Lake**	**Kolleru Lake**	**Rabindra Sarovar**
Physical				
Water temperature (°C)	5—31	—	24—32	22—33
pH	7.2—9.8	6.2—6.4	—	7.7—9.3
Total hardness	—	—	60—964 (ppm)	61.4—448.4 mg/l
Turbidity	—	—	—	6.2—20.8 (NTU)
Conductivity (mmhos)	543	—	—	379—737
Total dissolved solids (mg/l)	—	—	—	181—314
Transparency (cms)	65—520	—	30—138	—
Chemical				
Dissolved oxygen	1.4—12.3	—	7.2—8.9	5.5—7.5
Alkalinity	195 (mg/l)	24—36 (ppm)	—	2.9—4.3 (mmol/l)
Chloride	—	—	—	36.8—76.1 (mg/l)
Total phosphorus	115 (mg/l)	0.01—0.40 (ppm)	2.4—7.8 (mg/l)	0.09—1.00 (mg/l)
Nitrate	780 (mg/l)	—	—	0.06—3.32 (mg/l)
Nitrite	—	—	—	0.04—0.23 (mg/l)
Ammonium	—	—	—	0.04—1.03 (mg/l)
Free carbon dioxide	—	—	0—130 (ppm)	0.05—2.6 (mg/l)

Table 10. Soil characteristics and hydrological conditions of floodplain beels

Parameters	Kulia beel (W.B.)	Dhir beel (Assam)	Maktapur maun (Bihar)
Soil Characteristics			
pH	6.4 — 6.8	5.1 — 5.8	6.7
Organic carbon (%)	4.0 — 9.0	2.8 — 5.9	4.8
Available nitrogen (ppm)	858 — 985	605 — 782	634
Available phosphate (ppm)	60 — 185	40 — 170	10
Water quality			
Dissolve oxygen (mg L^{-1})	6.6 — 7.78	4.27 — 11.2	3.4 — 10.0
pH	7.6 — 8.0	6.4 — 7.4	7.9 — 8.15
Alkalinity (mg L^{-1})	106.7 — 170.0	15.0 — 40.0	90.0 — 110.0
Sp. conductance (mmhos)	467.8 — 762.8	34.9 — 73.1	190 — 230
Dissolved organic matter (mg L^{-1})	1.0 — 2.4	2.8 — 4.8	1.8 — 3.2
Phosphate (mg L^{-1})	0.03 — 0.06	0.02 — 0.1	0.04 — 0.1
Nitrate (mg L^{-1})	0.12 — 0.25	0.05 — 0.4	0.12 — 0.3

Source : Pathak (1989) : CICFRI Bulletin No. 63 : 43—53

Table 11. Hydrobiological parameters of some small reservoirs

Parameters	Low	Govindgarh	Kulgarhi	Gulariya
pH	7.5 — 81	8.0 — 8.8	8.0 — 8.2	7.2 — 8.4
Transparency (cm)	58.0 — 69.8	55.8 — 102.1	9.4 — 116.9	11.0 — 80.0
D.O. (ppm)	6.7 — 7.5	6.2 — 12.1	6.2 — 11.5	4.9 — 9.0
Free CO_2 (ppm)	Nil — 1.69	1.48 — 3.65	2.14 — 5.25	Nil — 4.0
Total alkalinity (ppm)	85 — 162	26 — 54	38 — 130	38 — 80
Hardness (ppm)	27 — 101	15 — 39	30 — 73	13 — 34
Phosphate (ppm)	0.11 — 0.165	Trace — 0.058	Trace — 0.082	0.05 — 0.13
Nitrates (ppm)	0.13 — 0.24	Trace — 0.130	Trace — 0.047	0.08 — 0.20
Silicates (ppm)	8 —15	Trace — 13	2.5 — 13.2	5.0 — 14.0
Plankton (u/l)	490 — 1034	93 — 1908	32 — 860	245 — 4060
Macrobenthos (u/m^2)	6054 (av.)	387 — 1610	29 — 457	95 — 4769
Macrovegetation (g/m^2)	44 (av.)	Absent	Absent	Absent

Source : Jhingran (1986) reprinted in 1989 : CICFRI Bulletin No. 45 : 1-65

of organisms, representing almost all taxonomic groups. Besides fish, these wetlands are dominated by microscopic algal forms, protozoans and planktonic communities. Their diversity and growth is generally limited by the availability of essential nutrients like nitrogen and phosphorus in the wetlands. There are publications dealing with biota of freshwater wetlands in India indicating high biodiversity (Biswas and Calder, 1937 ; Desikachary, 1959 ; Tonapi, 1980 ; Jayaram, 1981 ; Michael and Sharma, 1988 ; Subba Rao, 1989; Anonymous, 1991 ; Gopal and Asthana, 1991). However, currently studies are being made to understand the role of wetlands as interfaces between dryland and water in

Fig. 4 : A wetland of the Malabar plains at the foot-hills of Western Ghats (*Courtsey* : C. Radhakrishnan, ZSI)

conservation and management of biodiversity (Bandhyopadhyay and Gopal, 1991 ; Gopal and Krishnamurthy, 1992; Nandi, 1996).

3.2.1. Flora : India has a great floristic diversity. The floral element in freshwater ecosystems is dominated by algae in open waters whereas the higher plants (macrophytes) dominate the littoral region. There are many diverse forms of bacteria and fungi but very few bryophytes. The estimated number of species of higher plant groups in Indian freshwater system is as follows : Pteridophytes—87 species and Angiosperms—690 species. There is no accurate information on many major algal groups. A large number of new species have recently been recorded. However, out of several thousands of algal species, many are endemic to India. Some algal flora are considered a nuisance, while the most play an important role in the food chain of fishes. The bluegreen algae (Cyanophyceae) are important for their ability to fix atmospheric nitrogen especially in the paddy fields. Many algae have also been demonstrated for their medicinal value. Some species belonging to *Spirulina*, *Chlorella* and *Scenedesmus* are a rich source of proteins for human beings.

Biswas and Calder (1937) made an overview of aquatic vegetation and they described more than 170 species of aquatic and marsh plants. Subrahmanyam (1960) reported only 117 common species. Lavania *et al.* (1990) listed 457 species of herbaceous plants from Indian subcontinent. However, expert plant taxonomists are of the opinion that the total number of higher aquatic wetland plant species in India exceeds 1200 species. Of these, more than 60 species of vascular plants are endemic to India. The freshwater wetlands in India have also been invaded by several exotic species,

Fig. 5 : Macrophytal flora of a freshwater wetland in West Bengal

most of which have acquired nuisance proportions threatening very existence of many of the habitats as well as native biota and total biodiversity. The water hyacinth tops the list followed by other major species like *Salvinia molesta* and *Alternanthera philoxeroides*. *Ipomoea carnea fistulosa* introduced as a terrestrial species has invaded waterbodies and wetlands in recent years all over India, and often forms dense strands.

The floristic component of Haigam Rakh, a high altitude shallow (1.25 m) freshwater lakes of Srinagar in Jammu and Kashmir is dominated by reeds belonging to *Typha, Phragmites, Phalaris, Scirpus, Carex*, etc., while its open water areas have a floating community of water lilies *(Nymphaea, Nymphoides)*, *Trapa natans* and beds of *Potamogeton* spp. Some 183 species of phytoplankton predominated by Chlorophyceae have also been recorded. In the Dal Lake, *Alisma plantago, Juncus glaucus* and *Hydrilla verticillata* occur in shallow areas ; *Myriophyllum spicatum, Ceratophyllum demersum* and *Potamogeton* sp. in the deeper parts and extensive mats of *Lemna* sp., *Salvinia natans* and *Spirodella polyrhiza* on the surface.

The wetland flora of Keoladeo Ghana National Park of Rajasthan is quite diverse and include *Nymphaea nuchalis, N. stellata, N. cristata, Nelumbium* sp., *Lemna* spp., *Azolla* sp., *Vallisneria* sp., *Hydrilla* sp., *Naja* spp., *Chara* spp., *Wolffia* sp., *Paspalum* spp., *Ipomoea* sp., *Cyperus* spp. and *Typha angustata*. Various species of *Potamogeton, Nymphoides, Scirpus* and *Eleocharis* have also been recorded. In recent years, following the exclusion of grazing water buffalo from the park, there has been a phenomenal increase in *Paspalum distichum, Cyperus alopecuroides, Eleocharis plantagenia, Typha angustata* and *Vetiveria zizanoides*.

The chaurs of North Bihar and West Bengal support a great abundance of aquatic vegetation. The emergent vegetation is dominated by *Cyperus rotundus* with *Hygroryza* sp., *Oryza sativa, Scirpus articulatus, S. littoralis* and *Paspalidium geminatum*. Free floating plants include *Eichhornia crassipes, Pistia stratiotes*,

Fig. 6 : A shallow freshwater wetland of West Bengal infested with different macrophytic communities

Lemna minor, Spirodella polyrhiza, Azolla pinnata and *Trapa bispinosa.* Rooted floating forms include *Ipomoea aquatica, I. rubens, Enhydra fluctuans, Eclipta prostata, Jussia repans, Nymphaea* sp., *Euryale ferok* and *Bacopa monieri.* Submergent species include *Potamogeton crispus, Hydrilla verticillata, Ceratophyllum demersum, Vallisneria spiralis* and *Najas graminea.* From the chaurs of North Bihar, Rai and Datta Munshi (1982) recorded eighty species of phytoplankton representing Cyanophyceae, Chlorophyceae and Bacillariophyceae.

The dominant aquatic plants of Loktak lake, Manipur, are *Eichhornia crassipes,* and species of *Polygonum, Vallisneria* and *Trapa.* The composition of floating 'phumdi' of Keibul Lamjao National Park was estimated as follows : *Phragmites karka* (45%), *Erianthus ravennae* (25%), *Saccharum munja* (15%), *S. latifolium* (5%), *Alpinia allughas* (5%), *Saccharum procerum* (2%) and 3% other species including *Zizania latifolia,* a plant much relished by endangered Manipur Brow-antlered deer, *Cervus eldi eldi.*

3.2.2. Fauna : Wetland fauna are herein considered those animals that reside permanently or temporarily in and around waterbodies or aquatic ecosystems for food, shelter and/or nesting. Some of them are permanently aquatic and live in water like fish, while some others are temporarily aquatic and live at least for a part of their life in water like dragon fly. There are some others recognised as wetland dependent fauna (e.g., Kingfishers) that live on land or trees or both, and depend on wetlands for fish and other aquatic organisms as their food. Still, some others are wetland associated fauna (e.g., Reed warblers) that are associated with wetlands and stay or roost on marshes and/or reeds. All these three categories of wetland fauna, *viz.,* (i) aquatic, (ii) wetland dependent and (iii) wetland associated comprise the faunal composition of wetlands. But a large number of still other animals, least depended on wetlands, which may often be found as ground-dwellers or tree-dwellers, either permanently or as occasional visitors, are termed as dryland terrestrial fauna of the wetland complex. Therefore, a typical wetland fauna should habitually be found to live or spend a major part of their life either permanently, or a part of their life, throughout or seasonally, as an integreal part of the ecosystem (Nandi *et al.,* 1993, 1999).

The major groups of wetland fauna, aquatic, wetland dependent and wetland associated, occurring in freshwater wetlands of India are estimated in Table 12. It is evident that about 7.7% of the total fauna in India are associated with freshwater wetlands. Mention may be made that the faunal diversity of Indian wetlands has been estimated at 17,853 (19.9%) of 89,451 species occurring in India (Alfred *et al.,* 1998 ; Alfred and Nandi, 2000). However, the faunal diversity can not be accurately estimated due to inadequate exploration of wetlands as well as lack of identification key to many invertebrate groups and especially for larval insects. The situation is also worst in case of microfauna and meiofauna that occur in freshwater wetlands. Furthermore, there are few expert taxonomists in country. All these add to the estimation of species very difficult, even though there is a surge of interests on wetlands in India.

Mammalian fauna

A wide variety of mammals occurs in Indian freshwater wetlands, but none of them occurs in large numbers. The wetlands of Keoladeo Ghana National Park represent 21 species of mammals including six species of ungulates, *viz., Antelope cervicapra, Axis axis, Cervus unicolor, C. porcinus, Boselaphus tragocamelus* and *Sus scrofa.* The Smooth Indian Otter, *Lutra perspicillata* is often seen in the wetlands. Cats include *Felis chaus, F. benghalensis* and the marsh-dwelling Fishing Cat, *F. viverrina.* The mongooses *Herpestes edwardsi* and *H. auropunctatus* are quite common, as is the hare *Lepus nigricollis.* The porcupine *Hystria indica* is frequently observed. *Vulpes bengalensis, Canis aureus* and *Hyaena hyaena* are present, along with *Viverricula indica* and *Paradoxurus hermaphroditus.* Primates are

Table 12. Estimated number of animal species occurring in freshwater wetlands in India

Taxonomic groups	Number of species occurring in India	Indian wetlands	Indian freshwater wetlands	% in freshwater wetlands to those in Indian wetlands
Kingdom PROTISTA				
Protozoa	2577	1250	550	44.0
Kingdom ANIMALIA				
Mesozoa	10	10	—	—
Porifera	486	400	33	8.2
Cnidaria	842	540	10	1.8
Ctenophora	12	10	—	—
Platyhelminthes	1622	1200	50	4.1
Rotifera	330	330	320	96.9
Gastrotricha	100	80	23	28.7
Kinorhyncha	10	10	—	—
Nematoda	2850	500	150	30.0
Acanthocephala	229	150	50	33.3
Sipuncula	35	30	—	—
Mollusca	5070	2300	183	7.9
Echiura	43	40	—	—
Annelida	840	500	350	70.0
Onychophora	1	—	—	—
Arthropoda	68389	7302	4050	55.4
Crustacea	2934	2000	800	40.0
Insecta	59353	5000	3000	60.0
Arachnida	5818	300	250	83.3
Pycnogonida	16	—	—	—
Chilopoda	100	—	—	—
Diplopoda	162	—	—	—
Symphyla	4	—	—	—
Merostomata	2	2	—	—
Phoronida	3	3	—	—
Bryozoa (Ectoprocta)	200	100	35	35.0
Entoprocta	10	5	1	20.0
Brachiopoda	3	3	—	—
Chaetognatha	30	10	—	—
Tardigrada	30	20	10	50.0
Echinodermata	765	500	—	—
Hemichordata	12	10	—	—
Chordata	4952	2550	1141	44.7
Protochordata	119	70	—	—
Pisces	2546	2000	742	37.1
Amphibia	209	150	150	100.0
Reptilia	456	50	24	96.0
Aves	1232	250	200	80.0
Mammalia	390	30	25	83.3
Total	**89,451***	**17853****	**6956**	**38.9**

Source : * Alfred *et al.* (1998), ** Alfred and Nandi (2000) represented in the park by *Macaca mulatta* and *Presbytis entellus* (Scott, 1989). But all these 21 species are not typical component of wetland fauna.

The wetlands in Jaldapara Wildlife Sanctuary in West Bengal are primarily protected for One-horned Rhinoceros, *Rhinoceros unicornis.* Other large mammals include Tiger *Panthera tigris,* Indian Elephant *Elephas maximus,* Swamp Deer, *Cervus duvaucelli* and possibly the rare Pygmy Hog *Sus salvinus.* The wetlands of Manas Wildlife Sanctuary in Assam also support an extremely varied mammalian fauna including Indian Elephant and One-horned Rhinoceros. There are several wetland and grassland species, such as, *Caprolagus hispidus, Lutra perspicillata, Felis viverrina, Sus salvinus* and *Cervus duvaucelli.* There is also a residential population of wild Water Buffalo, *Bubalus bubalis.* The wetlands in Kaziranga National Park, Assam contain mammalian fauna almost similar to those in Manas Wildlife Sanctuary. The Park also contains Common Otter *Lutra lutra* and Ganges River Dolphin, *Platanista gangetica* in its rivers. The swamp of Keibul Lamjao National Park is inhabited by a variety of mammals, such as, Sambar, Hog Deer, Common Otter, civets and Wild Boar. But it is famous as the last refuge of the Manipur Brow-antlered Deer, *Cervus eldi eldi,* locally known as "Sangai" The subspecies was thought be extinct in the wild, but a small heard was discovered in Keibul Lamjao in 1950. Under protection in the park, the population has slowly increased from 14 individuals in 1975 to 106 animals in 1991 (Mukherjee, 1994).

Avifauna

The high altitude freshwater lakes, *viz.,* Dal lake of Jammu & Kashmir State was a very important breeding area for a variety of waterfowl and also a wintering area for large numbers of Anatidae. At present, the avifuna of this lake is in serious decline. However, Haigam lake in Baramullah district, Mirgund lake of Srinagar and Hokarsar lake in Badgam district of Jammu and Kashmir support both resident and migratory waterfowl. These lakes are important wintering areas for migratory ducks and breeding areas for herons, egrets, rails, etc. In spring and autumn, Haigam lake provides a vital staging area for many passage migrants including at least 18 species of shorebirds and several trans-himalayan passerine migrants. In Hokarsar lake, up to 25,000 wintering ducks have been recorded at one time ; the common species are : *Anas penelope* (7,000), *A. crecea* (10,000), *A. acuta* (15,000), *A. strepera* (5,000), *A. platyrhynchos* (15,000), *A. clypeata* (5,000), *Netta rufina* (2,000), *Aythya ferina* (10,000) and *A. nyroca* (1,000).

Harike Lake in Amritsar district of Punjab state is extremely important staging and wintering area for migratory waterfowl, particularly ducks. At one time over 20,000 ducks have been counted at the peak of the migration season. The lake is evidently very attractive to diving ducks, *Netta rufina, Aythya ferina* and *A. fuligula,* Resident species occurring in good numbers include cormorants, herons, egrets, etc. Dihalia jheel in the Karera Bustard Sanctuary, Madhya Pradesh is an extremely important wetland for both resident and migratory waterfowl. In January 1987, it was estimated that well over 500,000 waterfowl were present on the lake. The great majority were the dabbling ducks *Anas penelope, A. strepera, A. crecca, A. acuta, A. querquedula* and *A. clypeata,* but large numbers of diving ducks were also present. Besides these, 11 species of other waterfowl and 21 species of shorebirds and a variety of birds of prey, such as, *Pandion haliaetus, Haliaeetus leucoryphus, Circus aeruginosus, Aquila rapax* and *Falco peregrinus* occur in the vicinity of the jheel. The population of Great Indian Bustard *Ardeotis nigriceps* has increased from 14 adults in 1982 to about 30 in 1987. Chandpata Lake also known as Sakhya Sagar is a small freshwater lake within Madhav (Shivpuri) National Park of the Vindhyan Range, Madhya Pradesh. Like Dihalia jheel, Chandpata lake is also important for a wide variety of resident and migratory waterfowl.

Fig. 7 : An Openbill Stork (*Anastomus oscitans*) foraging in Kabar Lake, Bagusarai District, Bihar (*Courtsey* : S. Z. Siddiqui, ZSI)

Groves of trees around the lake support a nesting colony of cormorants, herons, egrets, storks and ibises, and large numbers of ducks, geese and cranes occur in winter.

The Keoladeo Ghana National Park was established as a wetland of International Importance in October, 1981, and was nominated as World Heritage Site in 1984, having been designated as a Bird Sanctuary in March 1956. This important Ramsar site supports at least 332 species of birds and is particularly famous for its wintering flock of Siberian White Crane *Grus leucogeranus*. This flock has decreased over the years from 76 individuals in 1970 to only 31-37 in the winter of 1987/88. Recently, after an absence of two

Fig. 8 : A flock of Little Egrets at feed, at Asan Reservoir, Dehra Dun Valley. (*Courtsey* : Arun Kumar, ZSI)

years, the endangered Siberian Crane (4 individuals) was reported in February 1996 from its traditional site (Meine and Archibald, 1996). However, based on Shonon-Weiner Index, the species diversity of freshwater wetland birds in India is found to be highest in Keoladeo (Rajasthan), followed by Karera of Madhya Pradesh and Harike of Punjab (Vijayan, 1986). Mention may be made that the Keoladeo Ghana National Park was not covered by the Asian Waterfowl Census 1994-96. Even then 34 out of 1,421 sites counted in India qualify as sites of international importance hosting more than 20,000 waterfowl. Of these sites, it should be mentioned, only 17 have been reported to be under legal protection. Among the States, Gujarat (8) remained the top contributor to the number qualifying for Ramsar site followed by Orissa (6), Andhra Pradesh (3) and Karnataka (3). And of the two sites in West Bengal hosting over 20,000 birds, one (Jaldapara Wildlife Sanctuary) is under legal protection, while the other (Kangsabati reservoir 22,274 birds in 1996) lacks legal protection (Lopez and Mundkur, 1977).

Herpetofauna

Both reptilian and amphibian fauna of Indian freshwater wetlands are ill-explored. From Kashmir valley the occurrences of *Rana cyanophlyctis* and *Bufo viridis* in Haigam Lake and Mirgund Lake have been recorded. In Harike Lake, Punjab, several species of freshwater turtles are found, of which *Kachuga tectum* and *Lissemys punctata* are the most common. The wetlands in Corbett National Park support the Marsh Crocodile *Crocodylus palustris* and the Gharial *Gavialis gangeticus*, which has been re-introduced into the park in the early 1980's. The Chandpata Lake of Madhya Pradesh supports a large population of *Crocodylus patustris*. Keoladeo wetland sanctuary supports snakes like *Naja naja*, *Python molurus*, *Bungarus fasciatus* and *Zaocys nigromarginatus*. Other reptiles include monitor lizard, *Varanus* sp. and six species of freshwater turtle. Nandi *et al.* (1993, 1999) reported six species of reptiles and six species of amphibians as aquatic or wetland associate, from freshwater wetlands of North 24 Parganas, South 24-Parganas, as well as Haora and Hugli. districts, West Bengal. Among reptiles, two species of colubrid snakes *(Enhydris enhydris* and *Xenochrophis piscator)* are the most common and among amphibians three species ranid frogs *(Rana cyanophlyctis, R. limnocharis* and *R. tigerina)* and a species of toad *(Bufo melanostictus)*. Sarkar (1984), however, recorded 13 species of amphibians from Calcutta and its environs with the mention of *R. cyanophlyctis* as the commonest frog of the area.

Ichthyofauna

Inland freshwater ichthyofauna represent 742 species falling under 133 genera, 64 families and 16 orders (Jayaram, 1981). Like avifauna, it is one of the best known group of wetland fauna of Indian region. Das (1962) recorded 36 species of fishes from rivers and lakes of Kashmir area. The floodplain marshes of Jhelum river in the vale of Kashmir support rich fish fauna, such as, *Cyprinus carpio, Crossocheilus, Gambusia* spp., *Barbus* spp. and *Schizothorax* spp. More than 15 species have been recorded from Harike Lake, Punjab, including several commercially valuable species. The fish fauna in the swamp of Keibul Lamjao National Park includes *Channa striatus, C. punctatus, Cyprinus carpio, wallago attu* and *Puntius sophore.*

Kolleru Lake supports 63 species of fishes belonging to 29 families. These include *Notopterus notopterus, Chanos chanos,* 18 species of Cyprinidae, *Wallago attu, Ompak pabda, O. bimaculatus, Mystus* spp., *Clarias batrachus, Heteropneustes fossilis, Xenentodon cancila, Chanda* spp., *Nandus nandus, Mugil cephalus, Glossogobius giuris, Anabas testudineus, A. oligolepis, Colisa fasciata, Channa* spp. and *Mastacembelus armatus.*

Macroinvertebrates

The macro-invertebrate elements in freshwater systems include a wide variety of Mollusca (Subba Rao, 1989) as well as Annelida

Table 13. Commonly occurring macrobenthic fauna of freshwater lakes and ponds in India

Groups		Species of genera
Oligochaeta	:	*Branchiura, Limnodrilus, Chaetogaster, Branchiodrilus, Dero, Aulophorous, Nais, Aeolosoma, Enchytraeus*, etc.
Crustacea	:	*Nichollsia, Ampelisca, Caridina, Palaemon, Macrobrachium, Paratelphusa*, etc.
Ephemeroptera	:	*Ephemerela, Caenis, Ephemera*, etc.
Odonata	:	Anisopteran (Dragonfly) nymphs—*Anax, Hemianax, Ictinogomphus, Trithemis, Neurothemis, Brachythemis*, etc.
Hemiptera	:	*Laccotrephes, Diplonychus, Lithocerus, Corixa, Micronecta*, etc.
Coleoptera	:	*Cybister, Hydaticus, Eretes, Laccophilus, Canthydrus, Hydrophilus, Sternolophus, Regimbartia, Berosus*, etc.
Diptera	:	*Tendipes, Cryptochironomus, Polypedilum, Harinchia, Culicoides, Ceratopogon, Pentaneura*, etc.
Hydracarina	:	*Arrenurus, Hydrachna, Hydrodroma*, etc.
Gastropoda	:	*Bellamya, Pila, Lymnaea, Gabbia, Thiara, Digoniostoma, Indoplanorbis, Gyraulus, Brotia*, etc.
Bivalvia	:	*Lamellidens, Parreysia, Pisidium*, etc.

Table 14. Macrofaunal community associated with macrophytes of freshwater wetlands in India

Groups		Species of genera
Oligochaeta	:	*Aulophorus, Branchiodrilus, Nais, Allonais, Pristina*, etc.
Hirudinea	:	*Hirudinaria, Glossiphonia, Helobdella*
Crustacea	:	*Caridina, Palaemon, Macrobrachium, Paratelphusa*, etc.
Ephemeroptera	:	*Baetis, Caenis, Cloen*, etc.
Odonata	:	*Brachythemis, Crocothemis, Orthetrum, Ceriagrion, Ischnura*
Hemiptera	:	*Diplonychus, Limnogonus, Hydrometra, Ranatra, Mesovelia, Notonecta, Anisops, Plea*, etc.
Coleoptera	:	*Canthydrus, Laccophilus, Amphiops, Helochares, Regimbartia, Haliplus, Dineutes*, etc.
Diptera	:	*Chironomus, Mansonia, Mansonoides*, etc.
Hydracarina	:	*Hydrachna, Arrenurus*, etc.
Gastropoda	:	*Lymnaea, Bellamya, Pila, Indoplanorbis, Digoniostoma, Gyraulus*, etc.

and Arthropoda (Tonapi, 1980 ; Alfred and Nandi, 2000). The commonly occurring benthic species in lakes and ponds are listed in Table 13, while the animal communities associated with aquatic plants are shown in Table 14. Most of them form essential food items of commercially important fishes. Kaul (1982) studied two lakes of Kashmir and stated that the dominant invertebrate group was constituted by a varied combination of these three phyla. The seasonal patterns of total macroinvertebrates population and standing crop in all the four basins of Dal Lake on the whole revealed a unimodal growth curve with late spring and summer distinguished as a period of enormous growth. The standing crop at the peak growth stage ranged from 2.95 to 11.98 dry wt gm/m^{-2}. The maximum contribution to the total standing crop is due to molluscs (snails) followed by insects. Michael (1964) who studied the bottom fauna of perennial tank at Barrackpore (West Bengal), found most of the organisms in maximum densities during January to April with an average of 3,242 organisms/m^2. Nandi *et al.* (1993, 1999) recorded 7 species of decapod crustaceans, 27 hemipterans, 35 coleopterans and as high as 8 species of spiders, 8 species of annelids and 16 molluscan species from various freshwater wetlands of West Bengal. These include a number of commercially important prawns, crabs and molluscs including a species of pearl-bearing mussel, *Lamellidens marginalis*. Mention may be made that Nandi and Mukherjee (1996) recorded as high as 14% prevalence of pearl-bearing mussel in Calcutta wetlands.

Kawar Lake in Bihar is one amongst 21 lakes under National Lake Conservation Plan (NLCP). Altogether 87 macroinvertebrates were recorded in the lake (Sharma, 1996). They belong to 3 major groups among which arthropods were dominant (68 species ; 78.77%) over molluscs (11 species, 12.64%) and annelids (8 species; 9.19%). A survey of lake districts in North Bihar by Ojha (1989) revealed greater dominance of molluscs in almost all the lakes varying between 220-6500 organisms/m^2. The qualitative spectrum revealed the presence of Trichoptera. Diptera, Hemiptera and Mollusca. High dominance of molluscs was most significant represented by 8 species belonging to *Melanoides lineatus, Vivipera bengalensis, V. variatus, Pila globosa,* and *Indoplanorbis, Corbicula, Gyraulus,* and *Gabbia* species.

Zooplankton

The animal communities that spend their whole life drifting in water can be classified as microzooplankton, having less than 3 mm in size and macrozooplankton which are larger than 3 mm in size. The microzooplankton includes suspended organisms like protozoans, rotifers and crustaceans, while the largest floating forms or macrozooplankton comprise of euphausids, mysids and various invertebrate larvae. Our knowledge of freshwater zooplankton in India is still fragmentary, even though a large number of contributions are available (Anandale, 1911 ; Cook, 1967; Hubbard and Peters, 1978; Victor and Fernando, 1979; Tonapi, 1980 ; Sehegal, 1983; Sharma and Michael, 1987; Michael and Sharma, 1988; Sharma, 1996; Alfred *et al.*, 1998). However, the seasonal fluctuations of various groups of zooplankters have been studied by several investigators (Das and Srivastava, 1956, 1959 ; Bhowmick, 1968, Michael, 1969; Saha *et al.*, 1971).

In a fish pond at Cuttack (Orissa), Saha *et al.* (1971) found that rotifers (73-87%) dominate among zooplankton followed by Copepoda (15.3-29.9%). Protozoans and cladocerans formed an insignificant number in the total plankton. Cladocerans (3-5%) were mainly represented by *Moina* species. Of the zooplankters, plantonic crustaceans (Cladocera and Copepoda) comprise very largely the species which exhibit diurnal vertical movements. Certain rotifers also display diurnal movements.

In Haigam Lake of Jammu and Kashmir State, zooplankton diversity includes 51 protozoans, 25 rotifers and 40 crustaceans. Similarly, from this state the zooplankton is known to consist of at least 39 protozoans, 17 rotiferans and 41 crustaceans in Mirgund Lake, while 44 species of protozoans, 18 rotiferans and 38 crustaceans represent Hokarsar Lake. From Keoladeo Ghana or Bharatpur wetland, a total of 117 species of protozoans belonging to 78 genera have been identified (Mahajan *et al.*, 1982), while Venkataraman (1992) recorded 29 sepecies of cladocerans from this wetland.

In freshwater wetlands of Haora and Hugli districts, West Bengal, Nandi *et al.* (1999) reported a total 74 species of zooplankton belonging to 5 major groups in which cladocerans diversity dominates representing 52 species (70.2%) followed by copepods (8 species, 10.8%), rotifers (7 species, 9.4%) and ostracods (6 species, 8.1%). Among zooplankton, rotifers often account for about 70% of the total population followed by Copepoda (ca. 30%). Protozoans and cladocerans, though represent greater diversity, form an insignificant percentage in the total plankton. Alikunhi *et al.* (1955) have reported the occurrence of planktonic swarms in freshwater fish pond. Such swarms produced numerical increase of plankters belonging to Cladocera, Protozoa and others forming great bands or streaks or arranged into areas of thick and thin concentrations. The rhizopod protozoan *Difflugia*, the rotifers *Branchionus, Keratella, Filinia, Polyarthra* and *Pedalia*, the copepods *Cyclops* and *Diaptomus* and their nauplii and cladoceran *Monia* are some of the zooplankters encountered in swarms.

Parasitofauna

Parasites are distributed along with their hosts. Both vertebrate and invertebrate species of freshwater ecosystems are known to be infected by protozoan and helminth parasites. As a matter of fact one species of host is expected to harbour at least one species of parasites. But there is paucity of parasitological survey specially in freshwater wetlands in India. However, there are reports on the occurrence of protozoan parasites from fishes (Nandi *et al.*, 1983), amphibians (Ray and Choudhury, 1983 and 1984), reptiles (Mandal *et al.*, 1993), and other animals (Das *et al.*, 1993). Endocommensal opalinates and ciliates from frogs and toads have been studied by several workers in India (Bhatia, 1938 ; Mandal *et al.*, 1991). Ali (1956) conducted a survey of nematode parasites from fishes of Hyderabad, while Soota (1983) updated our knowledge of nematode parasites of Indian fishes. Kaw (1950) reported a new species of monoganetic trematode, *Diplozoon kashmirensis* infecting gills of *Schizothorax* sp. in Dal Lake, Srinagar. Tripathi (1957) published a monographic paper on monogenea fauna of India. Jain (1958-1961) as well as Agarwal and Singh (1980-1990) worked on the monogenea of freshwater fishes of Lucknow, while Karyakarte (1967-72) and Kulkarli (1969) investigated on these parasites from Marathwada and Hyderabad fishes respectively. Similarly, several investigators recorded the occurrence of trematode and cestode parasites of freshwater fishes (Chauhan, 1954; Mehra, 1980; Srivastava, 1982; Kundu, 1992). Datta (1936-1963) and Tripathi, (1959) added several acanthocephalan parasites from fishes. Sarkar *et al.* (1986) reported water mite parasitism on Indian mosquitoes.

4. SPECIAL FEATURES

The floristic component of Indian freshwater wetlands is dominated by macrophytes. But there are several thousands of freshwater algae, playing the most important role in the food chain of fishes. Many of these algal flora are endemic to India, while among the vascular plants, more than 60 species are known to be endemic to India. The estimated numbers of wetland plant species in India exceeds 1200. Even then there is no accurate information on many major floral groups as a large number of new species have been added in recent years. It is worth mentioning that the family Podostemaceae, a highly interesting group occurring in highly specialised habitats under the falls and on rocky beds of river in Kerala, Karnataka, Maharashtra and northeast India, represents more than 20 endemic species.

Among the known fauna, about 28,145 animal species are estimated to be endemic to India (Alfred, 1998). Of the 17,853 species, about 6956 species occur in freshwater wetlands in India (Table 12). The degree of endemism at the species level varies from group to group. Amongst invertebrates, more than 40% freshwater sponge, leeches and molluscs are endemic to the Indian region. Amongst vertebrates, the highest degree of endemism (61.24%) is seen in Amphibia (Alfred, 1998), which depend on wetland for their larval development, while 223 fishes mostly belonging to Cypriniformes, Siluriformes and Cyprinodontiformes are endemic to India. A single species of mammal *Herpestes palustris*, reported from Salt Lake swamp could be definitely recognised as endemic wetland mammal in India. Similarly, the only endangered wetland amphibian in India is represented by the Himalayan Newt *Pleurodeles verrucosus.* About 44 avian species including Openbilled Stork, Mandarin Duck, Whitewinged Wood Duck, Redcrested Pochard, Pinkheaded Duck, etc., are endemic to Indian wetlands.

5. INTRODUCED BIODIVERSITY

The occurrences and distribution of introduced species, either plants or animals, in Indian wetlands have not so far been highlighted. But there are ample evidences of introduced elements from Ethiopian, Neotropical and Australian realms to the Indian/Oriental region. Instances of plant invasion acquire nuisance proportions threatening very existence of wetland habitats. Several exotic species are reported to influence the native biota and total biodiversity. The list is topped by water hyacinth, *Eichhornia crassipes* which was introduced into India about a century ago (Gopal, 1987) and now occurs throughout India except in the cold regions of high altitudes and Jammu and Kashmir. The other major species that have gradually spread over large parts of the country are *Salvinia molesta* and *Alternanthera philoxeroides.* An exotic terrestrial species *Ipomoea carnea fistulosa* introduced into India has invaded waterbodies and wetlands all over India, and often forms dense strands.

Amongst animals, introduction of invertebrate species to Indian wetlands has been revealed from the study of Venkataraman (1992) and Venkataraman and Das (1993, 1994) who reported the occurrence of several temperate and palearctic species of Cladocera in the floodplain wetlands of West Bengal (Table 15). Several fish species have been introduced in India (Table 15) for piscicultural purpose since 1863 when Francis Day attempted to introduce the English trout, *Salmo truatta fario* in Nilgiri waters. These introduced elements are brought into India mainly through human. However, birds also play a profound role in the dispersal of cladoceran species (Proctor *et al.*, 1967).

6. VALUE

Besides food and food chain relationships, many animals (such as, swans, crane, turtles, crocodiles, snakes, etc.) and plants (like lotus, water lily, water chestnut, reeds, cattails, wildrice, etc.) have been a part of social and cultural life of humans in India. The passively floating algal flora play the important role as food for fishes. Many algae have medicinal values whereas some like *Spirulina, Chlorella* and *Scenedesmus* are a rich source of protein

Table 15. Some introduced faunal elements occurring in Indian freshwater wetlands

Groups	Species
Cladocera	: *Diaphanosoma brachyurum, D. senegalensis, Daphnia similis, Chydorus flavifrons, C. pubescens, Alona intermedia, A. rectangula, A. costata, Camptocercus australis, Pleuroxus similis, Grimaldina brazzai, Graptoleberis testudinaria, Leydigia australis, L. acanthocercoides.*
Pisces	: *Oreochromis mossambica, O. nilotica, Ctenopharhyngodon idella, Hypophthalamicthys molitrix, H. nobilis, Cyprinus carpio, Osphronemus gorami, Salmo truatta, Carassius auratus, C. carassius, Tinca tinca, Gambusia affinis, Poecilia reticulata.*

for human as well. Several wetland plants are used as food, vegetables, fodder, medicine, mat-making, thatching, fuelwood, fertilizer and pollution abatement purposes. Fruits of *Trapa* spp. and seeds of lotus are eaten as food. Leaves of *Typha* sp. are commercially exploited for making mats and screen. The wetland plants like *Herpestis*, *Hygrophilla*, *Centenella*, etc., have medicinal values. The seeds of *Nymphaea* sp. are made into puffed grain by frying them like popcorn. The stems and leaves of *Marselia*, *Ipomoea*, *Colocasia*, etc., are used as vegetables. The grasses belonging to the family Cyperaceae, Graminae, etc., are used for mat making and also as fodder for domestic livestock. Water hyacinth, *Azolla* and other free floating forms are used for making compost fertilizer and for the bio-gas plant. These free floating species and reeds act as water purifiers by trapping and treating sediment and metallic substances from sewage and polluted effluent waters.

Aquaculture with species of freshwater molluscs, crustaceans and fishes is augmented in recent years (Jhingran, 1997). It has developed primarily to provide protein meal for the increasing population in India. Fishes like major carps are a staple item in the diet of all classes of people from many states in India. The freshwater fish production from inland freshwater wetlands has increased manifolds from 218 tonnes in 1951 to 1450 tonnes in 1991. The freshwater mussel *Lamellidens* spp. are also known to bear pearl in wetlands of West Bengal (Raut and Biswas, 1989 ; Nandi and Mukherjee, 1996). The Directorate of Fisheries, Government of West Bengal has initiated freshwater pearl culture in ponds.

7. THREATS

Major threats to freshwater wetlands in India are summarised in Table 16. But very little information is available relating to threatened species of wetland invertebrate fauna in India. A total of 126 species of butterflies and one dragonfly are included in the Indian Wildlife Schedule I, Part IV of the Wildlife (Protection) Act, 1972. Of these, the single relict species of dragonfly, *Epiophlebia laidlawi* is associated with pools of hill streams from Darjeeling district in the Eastern Himalaya. There is no report of this species since last 80 years from India, though it has been found in Nepal (Varshney, 1998).

Among vertebrates, one species of amphibian, namely, the Himalayan Newt, *Pleurodeles verrucosus* and several species of reptiles, birds and mammals are now listed as threatened or endangered species (Table 17). But the degree of threat varies with the species for their flesh, skin, medicine, etc., as well as with the natural and man-made threat. Silting of lakes and reservoirs are the causes or threats for the decline of large indigenous carps of Peninsular India, such as, *Labeo fimbriatus*, *L. kontius*, *L. porcellus*, *Puntius pulchellus*, *P. dobsoni*, *P. dubius* and *Cirrhina cirrhosa*. Dams and weirs at the higher reaches of major Indian rivers have reportedly affected the world famous game fishes, *viz.*, mahaseers (*Tor* and *Acrossocheilus* spp.). The decline of *Notopterus chitala* and *Semiplotus semiplotus* attaining large size in major rivers of Assam, Bihar and Uttar Pradesh are rarer these days. Like-wise *Thynnichthys sandhkhol*, *Osteocheilus* and *Osteobrama* spp. of Godavari and Krishna river system are steadily declining in catches. *Bagarius bagarius*, *Pangasius pangasius* and *Silonia childreni* are overfished in the Indian Peninsula (Menon, 1989). Common carp introduced into Kashmir valley has almost exterminated the indigenous schizothoracine fishes. Likewise, *Osteobrama belangir* of Loktak lake is fast disappearing due to the introduction of common carp for culture purpose there. In the Govindsagar dam *Catla* has already been replaced by the silver carp introduced there for culture, both species being plankton feeders. Chemical pollution from factories and plantations in Nilgiris, Mysore and Coorg have exterminated certain groups of hill stream fishes.

Nowadays, there has been severe decline

Table 16. Major threats to freshwater wetlands in India

Categories of wetlands		Major threats
1. Tanks, reservoirs and other waterbodies of Deccan plateau (Karnataka, Goa, Maharashtra) of west coast of the peninsula	:	Arid landscape, capracious rains and damming of rivers for hydro-electric projects as well as indiscriminate conversion to residential or industrial estates and/or agricultural practices.
2. Freshwater lakes and reservoirs of Gujarat eastwards through Rajasthan and Madhya Pradesh	:	Semi-arid landscape, inadequate rains, successive droughts and human activities prevalent along with intensive agriculture using fertilizers and herbicides and also increased demand for forest products.
3. Marshes, jheels, terai swamps and chaurlands of Gangetic plains	:	Weed infestation, poaching and pollution along with excessive human population, hunting pressure and especially duck trapping.
4. Floodplains of the Brahmaputra and marshes and swamps in the hills of Northeast India	:	Encroachment, exploitation for timber, reclamation for agriculture, fishing and particularly poaching of Rhino.
5. Lakes and rivers of the montane region of Kashmir and Ladakh	:	Soil erosion, grazing by domestic livestock, human activities as well as encroachment and intensive cultivation. Eutrophication and siltation in Dal Lake and contamination by domestic and industrial wastes in Wular Lake.

Table 17. Threatened species occuring in freshwater wetlands of India

Groups		Threatrned species
1. Invertebrates		
Odonata	:	*Epiophlebia laidlawi*
2. Vertebrates		
Pisces		
Endangered fishes	:	*Barilius bola, Semiplotus semiplotus, Puntius chilinoides, Enobarbichthys maculatus*
Threatened fishes	:	*Notopterus chitala, Acrossocheilus hexagonolipis, Cirrhinus cirrhosa, Labeo fimbriatus, L. potail, L. kontius, Punitius jerdoni, P. cumacea, Tor tor, T. putitora, T. khurdee, Schizothorax richardsonii, Schizothoraichthys pragasium, Silona, childreni, Pangasius pangasius, Bagarius bagarius, Osteocheilus* and *Osteobrama* spp. etc.
Amphibia	:	*Pleurodeles verrucosus*
Reptilia		
Crocodylia	:	*Gavialis gangeticus, Crocodylus palustris*
Chelonia	:	*Batagur baska, Trionyx gangeticus, T. hurrum, Kachuga tecta, Lissemys punctata*
Lacertilia	:	*Varanus bengalensis, V. flavescens*
Ophidia	:	*Python molurus, P. reticulatus*
Aves		
Pelecaniformes	:	*Pelecanus philippinensis*
Ciconiformes	:	*Ardea goliath, A.insignis, Leptotilos dubius, L. javanicus, Ciconia ciconia, Platelea leucorodia*
Anseriformes	:	*Dendrocygna bicolor, Anas gibberifrons, Rhodonessa caryophyllacea, Carinia scutalata*
Gruiformes	:	*Grus nigricollis, G. monacha, G. leucogeranus, Heliopais personata.*
Charadriiformes	:	*Cursorius bitorquatus, Rynchops albicollis*
Mammalia		
Carnivora	:	*Anyx cinerea, Felis viverrina*
Cetacea	:	*Platanista gangetica*
Perissodactyla	:	*Rhinoceros unicornis*
Artiodactyla	:	*Cervus duvauceli, C. eldi, Bubalus bubalis*

Source : Scott (1989) ; Menon (1989); Anonymous (1994) of freshwater fish and other aquatic fauna due to habitat destruction, over-exploitation, pollution, dynamiting and poisoning. As a result about 20 species of cyprinid and siluroid fishes are threatened and/or leading extinction. Thus, there is great need for to conservation of biodiversity as well as wetland habitats harbouring them.

8. CONSERVATION

Conservation of wetland ecosystem can be defined as the total management of the diversified features of a particular wetland for the fair and equal benefit of all groups which have a direct interest in its use (Moss, 1980). However, the problems of conservation are inseparable from the problems of environmental degradation. In fact, conservation of habitat is more important than the conservation of species. The health of the aquatic ecosystem is expected to take care of its major biota. For conservation of wetland resources and for maintaining the maximum diversity of organisms in the ecosystem legislation is essential for effective management practices and to check adverse uses of wetlands. An ecosystem approach is needed to ensure that the wetland uses do not impair the trophic structure and functions of the ecosystems.

In India, declaration of sanctuaries, national parks and biosphere reserves even before independence helped to protect important wildlife and wetland habitat included in the reserve areas. In addition to Wildlife (Protection) Act, 1972, signing the CITES treaty also helped to check international trade on animals. The establishment of the Department of Environment & Forests with Wetland Wing has improved the scientific approach to conservation issues. For the purpose of conservation, some species-oriented conservation programmes have been taken in India and in this respect, the Manipur Brow-antlered Deer project (1977) of Loktak Lake, Manipur is worth-mentioning.

Mention may be made that biodiversity status of both national and international wetlands are being worked out in India. The National Lake Conservation Programme (NLCP) has also been taken up in the Ministry of Environment and Forests, Government of India. The Worldwide Fund for Nature-India (WWF-India) has published six separate documents on Ramsar Sites (Sambhar, Loktak, Wular, Chilka, Harike and Keoladeo Ghana National Park) of India in 1994 under Ramsar Sites Series. The Zoological Survey of India also initiated publishing the Wetland Ecosystem Series in which Series No. 1 on Chilka Lake has already been published in 1995, while Series No. 2 and 3, dealing with Renuka Lake and Ujani wetland respectively will be released shortly.

For conserving wetland habitats it is essential that information on wetland ecosystem should be readily available which can be instrumental in influencing government and even can be used for future planning linking national conservation strategies towards sustainable development. It is worthmentioning that IUCN has launched a vigorous intiative for conseravation of wetlands and has undertaken the following major steps :

- Conservation Network Wetland Programme—Involving governments, conservation organisations, scientists, technical experts and interested individuals.
- Information and Monitoring system—Developing information data base and wetland inventories.
- Planning Wetland Conservation—Preparing conservation plan and strategies for sustainable development.
- Conserving Wetland Species—Growing conducive habitat and declaring ramsar-sites, national parks, sanctuaries and national wetlands.
- Conserving wetland habitat—Preparing case studies on wetlands of international significance.

- Establishing various Commissions—Such as, Commission on National Parks and Protected Areas (CNPPA), Species Survival Commission (SSC), and Commissions on Education (C Educ), Environmental Planning (CEP) and Ecology (COE).

9. FUTURE DIRECTIONS

The degradation and loss of wetlands as well as their biodiversity for agriculture, human habitation and industrial purposes are increasing at an alarming rate and a national perspective is imperative for the conservation and sustainable management of wetland resources in the country. For conservation measure wetlands of national importance are required to be identified along with inventorisation and evaluation of physical, chemical, geomorphological and hydrobiological features and their ecological effects on social, cultural and aesthetic concerns of the user groups so that the problems associated with these wetlands can be diagnosed along with mitigation measures (Alfred and Nandi, 1996). Preparation of national, regional and sectoral wetland conservation and management plan as well as 'wise use' of these wetlands are required to be formulated minimising various anthropogenic pressures associated with these wetlands.

The biological resources especially endangered and endemic resources of the wetlands apart from development of fisheries should get due attention under environmental planning policy. Socio-economic aspects of the local population need to be studied in terms of dependence on utilisation of wetland resources, their population structure, occupation imbalances, if any, caused due to restoration and management activities as well as due to deterioration and degradation of wetland ecosystem. Details studies on morphometry, geology, hydrology, evapotranspiration rate, sedimentation rate, pollution status, soil erosion status, landuse pattern, etc., are essential to formulate management strategies and predictive models for improvement of the wetland concerned and the catchment area.

Monitoring of water quality and eutrophication abatement should be made at regular intervals so that physical, chemical and biological measures including harvesting of macrophytes can be worked out while making management action plan. Studies on the recycling and management of nutrients, aquatic ecosystem health management, diagnosis of disease entities, documenting of fish genetic resources are urgently required. Comprehensive studies on structural and functional relationship of the wetland ecosystem should be given priority to generate baseline data for ecologically and economically viable management strategy.

10. SELECTED REFERENCES

Alfred, J. R. B., Das, A. K. and Sanyal, A. K. (Eds.) 1998. *Faunal Diversity in India.* ENVIS Centre, Zoological Survey of India, Calcutta. pp. 1-497

Alfred, J. R. B. and Nandi, N. C. 2000. Faunal Diversity in Indian Wetlands. *ENVIS Newsletter,* ZSI, Calcutta, **6**(2). 1-3.

Annandale, N. 1911. *Freshwater sponges, hydroids and polyzoa.* The Fauna of British India inlcuding Ceylon and Burma, Taylor and Francis, London, pp. 1-251.

Anonymous. 1991. *Animal Resources of India.* Zoological Survey of India, Calcutta : 694 pp.

Anonymous. 1994. *The Red Data Book of Indian Animals. Part 1 : Vertebrata (Mammalia, Aves, Reptilia and Amphibia).* Zoological Survey of India, Calcutta, 534 pp.

Biswas, K. and Calder, C. C. 1937. *Handbook of Common Water and Marsh Plants of India and Burma, 1936*. Health Bulletin No. 24, Malaria Bureau No. 11, 140 pp. Manager of Publications, Delhi.

Cook, D. R. 1967. Water mites from India. *Mem. Amer. Ent. Inst.*, **9** : 1-411.

Gopal, B. and Asthana, V. (Eds.) 1991. *Aquatic Sciences in India.* Indian Association for Limnology and Oceanography.

Hubbard, M. D. and Peters, W. L. 1978. A catalogue of the Ephemeroptera of the Indian sub-region. *Oriental Insects* (Suppl.), **9** : 1-43.

ILEC, 1996. *Conservation and Management of Lakes/Reservoirs in India*, March 1996, ILEC, Japan, 254 pp.

IUCN, 1989. In : Scott, D.A. (ed.) : *A Directory of Asian Wetlands.* IUCN, Gland and Cambridge.

Jayaram, K. C. 1981. *The Freshwater Fishes of India : A Handbook.* Zoological Survey of India, Calcutta, 475 pp.

Jhingran, V. G. 1997. *Fish and Fisheries of India*, Hindustan Publishing Corporation (India), Delhi, 3rd edition (Corrected reprint), 728 pp.

Michael, R. G. and Sharma, B. K. 1988. *Indian Cladocera (Crustacea : Branchiopoda : Cladocera).* Fauna of India and adjacent Countries, Zoological Survey of India, Calcutta.

Nandi, N. C. 1996. Draft Management Plan of Brace Bridge Nature Park (BBNP). Third International Training Course on Wetland Management, 20 May-28 June, 1996, Lelystad, The Netherlands, 50 pp.

Nandi, N. C., Das, S. R., Bhuinya, S and Dasgupta, J. M. 1993. Wetland faunal resources of West Bengal. 1. North and South 24-Parganas districts *Rec. zool. Surv. India Occ. Paper No.* **150** : 1-50.

Nandi, N. C., Venkataraman, K., Das, S. R., Bhuinya, S. and Das, S. K. 1999. Faunal resources of West Bengal. 2. Some selected wetlands of Haora ad Hugli district. *Rec. zool. Surv. India*, **97**(4) : 1-43.

NIE, 1999. *Proceedings International Conference on Tropical Aquatic Ecosystems : Health, Management and Conservation.* 25-30 October, 1999. Nainital, India. National Institute of Ecology, New Delhi, 194 pp.

Subrahmanyam, K. 1960. Aquatic Angiosperms. *Bot. Mongr.* 3. Council of Scientific and Industrial Research, New Delhi.

Sehgal, K. L. 1983. Planktonic Copepods of Freshwater Ecosystem. pp. 1-165. Environmental Science Series, Interprint, Mehta House, New Delhi 110 028.

Subba Rao, N. V. 1989. *Handbook of Freshwater Molluscs of India*, Zoological Survey of India, Calcutta, 289 pp.

Rao, K. L. 1975. *India's water wealth.* Orient Longman, New Delhi, 255 pp.

Tonapi, G. L. 1980. *Freshwater Animals of India : An Ecological Approach.* Oxford and IBH Publishing Co., New Delhi, 341 pp.

Victor, R. and Fernando, C. H. 1979. The freshwter ostracods. (Crustacea : Ostracoda) of India. *Rec. Indian Mus.*, **72**(2) : 147-242.

Wetlands : Brackishwater

N. C. NANDI

ENVIS–Zool. Surv. India
Ecosystems of India : 195-217, 2001.

Wetlands : Brackishwater

N. C. NANDI

Zoological Survey of India
'M' Block, New Alipore, Kolkata-700 053

1. INTRODUCTION

Water, be it fresh, brackish or salt, is one of the most important inputs in sustaining life. Besides being a constituent, it influences almost all biophysiological processes of plants and animals. Of the three broad categories, brackishwater is the admixture of freshwater and salt water and accordingly the low-lying inland areas, natural or man-made, located within the country, having such a mixed type of water is termed as inland brackishwater wetlands. It includes the sprawling estuaries at the confluence of the river system with the sea ; large lagoons, brackishwater lakes and backwaters ; intertidal mud, sand or salt flats ; intertidal salt marshes and salt meadows ; salt pans and salines as well as brackishwater impoundments and the vast areas of mangrove swamps containing tidal waters of fluctuating salinity. However, leaving estuarine wetlands and mangroves, as assigned, this paper concentrates on aspects related to brackishwater lagoons, lakes and impoundments as well as backwaters. These four categories of brackishwater wetland habitats are defined as follows :

(1) **Brackishwater lagoons** : Large, shallow inland, natural brackish or salt water lakes connected or separated from the sea by dunes.

(2) **Brackishwater lakes** : Large, shallow, inland body of brackishwater, usually natural, containing standing water, not connected with sea.

(3) **Brackishwater impoundments** : Man made brackishwater ponds including fish ponds and shrimp ponds.

(4) **Backwaters** : Currentless, usually coastal, water held back by dam etc., beside streams, rivers and estuaries, is known as backwaters.

2. GENERAL DESCRIPTION

Despite various estimates, IUCN (1989) data on Indian wetlands indicate that brackishwater wetlands suitable for fish culture is 2.0 million ha and backwaters as 3.5 million ha. According to Central Marine Fisheries Research Institute (CMFRI), the various brackishwater systems cover an area of over 1.19 million ha of which 0.88 million ha are under culture distributed within the ten maritime states/union territories in India (Table 1). But some wetlands in the montane region of Kashmir and Ladakh and several saline lakes of Rajasthan are also known to hold brackishwater seasonally even though they are used for salt production. For example, about 7800 ha of the eastern arm of Sambhar Lake (23,300 ha) in Rajasthan is devoted to salt production and approximately 20% of Didwana Lake (200 ha) of this State is given over to salt pans. These saline lakes in Rajasthan located under tropical monsoon climate with an annual rainfall of about 490-640 mm, summer and winter temperatures

Table 1. Statewise distribution of total brackiswater area and area under culture

State	Estimated brackishwater area (ha)		
	Total	Under culture (as on March 1992)	Percentage (%)
West Bengal	4,05,000	33,918	2.85
Orissa	31,600	7,417	0.62
Andhra Pradesh	1,50,000	8,100	0.68
Tamil Nadu	56,00	480	0.04
Kerala	65,000	13,145	1.10
Pondicherry	800	—	—
Karnataka	8,000	2,542	0.21
Goa	18,500	525	0.04
Maharashtra	80,000	1,869	0.15
Gujarat	3,76,000	231	0.02
Total	**11,90,900**	**68,232**	**5.72**

Source : CMFRI, Kochi

ranging from 24.4°C to 36.7°C, and from 11.7°C to 31.7°C respectively and often dry out completely due to intense evaporation creating an extremely saline environment in summer (March—June). In the montane region, Pangong Tso, (6500 ha) about one-third of which is in India and the rest in the peoples Republic of China is a long narrow brackish lake spanning the Indian/Chinese border, while Tso Morari (12,00 ha), a national wetland, is the largest of the high altitude trans-himalayan lakes and lies entirely within Indian territory. These high altitude brackish lakes invariably remain frozen from November to March and are fed by springs and snow-melt, characterized by arid Tibetan climate with low humidity, little precipitation (average annual precipitation about 75 mm) and extreme winter temperature ranging from -10°C to as low as -40°C. However, most of the brackishwater wetlands and backwaters being located at the coastal region are not subjected to extreme climatic conditions. These coastal backishwater wetlands are situated mainly in the tropical monsoon climate with annual rainfall ranging from 1000—2500 mm. The rainfall occurs mostly in July to September during the South-west Monsoon and/or in October to December during the receding North-east Monsoon. There are two monsoons in the year in the coastal states of Andhra Pradesh, Maharashtra and Karnataka. In Gujarat State, the climate is dry tropical monsoon type with an average annual rainfall about 400 mm, while in coastal West Bengal it is humid tropical monsoon climate with annual rainfall of 1500—2500 mm with a pronounced dry season from December to April. In West Bengal alone more than one-third (0.40 million ha) of the total 1.19 million ha of brackishwater wetlands are located. However, general information and physiographical features, of the four representative national/international brackishwater wetlands, *viz.*, Tso Morai, Sambhar Lake, Chilka Lake and Pulicat Lake are presented (Tables 2 and 3) with special reference to baseline information on physico-chemical parameters and biological characteristics of brackishwater bheries of West Bengal (Tables 4-7).

Table 2. General information, physiography and geomorphology of the four representative brackishwater wetlands in India

General, physiographical and geomorphological parameters	Representative brackishwater wetlands			
	Tso Morari Lake	Sambhar Lake	Chilka Lake	Pulicat Lake
General/geomorphological parameters				
Location				
Latitude	32°50'N	27°00'N	19°28—19°54'N	13°25—13°55'N
Longitude	78°20'E	75°00'N	85°06—85°35'E	80°03—80°19'E
State	Jammu and Kashmir	Rajasthan	Orissa	Andhra Pradesh and Tamil Nadu
Area (ha)	12,000	23,300	1,16,500	72,000
Altitude (m)	4511	360	0—2	0—10
Land tenure	State owned	State owned	State owned (Except a small island)	State owned
Wetland type	Upper perennial salt lake	Salt Lake with salt pans	Saline lagoon	Saline lagoon
Lake basin	Mountain range and cold desert	Mountain range (Aravalli) and sand flats	Coastal	Coastal
Soil	Mountain	Grey brown to alluvial	Coastal alluvium	Coastal alluvium
Climatic conditions				
Overall climate	Arid Tibetan/ Dry temperate	Tropical monsoon	Tropical monsoon	Tropical monsoon
Summer temperature (°C)	0—30	24.4—36.7	25.5—34.8	Upto 45°C
Winter temperature (°C)	-10 — -40	11.7 — 31.7	24.2 — 33.8	Upto 15°C
Humidity	Low	Low	Medium	Medium
Precipitation (mm)	75	500	1200 — 1600	1000
Vegetation				
Principal vegetation	Arid steppic	Dry thorn scrub	Plantation forest	Littoral scrub, patchy wood-land
Lake vegetation	Sedge, rush, *Carex, Potamogeton*	Algae, halophytes, *Sueda, Salsola, Cressa*	Algae, reeds	Algae, littoral scrub
Land use	Grazing by domestic live-stock (yak)	Salt extraction, grazing, marble mining nearby	Fishing, grazing, reed gathering, tourism	Fishing, navigation route

Table 3. Physico-chemical parameters of Chilka Lake and Pulicat Lake

Physico-chemical parameters	Brackishwater lakes	
	Chilka lake	Pulicat lake
1. Water temperature (°C)	19 — 35	25.0 — 32.6
2. Transparency (cm)	69 — 116	26 — 106
3. Turbidity (ppm)	0.08 — 1.61	7.5 — 28.0
4. pH	6.8 — 9.7	8.3 — 8.7
5. Total alkalinity (ppm)	27 — 189	45 — 91.4
6. Salinity (ppt)	2.6 — 3	7.1 — 39.3
7. Dissolved oxygen (mg/L)	1.3 — 13.4	3.8 — 10.0
8. Nitrate nitrogen (mg/L)	Trace — 0.19	—
9. Phosphate phosphorus (mg/L)	Trace — 0.18	0.1 — 0.8
10. Dissolved silica (mg/L)	0.1 — 6.0	4.0 — 24.4
11. Free carbon dioxide (ppm)	0 — 31	—

Note : The average concentrations of other elements in Chilka lake are as follows : Ca (66 mg/L), Mg (217 mg/L), Na (1462 mg/L), Cl (2621 mg/L) and SO_4 (438 mg/L) as reported by Katre and Das (1988).

The backwaters which comprise a system of inter-connected lagoons, bays and swamps penetrating the mainland are famous in Kerala, while some others are located at Kovalam, Pamban and Ennur in Tamil Nadu, Visakhapatnam and Bhimunipatnam in Andhra Pradesh and Sunkeri (Karwar) in Karnataka. The total area of Kerala backwaters is estimated to be 500 sq km. The system is flushed by rains and freshwater run-off during southwest monsoon from May to September. This area is located under tropical monsoon climate with an average rainfall of 3,600 mm and subjected to a short dry period/season from December to March. The surface water salinity ranges from almost freshwater conditions during monsoon to about 34 ppt near the mouth of the backwaters during the dry season.

The Cochin backwaters of Kerala constitute a chain of fresh to brackish coastal lagoons and swamps. The area is about 26,500 ha, on average about 3-4 km wide, stretching for 96 km from the estuary of the Chalakaudi and Periyar Rivers south along the coast to Vembanad Lake and its surrounding flood plain. The Vembanad Lake is situated in the higher reaches of the Cochin backwaters, covering an area of 70,000 ha in the past, but has gradually been reduced to 8,000 ha by reclamation for agriculture. The reclaimed land suffered from increased soil salinity and the formation acid sulphates. The Cochin backwaters lie in an alluvial plain, parallel to and in between the Indian Ocean and the

Fig 1 : Backwater wetland in Kerala

Western Ghats. The system of lagoons has two permanent openings at Cranganore and Cochin along with a third temporary opening at Thollappally, south of Aleppey, which is only open during the southwest monsoon. The hydrographical features of Cochin backwaters are summarised in Table 8 (Qasim *et al.*, 1969). These environmental factors are greatly influenced by tidal rhythm (Qasim and Gopinathan, 1969).

Brackishwater bheries of West Bengal are large shallow waterbodies embanked by low earthen dykes located in the North and South 24-Parganas districts of this state. Inventory

Table 4. Baseline information on brackishwater bheries of 24-Parganas district, West Bengal

Baseline data	Different saline zones: Low	Medium	High	Total
1. Number of bheries	387	458	489	1334
2. Area (ha)	9844.11	15613.25	7472.20	32929.56
3. Size : Range (ha)	2—200	2—267	2—120	—
Average (ha)	25.44	34.09	15.28	24.68
4. Type of bheries (in % Area)				
Seasonal	94.12	92.00	5.78	—
Perennial	5.88	8.00	94.22	—
5. Type of fish and prawn cultured	Brackishwater and Freshwater	Brackishwater and Freshwater	Brackishwater species only	—
i) Brackishwater fishes	*Liza* spp., *Rhinomugil corsula*, *Lates calcarifer*	*Liza* spp., *Rhinomugil corsula*, *Lates calcarifer*	*Liza* spp., *Rhinomugil corsula*, *Lates calcarifer*	—
ii) Freshwater fishes	Common carps, Exotic carps, *Mystus gulio*, Tilapias	Common carps, Exotic carps, *Mystus gulio*, Tilapias	—	—
iii) Brackishwater prawns	*Penaeus monodon*, *P. indicus* and *Metapenaeus monoceros*	*Penaeus monodon*, *P. indicus* and *Metapenaeus monoceros*	*Penaeus monodon*, *P. indicus* and *Metapenaeus monoceros*	—
iv) Freshwater prawns	*Macrobrachium rosenbergii*	*Macrobrachium rosenbergii*	—	—
6. Estimated annual production				
i) Total fish & prawns				
Total (tons)	8641.16	11691.67	5184.74	—
Catch/ha(kg)	877.80	748.83	693.87	—
ii) Prawn *(P. monodon)*				
Total (tons)	689.78	3348.73	625.20	—
Catch/ha(kg)	70.07	214.48	83.67	
iii) % of *P. monodon* to the total production	7.98	28.64	12.06	—

Source : Saha *et al.* (1986)

Table 5. Physico-chemical parameters of brackishwater bheries in West Bengal

Physico-chemical parameters	Saline Zones		
	Low	Medium	High
Temperature (°C)	21.0 — 32.0	23.1 — 32.0	20.0 — 30.6
Turbidity (ppm)	72 — 360	63 — 350	57 — 240
pH	6.8 — 7.8	7.0 — 8.2	7.0 — 8.3
Dissolved oxygen	4.0 — 6.8	4.2 — 6.6	4.2 — 6.2
E. C. (m. mhos/cm)	0.9 — 11.4	1.1 — 28.2	11.8 — 51.7
Salinity (ppt)	0.1 — 9.5	0.27 — 15.8	6.6 — 36.2
Total alkalinity (ppm)	84 — 212	90 — 196	88 — 155
Phosphate (ppm)	Tr. — 0.32	Tr. — 0.48	0.03 — 0.66
Nitrate nitrogen (ppm)	0.04 — 0.30	0.02 — 0.48	0.03 — 0.32
Magnesium (ppm)	25 — 230	24— 220	70 — 350
Calcium (ppm)	25 — 650	36 — 880	280 — 1640

Source : Saha *et al.* (1986)

Table 6. Soil characteristics of brackishwater bheries in different saline zones of West Bengal

Physico-chemical parameters	Different Saline Zones		
	Low	Medium	High
pH	6.9 — 7.5	6.5 — 7.4	7.0 — 7.4
E. C. (m. mhos/cm)	0.9 — 7.5	1.1 — 12.1	9.8 — 23.2
Available nitrogen (mg/100g)	9.8 — 23.2	14.1 — 22.9	10.6 — 22.2
Available phosphorus (mg/100g)	5.2 — 22.0	6.0 — 18.0	6.0 — 24.0
Organic carbon (%)	0.60 — 0.92	0.48 — 0.88	0.41 — 0.62

Source : Saha *et al.* (1986)

survey made by the scientists of the Central Inland Fisheries Research Institute (CIFRI), Barrackpore, reveals that there are 1334 brackishwater bheries covering an area of about 32, 930 ha spreading over three saline zones, such as, high (7472 ha), medium (15163 ha) and low saline zones (9844 ha). These bheries are categorised into low saline (below 10 ppt), medium saline (10—20 ppt) and high saline (above 20 ppt) waterbodies based on varying salinity of tidal water during cultural period depending on their distance from sea face. The low saline bheries are located under Barasat, Swarupnagar, Deyganga, Rajarhat and Baduria Police Stations in North 24-Parganas district. Both fresh and brackishwater fishes and prawns are cultured in this ecosystem. Besides Indian major carps *(Labeo rohita, Catla catla, Cirrhinus mrigala)*, Tilapia *(Oreochromis mossambica, O. nilotica)*, mullet *(Liza parsia)* and particularly tiger prawn, *Penaeus monodon* are extensively cultured. The average production has been estimated at about 878 kg/ha/yr of which *P. monodon* contributes to about 70 kg/ha/yr (Saha *et al.*, 1986).

The medium saline bheries are located under Haroa, Minakhan, Hasnabad, Basirhat and Hingalgunge Police Stations in North 24-

Table 7. Biological parameters of brackishwater bheries under different saline zones of West Bengal

Biological parameters	Different saline zones of West Bengal		
	Low	Medium	High
A. Phytoplankton			
1. Population (No/litre)	77 (18—178)	81 (30—198)	116 (34—400)
2. Dominant forms	*Melosira sp.* *Spirulina* sp. *Synedra* sp. *Spirogyra* sp. *Coscinodiscus* sp.	*Oedogonium* sp. *Spirogyra* sp. *Melosira* sp.	*Gyrosima* sp. *Bidulphia* sp. *Coscinodiscus* sp. *Amphora* sp.
B. Zooplankton			
1. Population (No/litre)	644 (60—2722)	239 (40—1155)	433 (50—2140)
2. Dominant forms	*Branchionus* sp. Mysids	*Diaptomus* sp. *Branchionus* sp. *Cyclops* sp. Mysids	Mysids *Acartiella* sp.
C. Benthic algae			
1. Wet biomass (g/m²)	675 (180—1170)	110 (89—131)	2700 (1100—4300)
2. Dominant forms	*Nostoc* sp. *Anabaena* sp. *Oscillatoria* sp. (1986)	*Oscillatoria* sp.	*Lyngbya* sp. *Oscillatoria* sp. *Spirogyra* sp.
D. Benthic worms, etc.			
1. Population (No/m²)	1071 (10—6375)	2403 (135—6400)	790 (5—6160)
2. Dominant forms	*Gammarus* sp. Tenedes Polychaetes	*Gammarus* sp. Polychaetes	Tenedes Polychaetes *Gammarus* sp. Oligochaetes
E. Benthic molluscs			
1. Population (No/m²)	1008 (675—3601)	1600 (550—5945)	982 (135—2145)
2. Dominant forms	*Bellamya* sp. *Digoniostoma* sp. *Planorbides* sp.	*Bellamya* sp. *Digoniostoma* sp. *Thiara* sp.	*Bellanya* sp. *Digoniostoma* sp. *Lamellidens* sp.

Source : Saha *et al.*

Table 8. Hydrographical features of Cochin backwaters

Hydrographic parameters	Range values at	
	0 depth	9m depth
Temperature (°C)	28.9 — 31.8	25.4 — 31.2
Salinity (‰)	1.40 — 33.51	29.57 —33.33
Oxygen (m/l)	03.49 —5.05	2.62 — 05.89
PO_4 - P (mg-at/l)	0.36 — 1.27	0.53 — 2.10
NO_3 - N (mg-at/l)	0.31 — 39.97	0.89 — 39.46
SiO_3 - Si (mg-at/l)	5.00 — 59.71	4.79 — 35.73
Alkalinity (mg C/m³)	5.88 — 26.25	17.39 — 27.15

Source : Qasim *et al.* (1969)

Fig. 2 : A wetland ecosystem in Cauvery Delta (*Courtsey* : P. T. Cherian, ZSI)

Parganas district. The average production of about 749 kg/ha/yr which includes prawn production of 214 kg/ha/yr is the highest amongst the three zones. The average production in high saline zone is about 694 kg/ha/yr including *P. monodon* production of 84 kg/ha/yr (Table 4). In the high saline zones, brackishwater fishes, *viz.*, *Liza parsia*, *L. tade*, *Lates calcarifer*, *Mystus spp.*, *Eleutheronema tetradactylum*, *etc.*, and prawns like *P. monodon*, *P. indicus* and *Macrobrachium monoceros* are generally reared (Saha *et al.*, 1986). The details of water qualities of the three saline zones pertaining to important physico-chemical parameters are shown in Table 5. In both low and medium saline bheries, the water turned into fresh during monsoon, while salinity of high saline bheries declined to a low saline range. The chemical conditions of soil in three different saline bheri systems are presented in Table 6. In general, these bheri soils are silty clay to silty clay loam in texture with high water retentive capacity and nutrients which encourage development of benthic algae as well as the natural fish food organisms (Saha *et al.*, 1986).

3. BIOLOGICAL DIVERSITY

Despite global interest on brackishwater environment especially in estuaries and brackishwater aquafarming during the last three decades, very litte is known about the brackishwater floral and faunal diversity other than the comercially important species. However, the publications dealing with brackishwater lagoons, *viz.*, Chilka Lake and Pulicat Lake being relatively rich, thus dealt hereunder with some greater details along with brackishwater impoundments of coastal West Bengal.

3.1 Ecosystem/Habitat diversity

Like freshwater ecosystems, brackishwater habitats are complex ecosystem representing an extremely important resource. There are 15 categories of salt water wetlands, 13 natural and 2 man-made, and of the 13 natural salt water wetlands, 7 are marine, 4 estuarine, and one each from lagoonar and salt lake categories (Dugan, 1990; Alfred and Nandi, 2001). The latter two categories as well as backwaters and the two man-made ones, *viz.*, aquacuture/mariculture shrimp ponds and salt pans/salines are subjected in this study. Lagoons, backwaters and salt lakes are complex environments supporting a range of wetland types, including intertidal mud and sandflats, salt marshes, beaches, rocky shores as well as shallow waterbodies. Aquaculture ponds, salt pans and salines also offer ecological and physiographical diversities in relation to salinity regime. The character and ecological stability of these wetlands, being a specialised ecosystem with admixture of fresh and salt water, are hard to be kept in normal ecological homeostasis.

The distribution and diversity of brackishwater ecosystems including estuaries, backwaters, mangroves and coral reefs of India can be divided by region into six basic categories as follows :

- Backwaters and estuaries of west coast of the peninsula ;
- Saline expanses of Rajasthan and Gujarat including the Gulf of Kutch ;
- Deltaic wetlands, lagoons and salt swamps of Indian east coast ;
- Brackishwater lakes and saline marshes of the montane region of Ladakh ;
- Coastal brackishwater wetlands in West Bengal, Andhra Pradesh, Tamil Nadu and Kerala ;
- Wetlands (primarily mangroves and coral reefs) of islands of Bay of Bengal and Arabian Sea.

3.2. Species diversity

Tropical brackishwater wetlands usually support a wide range of species. The lagoonar and brackishwater ecosystems, include marine littoral species, some brackishwater forms and some freshwater species. Although it is difficult to prepare an authentic account of these flora and fauna due to paucity of data, an attempt has been made herein to provide a brief review of the work done in the Indian scenario.

3.2.1 Flora : The aquatic plant species of high altitude brackishwater wetlands of Ladakh region are dominated by *Hydrilla*, *Myriophyllum* and *Potamogeton* in the ponds ; and *Carex* sp., other sedges and grasses in the saline marshes. The deeper parts of the Tso Morari brackish lake are reported to be devoid of any vegetation, while various species of sedge and rush grow in the marshes. The saline wetlands of Rajasthan, *viz.*, Sambhar, Phulera and Didwana salt lakes are inhabited by halophytic shore vegetation, such as, *Sueda fruticosa*, *Salsola barysoma* and *Cressa cretica* in addition to various green and blue-green algae in the lakes. The low salinity areas in the Great Rann of Kutch support grassland with many grass species, notably *Dichanthium annulatum*, *Sehima nervosum*, *Cenchrus ciliaris*, *C. setigerus* and *Panicum antidotale*, and the occasional *Acacia nilotica* and *Capparis* sp. In the Little Rann of Kutch the open saline flats are devoid of vegetation, while the bets support a slightly richer flora dominated by Graminae and Cyperaceae, such as, *Aleuropes lagoprides*, *Cenchrus* spp., *Sporobolus marginatus*, *S. helveticus* and *Cyperus rotundus* which are better adapted to such hydromorphic conditions. In the coastal brackishwater wetlands and logoons of Jamnagar, Gujarat, two endemic species, *viz.*, *Cyperus dwarakensis* and *Tephrosia jamnagarensis* have been described.

The Cochin backwater area was occupied by mangroves, *viz.*, *Rhizophora apiculata*, *Derris heterophylla*, *Sonneratia alba*, *Acanthus ilicifolius*, *Acrostichum aureum* and *Cerbera manghas* but most of them are destroyed and only a few pockets of stunted *Rhizophora* and *Sonneratia* can still be found there. The predominant phytoplankton crop in the Cochin backwater consisted of diatoms and dinoflagellates in addtion to minor unidentified nannoplanktonic organisms (Qasim *et al.*, 1969; George, 1958).

The vegetation in the deltaic wetlands, lagoons and brackishwater impoundments of India's east coast varies with salinity. In highly saline conditions of Chilka lagoon, various species of algae belonging to the genera *Enteromorpha, Gracillaria, Spirogyra, Cladophora* and *Polysiphona* are abundant. The low saline conditions, on the other hand, promote the growth of *Najas, Chara, Nitella Hydrilla, Halophila* and *Potamogeton* species. With the decrease in salinity in recent years, *Potamogeton* has become abundant throughout the year but there are small reed beds of *Phragmites* sp. which still survive in some bays. Pulicat Lagoon also supports a rich growth of algae, particularly flamentous algae. Algal flora comprising of 59 species include Cyanophyceae (8 species), Chlorophyceae (7 species), Rhodophyceae (2 species) and Bacillariaceae (42 species). At Sriharikotta island large areas of littoral scrub and patches of residual dry evergreen forest are found, while surrounding plains are invaded by *Prosopis julifera.*

In the brackishwater bheries of 24-Parganas district, West Bengal, phytoplankton is higher in occurrence in high saline bheries than in the others, dominated by *Gyrosima, Bidulphia* and *Coscinodiscus* species. Medium and low saline bheries are dominated by species belonging to the genera *Melosira, Spirulina* and *Spirogyra.* The dominant forms of benthic algae belonging to Myxophyceae (*Lingbya* and *Oscillatoria*), Chlorophyceae (*Spirogyra* and *Scenedesmus*) and Diatomaceae (*Gyrosima* and *Navicula*) have been reported from high saline bheries. Low saline bheries are dominated by *Nostoc sp., Anabaena* sp., *Oscillatoria* sp. and *Lyngbya* sp. The maximum density of benthic algae was recorded in high saline bhery (2200 g/m^2)

In salt marshes along the sea coast of West Bengal, Mumbai and the Deccan areas *Sueda nudiflora, S. maritima, Arthrocnemum indicum, Salicornia brachiata,* etc., are commonly grown between the zones of tidal marks. *Ruppia maritima, Acrostichum aureum, Phragmites karka* and *Zannichellia palustris* are common in brackishwater salt marshes throughout India.

3.2.2 Fauna : The backwaters and brackishwater wetlands of coastal India offer suitable living conditions to a variety of faunal elements both from marine and freshwaters in addition to some species exclusively occurring in this habitat. Each major faunal group of brackishwater habitat has its representative in marine and freshwaters.

The higher vertebrates *viz.*, birds and mammals associated with backwaters and brackishwater wetlands can also be found in freshwater wetlands. Some fishes and molluscs exclusively inhabit brackishwater wetlands, while both marine and freshwater forms of fishes and molluscs are quite common in occurrence in these habitats. Similarly crustaceans and other macroinvertebrates of brackishwater wetlands are represented both from marine and freshwaters. The insect communities inhabiting brackishwater systems are, however, extremely poorly explored in India.

An estimate of the total number of species of different animal groups occurring in brackishwater wetlands including backwaters in India is presented in Table 9 and compared with those known from Indian wetlands (Alfred and Nandi, 2000), while faunal diversities of Chilka Lake, Pulicat Lake and from brackishwater wetlands of North and South 24-Parganas districts, West Bengal are given in Table 10. From the Table 9 it is evident that brackishwater wetlands represent nearly 5 per cent of the total wetland fauna of India.

Mammalian fauna

In all 10 species of mammals could be recognised as brackishwater wetland dependent or associates in India. But 18 species have been reported from Chilka Lake

Table 9. Estimated number of species occurring in India and Indian wetlands as well as brackishwater wetlands (excluding estuaries, and mangrove)

Taxonomic groups	Number of species occurring in: India	Indian wetlands	Brackishwater wetlands	% in brackish water wetlands to those in Indian wetlands
Kingdom : PROTISTA				
Protozoa	2577	1250	61	4.9
Kingdom : ANIMALIA				
Mesozoa	10	10	—	—
Porifera	486	400	6	1.5
Cnidaria	842	540	10	1.8
Ctenophora	12	10	1	10.0
Platyhelminthes	1622	1200	29	2.4
Rotifera	330	330	2	0.6
Gastrotricha	100	80	—	—
Kinorhyncha	10	10	—	—
Nematoda	2850	500	37	7.4
Acanthocephala	229	150	—	—
Sipuncula	35	30	1	3.3
Mollusca	5070	2300	130	5.6
Echiura	43	40	3	7.5
Annelida	840	500	35	7.0
Onychophora	1	—	—	—
Arthropoda	68389	7302	125	1.7
Crustacea	2934	2000	100	5.0
Insecta	59353	5000	25	0.5
Arachnida	5818	300	—	—
Pycnogonida	16	—	—	—
Chilopoda	100	—	—	—
Diplopoda	162	—	—	—
Symphyla	4	—	—	—
Merostomata	2	2	—	—
Phoronida	3	3	—	—
Bryozoa (Ectoprocta)	200	100	2	2.0
Entoprocta	10	5	1	20.0
Brachiopoda	3	3	—	—
Chaetognatha	30	10	3	30.0
Tardigrada	30	20	—	—
Echinodermata	765	500	6	1.2
Hemichordata	12	10	—	—
Chordata	4952	2550	438	17.1
Protochordata (Cephalochordata+ Urochordata)	119	70	1	1.4
Pisces	2546	2000	250	12.5
Amphibia	209	150	8	5.3
Reptilia	456	50	9	18.0
Aves	1232	250	160	64.0
Mammalia	390	30	10	33.3
Total	89,451*	17853**	886	4.9

Source : *Alfred (1998); ** Alfred and Nandi (2000)

Table 10. Faunal diversities in some brackishwater wetlands of India

Taxonomic groups	Numher of species occurring in Chilka Lake (ZSI, 1995)	Pulicat Lake (MoEF, 1990)	North and South 24-Parganas (Nandi *et al.*, 1993)
Protozoa	61	1	—
Porifera	6	—	—
Cnidaria	7	5	—
Platyhelminthes	29	—	—
Nemathelminthes	37	—	—
Rotifera	—	—	—
Sipuncula	1	—	2
Mollusca	60	26	13
Echiura	3	—	—
Annelida	31	5	—
Arthropoda	60	26	56
Crustacea	60	26	32
Insecta	—	—	20
Arachnida	—	—	4
Echinodermata	5	1	—
Protochordata	1	—	—
Chordata			
Pisces	217	64	73
Amphibia	7	—	6
Reptilia	30	—	7
Aves	156	87	71
Mammalia	18	—	3
Total	**729**	**215**	**231**

Source : ZSI (1995); MoEF (1990) ; Nandi *et al.* (1993)

(ZSI, 1995) including Dugong, *Dugong dugon*. Most of these species are arboreal or terrestrial mammals including bats. Other mammals include *Antelope cervicapra, Axis axis, Hyena hyaena* and *Canis aureus* (IUCN, 1987). The Little Rann of Kutch in its saline flats supports a sizeable population of the Indian Wild Ass *Equus hemionus*, Chinkara *Gazella gazella* and Blackbuck *Antilope cervicapra*. The Wild Ass, *Equus hemionus* and Tibetan Gazelles *Gazella* sp. forage in the marshes and meadows around high altitude brackish lakes of Ladakh region, while *Canis lupus* and *Vulpes* sp. occur in surrounding hills. Only three species of wetland dependent mammals, *viz.*, the Fishing Cat *Felis viverrina*, the Bandicoot Rat *Bandicota indica* and the Smooth Indian Otter *Lutra perspicillata* have been reported from brackishwater wetlands of North and South 24-Parganas districts (Nandi *et al.*, 1993). The Bandicoot Rat is reported to devour both aquatic *(Pila globosa)* and land snails, fishes and even snakes from water-edges (Nandi, 1984). Ghose (1965) described the Marsh Mongoose *Herpestes palustris* from Salt Lake swamp areas on the southeastern periphery of Calcutta city, West Bengal. A total of 22 species of mammals have been recorded from Salt Lake area (Ghosh, 1990).

Avifauna

About 150 species and subspecies of migratory and resident birds, have been recorded from Chilka Lake and its environs (Dev, 1988 ; Mahapatra and Hussain, 1988 ; ZSI, 1995) of which about two-third (97 species) are intercontinental migrants. The lake supports the largest concentration of migratory waterfowls in India 1,484, 186 waterbirds of 85 species in 1996 which include

Fig. 3 : Whitethroated munia (*Lonchura malabarica*) in reedbeds of Nalsarovar, Gujarat (*Courtsey* : Sanjeev Kumar, ZSI)

regular visitors like ducks, flamingoes, plovers, sand pipers, coots, gulls and terns. Some of the notable migratory waterfowls include *Anser acuta, A. clypeata, A. strepera, Anas crecca, A. fuligula, A. penelope, A. querquedula, Aythya ferina*, etc., in addition to shorebirds viz., *Rostratula benghalensis, Glareola lactea, Pluvialis dominica, P. squatarola, Charadrius alexandrinus, C. dubius, C. leschenaulti*, etc. In 1960s, millions of ducks and thousands of geese were reported from Chilka Lake. The bird population has declined considerably during the past two decade but the numbers are still impressive (IUCN, 1987). Large numbers of waterfowl are known to occur in backwaters. Vembanad lake, located in the higher reaches of Cochin backwaters, supports 29,991 birds in 1994 and thus, like Chilka Lake, etc. (total 34 sites) qualifies as site of international importance in India (Lopoz and Mundkar, 1997).

Pulicat Lake is the third most important wetland for migratory shorebirds, on the eastern seaboard of India, and is especially important during the spring and autumn migration seasons. The lagoon supports significant populations of *Tachybaptus ruficollis, Pelecanus philippensis, Phalacrocorax fuscicollis, P. niger* and several species herons and egrets. The large concentrations of Greater Flamingos *Phoenicopterus ruber* occur in the Andhra Pradesh part of the Pulicat Lake Sanctuary. The area is rich in birds of prey *viz., Haliaeetus leucogaster, Pandion haliaetus, Circus* spp. and *Falco peregrinus*. Pulicat Lake and Sambhar Lake support 47,496 and 31,394 birds respectively in 1996.

The Asian population of the Greater and Lesser Flamingoes *Phoenicopterus ruber* and *P. minor* is centered around saline wilderness of the Rann of Kutch, Gujarat. This region also supports a wide variety of waterfowls such as pelicans, herons, egrets, storks, spoonbills, ducks and shorebirds. Thousands of Common Cranes *Grus grus* winter in the area. The wetlands of Kutch Peninsula provide a very important wintering area for migratory waterfowl, particularly Anatidae in the years of average and above average rainfall.

The high altitude brackish to saline lakes of Ladakh, namely, Tso Morari is thought to be the most important breeding locality for Barheaded Geese *Anser indicus* and other birds, *viz., Podiceps cristatus, Todorna ferruginea, Charadrius mongolus, Larus brunnicephalus* and *Sterna hirundo*. The lake was an important nesting area for Black-necked cranes *Grus nigricollis* and Black-necked Grebes *Podiceps nigricollis*.

In 1960s, a systematic survey of Salt Lake swamp was carried out by the scientists of Zoological Survey of India, during the process of reclamation of Salt Lake area, revealed as many as 248 species of birds, comprising of 90 aquatic or wetland associated species and the rest 158 land birds (Ghosh, 1990).

Herpetofauna

An estimated 9 species of reptiles and 8 species of amplibians are associated with brackishwater wetlands of Indian region. However, including land forms, 30 species of reptiles and 7 species of amphibians are reported from Chilka Lake (Murthy, 1995), while De *et al.* (1989) recorded 15 species of reptiles and 6 species of amphibians from a combination of freshwater and brackishwater wetlands of Calcutta Metropolitan district.

Fig. 4 : New breeding ground of flamingos at Sambhar Lake, Rajasthan (*Courtsey :* Sanjeev Kumar, ZSI)

Nandi *et al.* (1993) encountered 7 species of reptiles and six species of amphibians from brackishwater wetlands of North and South 24-Parganas districts. It may be mentioned that reports regarding herptofauna of brackishwater wetlands are meagre in the Indian context.

The Estuarine crocodile, *Crocodylus porosus* once occurred throughout the Cochin backwaters but is at present thought to be extinct in Kerala.

Ichthyofauna

Although 250 species of fishes are estimated to occur in brackishwater wetlands of India, as many as 217 species comprising 147 genera, 71 families and 15 orders, have been recorded from a particular wetland of international importance, namely, Chilka Lake (Rama Rao, 1995). At least 65 species of fishes are listed from Pulicat Lake (IUCN, 1989) and 73 species from brackishwater bheries supporting a major fishery of North and South 24-Parganas districts (Nandi *et al.*, 1993). But no specific information is available from various other wetlands except the very common occurrence of a small fish *Cyprinodon dispar* in the Rann of Kutch. The commercial ichthyofauna of Kerala backwaters include clupeids (*Chanos chanos*), mullets (*Mugil* spp.), Pearl spots, catfishes, etc. (George and Sebastian, 1970; Gopalakrishnayya, 1972).

Most important ichthyofauna of brackishwater systems of India are the mullets (*Mugil cephalus, Rhinomugil corsula, Liza macrolepis, L. tade, L. parsia*), clupeids (*Tenulosa ilisha, Nematolosa nasus*), sciaenids (*Pseudosciaena coibor*), threadifin (*Eleutheronema tetradactylum*), siluroid (*Mystus gulio*), cichlid (*Etroplus suratensis*) and the giant perch (*Lates calcarifer*). The rich and varied fish fauna of Chilka Lake, Pulicat Lake and brackishwater bheries of West Bengal are comprised of fresh, brackish and marine elements. Out of 76 species belonging to 28 families recorded from two different types, fresh and brackish wetlands of North and South 24-Parganas districts, 56 species were from freshwater wetlands and 73 species from brackishwater wetlands and of these 53 species (70%) occurred in both the wetland systems indicating their adaptation to varying salinity (Nandi *et al.*, 1993). It include important food fishes like common carps, exotic carps, tilapias in addition to barbs, catfishes, murrels, glass fishes, spiny eels, etc. A list of commonly available fishes of commercial importance of brackishwater bheries in West Bengal is as follows : *Lates calcarifer, Liza parsia, L. tade, Rhinomugil corsula, Eleutheronema tetradactylum, Scatophagus argus, Etroplus suratensis, Catla catla, Labeo rohita, L. bata, Cirrhinus mrigala, Cyprinus carpio, Hypophthalamichthys molitrix, Ctenopharyngodon idella, Oreochromis mossambica, O. nilotica, Mystus gulio, Odontamblyopus rubicundus, Glossogobius giuris*, etc.

Macro-invertebrates

The aquatic macro-invertebrates inhabiating brackishwater wetlands include crustaceans, insects, annelids, molluscs, etc. (Tables 8 and 9). A total of 117 species of benthic fauna and 77 species of macrophytal invertebrate species have been identified from Chilka Lake (Sarma *et al.*, 1988). The major macrobenthic groups include polychaetes, copepods, ostracods, isopods, amphipods, gastropods and pelecypods (Jhingran, 1997). The commonly occurring polychaetes belong to the genera *Nereis, Nephthys* and *Fabricia* from Chilka Lake proper and *Paranereis* and *Sternaspis* from the outer channel. Oligochaetes and hirudineans are rare. Only *Cypris* sp. has been reported amongst ostracods. Important isopods are *Cirolana* and *Calathura* species, while amphipods are species of *Quadrivisio, Niphargus, Orchestia* and *Talorchestia* and copepods of the genera *Amphiascus, Pseudodiaptomus, Labidocera, Acartiella, Nitocra, Enhydrosoma* and *Acartia*. Besides the above crustaceans, *Alpheus* sp. and *Squilla scorpio* have been recorded amongst decopods and stomatopods respectively (Bandyopadhyaya and Gopal, 1991). *Stenothyra* sp. is the dominant gastropod followed by *Thais carnifera* and *Cerithidia fluviatilis*. Among bivalves *Theora opalina* has a cosmopolitan distribution. In general, the mean faunal density of zoobenthos is 2,700/m^2 (Patnaik, 1971). However, a total of 160 species of invertebrate fauna comprising of sipuncula, echiura, annelida, arthropoda and echinodermata have been reported (ZSI, 1995) excluding insects even though aquatic insects are not uncommon to the Chilka Lake (Annandale and Kemp, 1915). Fraser and Dover (1922) recorded 30 species of dragonflies and damselflies from the Barkuda island of Chilka lagoon. Dash *et al.* (1988) identified 22 species of mosquito fauna inside and on the bank of Chilka Lake. The other macroinvertabrate fauna include 7 species of sponge (Annandale, 1915a) and 16 species of coelenterates from Lake Chilka (Annandale, 1915b).

It is mentioned that Nandi *et al.* (1993) reported as many as 20 species of insects from brackishwater systems of North and South 24-Parganas districts, West Bengal, besides 13 species of molluscs and 32 species of crustaceans. The Directory of Wetlands in India (MoEF, 1990) indicates that the Pulicat Lake supports a rich invertebrate fauna including many annelids (8), coelenterates (5), molluscs (26), crustaceans (26) and a species of flagellate (*Noctiluca miliaris*) and echinoderm (*Ophiocnemia mamorate*).

Zooplankton

The pelagic zooplankton of Chilka Lake belong to 26 faunal groups (Sarma *et al.*, 1988) which comprise of about 170 species (Rajan, 1964). They are dominated by copepods (43-70%), veliger stage of gastropods (5-32%) and nauplii (16-18%), and are followed by other groups like protozoans (7%), rotifers (4%), polychaete larvae (2%) mysids (1.5%), luciferids, medusae and fish eggs and larvae (Patnaik, 1973 ; Pattanaik, 1986).

Srinivasan and Satyanarayan (1995) found 18 groups of zooplankton in the order of abundance as follows : 1. Copepoda, 2. Crustacean nauplii, 3. Bivalve larvae, 4. Veliger larvae, 5. *Lucifer*, 6. Amphipoda, 7. Mysidaceae, 8. Medusae, 9. Cladocera, 10. Rotifera, 11. Polychaete larvae, 12. Fish eggs, 13. Fish larvae, 14. Foraminifera, 15. Decapod larvae, 16. Alima larvae of Squilla, 17. Ostracoda and 18. Chaetognatha.

Jhingran (1997) reported 20 species of copepoda of which 13 are brackishwater and 7 marine forms. The brackishwater species are *Pseudodiaptomus annadalei, P. binghami, P. hickmani, Acartia chilkensis, Acartiella major, A. minor, Paracalanus crasirostris*, etc. Sarma *et al.* (1988) recorded 41 species of calanoid copepods.

Twenty-three zooplankters were recorded from Pulicat lake of which *Pseudodiaptomus annandalei* and *Canthocalanus pauper* were common. Protozoans were represented by *Peridinium* spp., and *Noctiluca miliaris* ; annelids by larvae of Nereidae, Eunicidae and Spionidae ; Ostracoda by *Cypridina* sp. ; Copepoda by *Canthocalanus, Eucalanus, Paracalanus, Pseudodiaptomus, Acartia, Macrosetella, Corycaeus, Harpacticus* species and nauplii larvae; Mysidacea by *Rhopalophthalmus egregius* and *Mesopodopsis orientalis* ; Decopoda by *Acetes erythraeus* and various types of larvae ; and Mollusca by gastropod and pelecypod larvae (Chacko *et al.*, 1953). Twenty species of zooplankton were recorded from brackishwater wetlands by Nandi *et al.* (1993) from West Bengal, comprising of Cladocera (8), Ostracoda (1), Copepoda (9) and Rotifera (2). Of these, six cladocerans and six copepods occur in both freshwater and brackishwater wetlands.

The maximum zooplankters, both in volume and diversity, in Cochin backwaters occur during the period of high salinity (January-March). A variety of crustaceans comprising of copepods, cirripeds, mysids, amphipods, decapods as well as molluscan larvae and pelagic polychaetes occur in varying proportions throughout the year, while typically marine forms such as hydromedusae, ctenophores and chaetoganaths are abundant in premonsoon months.

Parasitofauna

The parasitic fauna from fishes and other vertebrates of Chilka Lake area have been investigated by several authors. Tripathi (1956, 1959, 1977) recorded as many as 17 species of monogenean trematodes from fishes of Chilka Lake. Chatterjee (1958) and Gupta and Ahmad (1976), contributed two new species of trematodes from fishes. Hafeezullah (1984) reported on the status of one of these two species, while Dutta (1995) recorded 29 digenetic treamatodes belonging to 13 families and 26 genera from 27 fishes of the lake which include 2 new genera and 8 new species. Dey Sarkar (1995) found 37 species of nematode fauna of vertebrate hosts from Chilka Lake and its adjoining areas. These species are contained in 28 genera, 20 families and 4 orders, of which 5 species are new of science.

4. SPECIAL FEATURES

Because of their connection with estuaries and/or sea water, the composition of flora and fauna in brachkishwater wetlands vary widely in accordance with the degree of mixing with monsoonal freshwater flow from interior areas. Most of the coastal lakes such as the Chilka lake and Pulicat lake are typically brackishwater wetlands which harbour a wide variety of organisms from the minute photosynthetic bacteria, to slightly bigger benthic diatoms, algae, halophytes to molluscs, crabs, prawns and fishes, particularly gobiids. The salinity regime such as high, medium or low and other factors determine species composition, diversity and abundance of biological elements in the brackishwater environment. Spatial and temporal heterogeneity of populations depend on successful colonisation by species or group forming zonations like algal beds, oyster beds, clam beds, etc. The knowledge of seasonal abundance and zonations of these curious organisms is meagre. It is further emphasized that this specialised brackishwater environment may be rich in biological diversity but it remains very ill explored representing only about 5 per cent species of the total faunal elements occurring in the Indian wetlands. A rootless floating insectivorous aquatic herb, *Aldrovanda vesiculosa* Linn. was reported by Roxburgh to occur in the salt lakes and other waterbodies of West Bengal, but Biswas and Calder (1937) could not find it even after a thorough search in the localities mentioned.

Endemicity of faunal elements in brackishwater environs has not so far been surveyed/studied even though about 28,145 animal species estimated to be endemic (Alfred, 1998). Amongst mammals 36 species are recognised as endemic to India but only the Marsh Mangoose, *Herpestes palustris* is endemic exclusively to salt lake swamp of West Bengal (Ghose, 1965). The Indian avifauna and herpetofauna are represented by a number of endemic genera and species but not a single species seems to occur exclusively in brackishwater lakes, However, out of 223 endemic fish species belonging to 78 genera and 23 families (Barman, 1998), only gobiid fishes (Family Gobiidae representing 7 and 9 endemic genera and species respectively) are to certain extent endemic to brackishwater wetlands and estuaries.

5. INTRODUCED BIODIVERSITY

A number of aquatic plants and animals like culturable fishes have been introduced in the country both knowingly and unknowingly. Amongst aquatic plants, water hyacinth *Eichhornia crassipes*, a native of Brazil, has acclimatized also in brackishwater wetlands of West Bengal and Assam since 1896. An annual grass *Panicum flavescens* first introduced in the Royal Botanic Garden, Calcutta from Mauritius, prefers to grow along the sides of tanks in West Bengal and Assam. The chloride contents of the Indian Botanical Garden soil and water indicate their low saline nature (Singh and Ghosh, 1984, 1988).

There are a good number of animal introduction of exotic species in India, chiefly concerned with culturable fishes. These species, *viz.*, silver carp, bighead carp, grass carp, common carp and tilapia, occur naturally in the freshwater of China, Korea, Japan, Taiwan, Europe and East coast of Africa. But they are now well adapted to low and medium saline impoundments in India. Though there is no record that invertebrate species has been introduced in the brackishwater wetlands in India, there is every possibility of introduction fish parasites as well as plankton along with transportation of fishes and migration of birds. Like-wise there is possibility of benthic barnacle introduction to India's brackishwater/ coastal wetlands through intercontinental cargo ships from outside.

6. VALUE

The brackishwater wetlands in India support a major fishery and provide livelihood for a considerable percentage of coastal population (Saha *et al.*, 1986; Nandi and Pramanik, 1994). Out of an estimated 1.19 million ha of country's brackishwater resources, 68,232 ha are currently available for culture. So far 12 species of finfishes, 4 species of prawns and only one species of crab have been brought under culture in brackishwater wetlands (Dhandapani, 1989). Tiger shrimp, *Penaeus monodon*, culture in these areas yields about 1200 kg/ha/yr in 2 short term crops. Production of monculture of bhetki fish, *Lates calcarifer* varies within 2000-2500 kg/ha/yr, while mixed culture of mullets, prawns, etc., also yields promising results (Jhingran, 1991).

The state-wise estimated shrimp production from brackishwater wetlands under culture is shown in Table 11, which represents an average yield of 0.586 t/ha in 1991-92. With a waterspread area of about 4,05,000 ha spanning across low, medium and high saline zones, brackishwater impoundments offer immense potential for fish and shellfish production in West Bengal (Table 11). The annual production of fish and prawn from these vast resources is about 23445 metric tonnes in 1995-96. One area of 4000 ha in Salt Lake locality stocked with carp, tilapia and other species provides employment for 20,000 fishermen and produces annual harvest of 6000 metric tonnes.

Fig. 5 : Macrophytes at the periphery of brackishwater bheries in West Bengal

The Chilka Lake in Orissa contributes an estimated 700 tonnes of fish annually with a net revenue of over 70 million rupees, while Pulicat lake supports an important fishery in Andhra Pradesh, especially for prawns. The annual production of Cochin backwaters in recent years has been estimated at 1,500-2,000 metric tonnes of shimps from traditional methods and 25,000 tonnes of fish from mechanised vessels and about 10,000 tonnes of molluscs (mostly clams).

Table 11. Statewise estimated shrimp production (in tonnes) from brackishwater wetlands under culture

State	Area under culture (1992)	Estimated production (1991-92)	Average production (t/ha)	% of production
West Bengal	33,918	13,800	0.407	34.50
Orissa	7,417	3,800	0.512	9.50
Andhra Pradesh	8,100	9,700	1.197	24.25
Tamil Nadu	480	700	1.458	1.75
Kerala	13,145	9,500	0.722	23.75
Pondicherry	—	—	—	—
Karnataka	2,542	1,100	0.432	2.75
Goa	525	300	0.571	0.75
Maharashtra	1,869	930	0.497	2.32
Gujarat	231	170	0.736	0.43
Total	**68,232**	**40,000**	**0.586**	**100.00**

The various other socio-economic values of brackishwater wetlands include (i) rich pastures for domestic livestock in Tso Morari Lake of Jammu & Kashmir, saline lakes of Rajasthan, saltflats of Kutch area in Gujarat and Chilka Lake in Orissa ; (ii) tourism especially in Chilka Lake ; (iii) navigation route for cargo and passenger vessels through the Buckingham canal in Pulicat Lake ; (iv) reed gathering for thatching purposes in Chilka

Fig. 6 : Mud crab culture demonstration centre in brackishwater wetlands of West Bengal.

Lake ; (v) mechanised ferry transport services for passengers in Chilka lake between various points; (vi) salt production from saline lakes of Rajasthan and from salt flats of Kutch region, Gujarat; (vii) exploitation for firewood and fooder ; (viii) supply of water for irrigation and domestic use; (ix) cultivation in surrounding areas during dry season by private land holders; (x) paddy-cum-fish culture in bheries of West Bengal; (xi) as oxidation ponds for treatment of domestic sewage in East Calcutta wetlands of West Bengal and (xii) for marble mining in the nearby hills of Sambhar lake, Rajasthan.

7. THREATS

The vast saline expanses of Rajasthan, Gujarat and the Gulf of Kutch together with backwaters and lagoons of India's east and west coasts as well as the deltaic brackishwater wetlands have suffered from uncontrolled urban development, agriculture and extensive construction of bunds altering the ecology of these wetlands. The extension of harbours and docks, conversion to residential or industrial estates and increasing pollution from sewage, industrial effluents and agricultural pesticides have ruined the coastal brackishwater wetland environment of India. The high altitude himalayan brackishwater lakes of Leh, in eastern Ladakh region of Jammu and Kashmir State also have suffered from increasing human population in the valley, and the concomitant increase in livestock population, particularly yaks, have intensified the grazing pressure on the saline marshes. Although there are no threats foreseen in the immediate future of Tso Morari lake in eastern Ladakh, human activities as well as sporadic incidence of hunting by armed forces personnel have been reported from Chushal saline marshes of Ladakh region. In and around Pangong Tso, a long narrow brackish lake of Ladakh area spanning the Indian/Chinese border, the grazing pressure has exceeded the carrying capacity of the land resulting in soil erosion and some disturbance to nesting birds.

Grazing pressure on the surrounding land of Sambhar Lake, Rajasthan has led to increasing desertification and siltation problem. Moreover, there are plans to increase salt production from this lake. There is excessive grazing by camels in the salt marshes of the great Rann of Kutchch in Gujarat, while large herds of domestic cattle are driven into salt flats in the Little Rann. Chilka Lake, Orissa is seriously threatened by increasing siltation, decreasing salinity and rapid expansion of *Potamogeton,* besides poaching of waterfowl, over-fishing, grazing and reclamation of the lake for agricultural purposes as well as pollution problem from domestic and industrial sources. Most important of them are the decline in fish yields and shrinkage of lake area (Bandyopadhyay and Gopal, 1991). Uncontrolled urban development has destroyed vast areas of mangrove forest around Cochin backwaters. The other threats to the area include construction and expansion of an airport, construction of a bund, pollution, eutrophication, weed infestation and incidence of mass fish kills in recent years. The principal disturbances of Pulicat Lake are caused by fishing activities and fish factories along the edge of the lagoon. The proposed construction of salt pans within the Tamil Nadu Pulicat Lake Sanctuary and also proposed planning to set up of a marine chemicals and salt manufacturing industry by the Andhra Pradesh Government within A. P. Pulicat Lake Sanctuary of the lagoon could pose serious threats in future.

The various other disturbances, such as, introduction of the exotic mesquite *Prosopis juliflora* from Mexico in the Rann of Kutch region may well pose a serious threat to indigenous flora, while the pressure of military personnel and equipment and deliberate chasing to Wild Asses and wildlife by tourists in their jeeps and motor cycles are causing considerable amount of disturbances to wildlife in the same region.

Table 12. Protection status of brackishwater wetlands in India.

Categories of Protection	Protected brackishwater wetlands
1. Ramsar sites/International wetlands	1. Chilka Lake (Orissa) and Sambhar (Rajasthan)
2. National wetlands	2. Ashtamudi (Kerala), Nalsarovar (Gujarat), East Calcutta wetlands (West Bengal), and Tso Marari (Jammu & Kashmir)
3. Wildlife sanctuary	3. Little Rann of Kutch (Gujarat) and Point Calimere (Tamil Nadu),
4. Bird sanctuary	4. Nalsarovar (Gujarat) and Khijadia lake (Gujarat),

On the other hand, intensive shrimp farming activities in the brackishwater bheries in West Bengal is of great significance in aquatic pollution related problems in the ecology of the area.

8. CONSERVATION

The conservation of Chilka Lake, Nalsarovar, etc., is accorded with the declaration of these wetlands as international and/or national watlands. Besides these, protection is also given to a considerable number of brackishwater habitats existing within biosphere reserves, national parks and sanctuaries. The declaration of protected areas presented in Table 12 provides indirect protection to brackishwater animals occurring in them. It seems, besides brackishwater mangrove and estuarine habitats, only a few saltwater wetlands are protected. However, as a mitigating measure against the problems associated with acid sulphates and increased soil salinity in the reclaimed land due to construction of the Thanneemukkam Bund across Vembanad lake of the Cochin backwaters, the gates of the dyke are at present kept permanently open to allow flooding with fresh and saline water for revival of soil fertility.

9. FUTURE DIRECTION

Brackishwater ponds, lakes and lagoons as well as backwaters are complex fragile, constantly changing and dynamic ecosystems. They are heavily exploited for their physical and biological resources. Therefore, these wetlands need to be understood in the context of geology, geomorphology, hydrology, drainage pattern, wave action and landuse of the drainage basin in addition to biotic resources. Although a few brackishwater wetlands are brought under ramsar sites, national wetlands and sanctuaries, there are vast areas of brackishwater systems that are being threatened due to encroachment, over-exploitation, pollution, sedimentation and human activities. So, there should be some rules and regulations as well as conservation and monitoring measures to protect these habitat types along with their natural resources for sustainable use to the local communities. However, the following future actions, in general, are suggested.

- Rapid surveys should be conducted to explore physical and biological resources from various brackishwater wetland types to make an inventory of the natural resources of the country.
- Over-exploitation and/or indiscriminate fishing should be stopped imposing regulatory measures through stock assessment studies.
- Socio-economic surveys should be conducted to understand the dependency of the local population on these wetlands.
- Environmental monitoring and impact assessment should be carried out at regular interval or as and when necessary.
- Proper management action plan should be prepared and implemented for ramsar sites, national wetlands and other important brackishwater wetlands of the country.

10. SELECTED REFERENCES

Alfred, J. R. B., Das, A. K. and Sanyal, A. K. (Eds.) 1998. *Faunal Diversity in India.* ENVIS Centre, ZSI, Calcutta.

Alfred, J. R. B. and Nandi, N. C. 2000. Faunal Diversity in Indian wetlands. *ENVIS Newsletter,* **6**(2) : 1-3.

Anonymous 1995. Fauna of Chilka Lake. *Wetland Ecosystem Series* **1** : 1-672, ZSI, Calcutta.

Bandyopadhyay, S. and Gopal, B. 1991. Ecosystem Studies and Management problems of a Coastal Lagoon, The Lake Chilka. In : Gopal, B. and Asthana, V. (Eds.). *Aquatic Sciences in India* : 117-172. Indian Association for Limnology and Oceanography, New Delhi.

Chacko, P. I., Abraham, J. G. and Andal, R. 1953. Report on the survey of flora, fauna and fishes of Pulicat lake, Madras State, India. *Contr. Freshwater Biol. Stn.,* **8** : 1-20.

Dhandapani, P. 1989. *Identification of Cultivable Species.* Marine Products Export Development Authority, Kochi-682 015, pp. 1-64.

Ghosh, A. K. 1990. Biological Resources of Wetlands of East Calcutta. *Indian J. Landscape System and Ecol. Studies,* **13** (3) : 214-226.

IUCN. 1989. *A Directory of Asian Wetlands : India.* In : D.A. Scott (ed.) IUCN, Gland and Cambridge (Reprint).

Jhingran, A. G. 1991. Challenging frontiers in freshwater fisheries of India. In : Gopal, B and Asthana, V. (Eds.) *Aquatic Sciences in India* ; pp. 31-48

Jhingran, V. G. 1997. *Fish and Fisheries of India.* Hindustan Publishing Corporation (India), Delhi, 3rd edition (Corrected Reprints), pp. xxiii+728.

Nandi, N. C., Das, S. R., Bhuinya, S. and Dasgupta, J. M. 1993. Wetland faunal resources of West Bengal. 1. North and South 24-Parganas districts. *Rec. zool. Surv. India Occ. Paper* No. **150** : 1-50

Nandi, N. C. and Pramanik, S. K. 1994. *Crabs and Crab Fisheries of Sundarban.* Hindustan Publishing Corporation (India), Delhi, pp.1-192.

Patro, S. N. 1988. *Chilka : The Pride of Our Wetland Heritage.* Orissa Environmental Society, Bhubaneswar

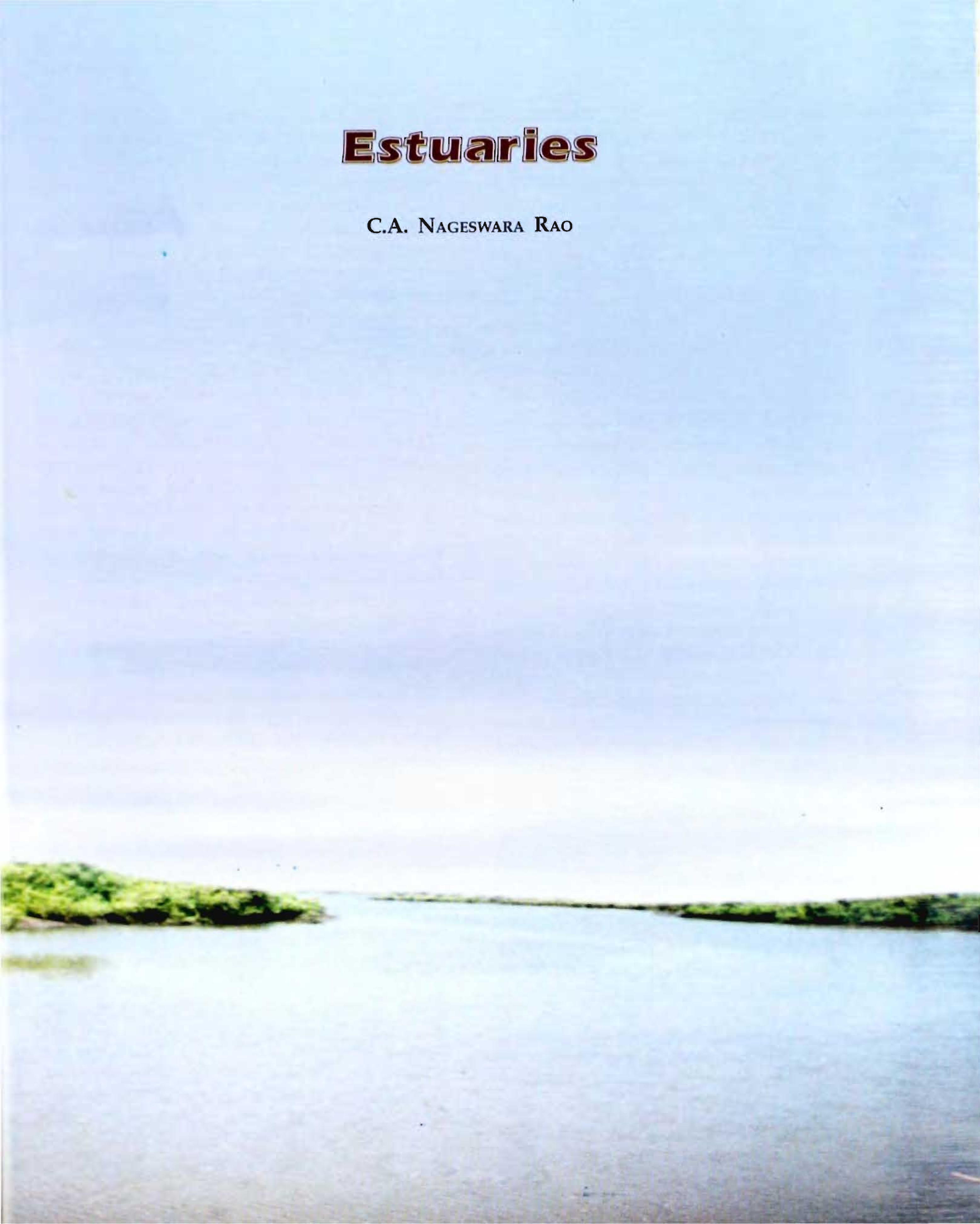
Raman, K., Ramkrishna, K. V., Radhakrishnan, S. and Rao, G. R. M. 1975. Studies on the hydrobiology and benthic ecology of Lake Pulicat. *Bull. Dept. Mar. Sci., Univ. Cochin,* **7**(4) : 855-884.

Saha, G. N., Thakurta, S. C., Laha, G. C. Nandy, A. C., Karmakar, H. C., Naskar, K. R., Das, P. B. and Chatterjee, S. K. 1986. Ecology and fishery management of brackishwater bheries in West Bengal. *Bullentin* No. **46**, pp. 1-23, CIFRI, Barrackpore.

Sewell, R. B. S. 1934. Study of the fauna of Salt Lakes, Calcutta. *Rec. Indian Mus.,* **36** : 45-121.

Estuaries

C.A. Nageswara Rao



ENVIS–*Zool. Surv. India*
Ecosystems of India : 219-237, 2001.

Estuaries

C.A. NAGESWARA RAO

Esturine Biological Station
Zoological Survey of India, Berhampur 760 005

1. INTRODUCTION

At and near the mouth of the river, where it meets the sea, a dynamic and distinct environment prevails. Here the river water mixes with the sea water, and the tides in regular recurring rythms push in and out in the eternal ebb and flow. This transitional ecotone which is the confluence of the river and the sea is the estuary. The Oxford dictionary defines it briefly as the tidal mouth of a large river. But estuaries are of different sizes and shapes. In reality, an estuary is a semienclosed coastal body of water which has a free connection with the open sea and within which the sea water is measurably diluted with freshwater derived from land drainage (Pritchard, 1967). However, this definition excludes those estuaries, which are temporarily cut off from the sea during the dry season and the estuaries which far from being diluted with seawater become hypersaline when evaporation exceeds freshwater inflow. In view of the above, Day (1981) defined an estuary as a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with freshwater derived from land drainage.

Being at the confluence of the river with the sea this environment naturally has the interaction of the sea, river and land characterised by variable gradients in physico-chemical factors. These in turn influence and determine the nature of living organisms of this area. Among the physico-chemical factors, the nature of substratum, the extent of tidal influence, the nature and distribution of salinity, the type of sediments, dissolved oxygen content of water, pH, temperature, amount of organic matter, the nature and extent of pollution among others are important (Balakrishnan Nair, 1987).

Estuaries are beautiful areas of our planet, situated as they are, between land and sea, play a dynamic role in the mixing, circulation, sedimentation and water dynamics. Penetrated by the sea through the recurring tides and flushed by the freshwater outflows of the lotic systems an estuary is indeed a very dynamic ecotone where freshwater mix with the sea water and these areas witnessed by the lush verdure of mangal forests (mangroves) that fringe this area. Blessed by the fertile flows of the both sea and rivers, these fascinating biotopes are by far the most productive ecosystems on our planet, the abode of unique species of plants and animals, the cradle of several species of fin fish, the nursery of commercially important shrimps, prawns and crabs and the natural habitat of various other invertebrates (Balakrishnan Nair, 1987). Estuaries have also been witnessing for ages and serving as high-ways for the phenomenal and spectacular instinctive migrations of such anadromous fishes as the Hilsa and Salmon from the sea to freshwater and the catadromus fishes like the eels from freshwater to sea during the reproductive cycles. These fascinating semi-enclosed and sheltered bodies of water have been since the dawn of history, the focal points of maritime activities culminating in the commercial, social and cultural interaction between the nations. No wonder most of the great cities of the world, have developed around the estuaries.

The process of mixing of fresh and salt waters in the estuary determines the ecology of tidal streams so much so the distribution of salinity. The incidence and relative abundance of organisms, movement of planktonic populations, the fisheries, etc., depend to a great extent on the nature of circulation of fresh and salt water.

Studies of ecology of estuaries is beset with difficulties since no two estuaries are alike. Interaction of so many variables and differences in the physico-chemical and meteorological parameters, that exist in different regions of the country considerably add up to the problem. This aspect makes generalisation some what difficult necessitating detailed studies on each estuary.

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

The definition of estuaries excludes coastal lagoons, back-waters as these exhibit structural variations from the geographically defined estuary. However, in a biological sense the coastal sea-boards, neretic inlets, lagoons, backwaters, and creeks, etc., are also treated as estuarine habitats. The geomorphological features in the waterbody formations result in distinct structural variations of morphometry from the normal pattern of riverine estuary. In the riverine estuary we have appreciable dilution of sea-water (entering through its mouth at the sea-estuary interphase) with the freshwater flowing from the upstream region. Viewed on a broader plane most of the coastal lakes (lagoons), backwaters and creeks could be considered as estuarine environment where mixing with monsoonal freshwater flow draining from interior areas occurs and because of its connection with the sea we encounter appreciable dilution of sea-water within. Though these may be considered as specialised estuarine environments, they are not dealt with in the paper except for occasional comparison.

The riverine estuary is thus emphasised as a dynamic ecosystem having a free connection with the open sea through which seawater enters normally according to the twice daily rhythm of tides. The entering sea water is then measurably diluted by freshwater flowing into the estuary from rivers. The pattern of dilution of seawater by freshwater varies from estuary to estuary depending on the volume of freshwater, the range of tidal amplitude and the extent of evaporation from the water within the estuary. The salinity of sea water is approximately 35 ppt. tending to be lower (33 ppt.) in coastal seas and higher (37 ppt.) in tropical waters. The salinity of freshwater is always less than 0.5 ppt. Thus the salinity of estuarine water is between 0.5-35 ppt. This range is generally termed brackish as distinct from marine or freshwaters and the pattern of salinity distribution may be used for classification of estuaries.

Three main types of estuaries can be recognised namely positive, negative and neutral. In positive estuaries the evaporation from the surface is less than the volume of freshwater entering the estuary from the rivers and land drainage. In such positive estuaries the outgoing freshwater floats on top of the saline water which has entered from the sea and water gradually mixes vertically from bottom to the top. This is seen in temperate parts of world and in perennial and glacial rivers.

In a negative estuary the evaporation from the surface exceeds the freshwater run off entering the estuary. This type of estuaries are mostly found in tropics. Although it can occur in temparate regions as well especially where the freshwater input is limited. In negative estuaries evaporation causes the surface salinity to increase. This saltier surface water is denser than water underneath and therefore sinks. Occasionally, the freshwater input to the estuary exactly equals the evaporation and in such situation a static salinity regime is established. Such an estuary is termed neutral but these are rare as evaporation and freshwater inflow are almost never equal (Donald S Mclusky, 1981).

Geomorphologically estuaries can be classified into drowned valleys, kayals and deltas (Ahmed, 1972). Reid and Wood (1976) classified the first two types as simple and irregular estuaries and Ahmed (1972) used the term 'ria' for the drowned river valley type of estuary.

2.1 Drowned river valley estuaries

Simple estuaries of this type are most common on the west coast between Gujarat and Mangalore. The river mouth areas of Mahe, Sabarmati, Narmada, Tapti, Damanganga, Mandovi-Zuari and Kali are geomorphologically identified as drowned river valley estuaries. Many of these are associated with extensive mudflats and saltmarshes. The small rivers between the Hugli and Godavari and Krishna on the east coast such as Subarnarekha, Vamsadhara, Nagavali also have simple estuaries, (Ahmed, 1972).

2.2 Kayals or irregular estuaries

The backwaters on the west coast between Kanyakumari and Mangalore are locally called Kayals. This type of estuary is very irregular and seperated from open sea by long spits of offshore bars. There are 30 Kayals on the south-west coast of India and Vembanand Lake is the largest. The second largest Kayal is the Asthamudi estuary.

2.3 Deltas

These are traiangular areas bordering the river valley towards the mouth. They are associated with the land projecting into the sea in the form of protruberances. The tributaries and the main branches of the river divide further into narrow channels and mangrove forests and marshy tidal flats usually occur on the seaward side of the deltas. Deltas largely occur on the east coast of India and the prominent ones are those of river Ganga (Hugli-Matla), Mahanadi, Godavari, Krishna and the Cauvery.

In the Directory of Asian Wetlands (IUCN, 1989) the extent of total Indian estuaries is shown as 3.9 million ha. According to Jhingran and Gopalakrishna (1973) about 2.14 million ha of estuarine areas including lagoons and lakes are distributed along the east and west coast of India. The mouths of great rivers such as Ganga, Mahanadi, Godavari and Krishna on east coast are the examples of typical positive type of estuaries. The force of tidal inflow is felt up to 295 km in Hugli-Matla estuarine complex and extends up to 65 km in small rivers like Mandovi-Zuari. Some of the estuaries are not open all through the year being partially or totally cut off from the sea during summer when the river flow is reduced by the formations of sand bar.

In the tropics and monsoon belt area we encounter many variations in the terrain, geomorphological and climatological features even within a country. Thus in India we have differences between east and west coast and these differences are reflected in the estuarine distribution. Greater annual precipitation in the west coast results in greater freshwater flow into the Arabian sea. But the Arabian sea water does not get diluted even during monsoon in contradistinction to the Bay of Bengal. In the Bay, riverine flow during monsoon season coming from rivers, such as, Brahmaputra, Ganga, Mahanadi, Krishna, Godavari and Cauvery, *etc.*, reduces the salinity to 18 ppt, from average 30 ppt even in the Andaman sea.

The river flow, tidal range, and sediment distribution in estuaries are continually changing and consequently estuaries probably never achieve a true steady state. With increased river flow the extent of tidal intrusion is reduced, while with decreased river flow the tidal intrusion is increased. The salinity at particular point of an estuary depends on the relationship between the volume of tidal water and the volume of freshwater inflow as well as the tidal amplitude, the topography of the estuary and the climate of the locality. For the animals and plants living within the estuary, salinity poses a challenge to the physical processes and on the basis of salinity, estuaries are divided into various zones, *viz.*, hypersaline (40 ppt), euhaline (40-30 ppt), polyhaline (30-18 ppt), mesohaline (18-5 ppt) and oligohaline (5-0.5 ppt). The salinity of the water bodies directly influences the nektonic and planktonic organisms living in the water column. But for majority of benthic estuarine organisms which live burried within the muddy deposits, the interstitial salinity varies much less than the salinity of the overlying water due to slow rate of interchange between them. On the intertidal mudflats where the most abundant populations of estuarine animals live, the interstitial salinity matches that of the high tide salinity which covers the mudflats. Because of this phenomenon it is usually possible for marine animals living burried in the sediment to penetrate further into estuaries than marine animals living planktonically.

Fig. 1 : A wetland in the lower reach of Krishna River in Andhra Pradesh

The estuary is divided geographically into different zones as follows :

- Head Where the freshwater enters the estuary and river currents predominate; tidal but limited salt penetration, maximum salinity 5 ppt.
- Upper reaches mixing the freshwaters and salt water; minimal currents especially at high tide leading to turbidity; mud deposition; salinity 5-18 ppt.
- Middle reaches faster currents due to tides; principally mud deposits, salinity 18-25 ppt; sandy, where currents are faster.
- Lower reaches Faster currents due to tides; principally sand deposits; salinity 25-30 ppt.
- Mouth strong tidal currents, clean sand or rocky shores, salinity equal to adjacent sea.

Fine sedimentary deposits of mud are a highly characteristic feature of estuaries. The water of estuaries tends to be very turbid as silt and clay particles in suspension are carried about until they eventually settled to form the vast mudflats around the estuarine mouths which are so characteristic of estuaries. The middle reaches of the estuaries are characterised by very turbid water with poor light penetration. Within many estuaries the suspended matter in estuarine water produces so called turbidity maxima. The presence and magnitude of turbidity maxima are controlled by number of factors including the amount of suspended matter in the river or sea water, the estuarine circulation, and settling velocity of available matter. Along with the huge quantity of sediments being carried into the estuaries from the vast river drainage, particles of organic debris during its course also derived from the death and decay of plants and animals are usually found. Once the dissolved and particulate organic matter reaches estuaries from freshwater to salt water it tends to remain there as it is deposited and incorporated into the estuarine ecosystem along with fine inorganic matter, *i.e.*, sediments of land origin (silt and clay). The organic matter within the estuaries consists of material resulting from the excretion and decomposition of estuarine animals and plants supplemented by fragments of dissolved organic material carried into the estuary. Thus the estuaries are rich in the organic matter which gets recycled and transformed to enrich the estuary with nutrients, thereby helping estuaries highly productive.

The sedimentation of both inorganic and organic suspended material leads to development of mudflats and other areas of deposition within estuaries which provide highly suitable conditions for rich flora and fauna to flourish.

3. BIOLOGICAL DIVERSITY

Estuaries are generally rich in nutrients needed for plant and animal growth, especially nitrogen and phosphates, as the supply of these nutrients is continually being replenished by supplies from rivers, the sea and the adjacent land. Studies on the distribution and abundance of animals and plants in estuaries have shown that the number of species within the estuaries is smaller than that within the sea or in freshwater alone.

Estuarine plants and animals fall into several categories as follows.

- Oligohaline organisms : The majority of animals living in rivers and other freshwater bodies can not tolerate salinities greater than 0.1 ppt but some oligohaline species persists at salinities upto 5 ppt.
- True estuarine organisms : These are mostly animals with marine affinities, which live in the central part of the estuaries. Most of them are capable of living in the sea but are not found there apparently because of competition.
- Euryhaline marine organisms : These constitute the majority of organisms living

in the estuaries with their distribution ranging from the sea into the central part of the estuaries. Many disappear by 18 ppt.

- Stenohaline marine organisms : These occur at the mouth of estuaries at salinities down to 25 ppt.
- Migrants : These animals mostly fish, and prawns spend only part of their life in the estuary.

Estuarine ecosystems provide different physiographic habitats in its course depending on the nature and size of the river which is forming the estuary. The estuarine ecosystem of some rivers provides habitats, such as, estuarine water column, with its plankton and nekton, and muddy bottoms at its middle reaches with benthic fauna, the mouth area completely sandy. This situation is seen in medium and minor rivers, such as, Rushikulya, Vamsandhara, etc., on east coast, Kali and other rivers on the west coast.

In the case of major and delta forming rivers, such as, Ganga, Godavari, Krishna, Mahanadi, *etc.*, in addition to the real estuarine water column habitats, vast stretches of mudflats and dense mangrove forests develop in and around the mouth of the river which divide into smaller channels before its confluence. Thus, estuarine ecosystem offers diverse habitats each endowed with a variety of fauna and flora.

The mudflats of the estuaries harbour rich benthic macrofauna, mostly belonging to molluscs, crabs, polychaetes and gobiid fishes. The sediments of mangrove forests are inhabited by rich benthic fauna consisting of coelenterates, polychaetes, crabs, prawns, isopods, amphipods, large population of hermit crabs, molluscs and few fishes.

3.1 Species Diversity

Studies on the distribution and abundance of plants and animals have shown that estuaries exhibit low diversity but high abundance since physical conditions fluctuate widely and thus organisms are exposed to physiological stress. However, biodiversity in the estuarine ecosystem is well represented by a variety of flora consisting of algae, fungi to highly specialised angiosperms, *viz.*, mangroves, while fauna comprises of almost all groups of animal kingdom starting from protozoans to mammals.

The flora and fauna in the estuarine ecosystem are grouped under three categories, such as, plankton, nekton and benthos along with great variety of flora present in the intertidal/supratidal region of estuaries as salt marsh plants and mangrove forests. Under plankton diatoms, dinoflagellates and other microalgae form the major component as phytoplankton, while several animals groups form the zooplankton component. Large populations of crustaceans, fishes and others with capacity to swim in water column represent the nekton component. Thick populations of annelids, crustaceans and molluscs which live within the sediments at the bottom as well as at the intertidal region form the benthic component. Large populations of meiofauna belonging to various groups, mainly nematodes, copepods and various others inhabit the interstitial spaces of sediments.

3.1.1. Flora

Fungi : The estuarine fungi include representatives of all classes. While Phycomycetes, Ascomycetes and the fungi imperfecti predominate, Deuteromycetes are the lowest. Myxomycetes are uncommon and Bacidiomycetes are virtually absent. All estuarine species of fungi are euryhaline but judged by the production of fruiting bodies most of them prefer low salinities. The phycomycetes are mainly saprophytic; some genera attack wood in association with ship worms.

The Saprolegniaceae are largely parasitic causing diseases in fishes and attacking eggs of crustaceans. About 40 species of fungi are reported to be associated with mangroves of the estuarine environment of Indian waters.

Macroalgae : Most estuarine algae particularly the macroscopic forms are immigrants from the sea, while unicellular algae are derived from freshwater. This is particularly true of the class Chlorophyceae. Benthic macroalgae of Indian estuaries has been well studied and in most of the estuaries, plants belonging to class Chlorophyceae, Florideophyceae and Cyanophyceae are found. Their composition and abundance vary with the distribution of salinity. In backwaters where salinity is comparatively high than the estuaries, macroalgae, such as, *Gracilaria sp., Hypnea sp., Acanthophora specifera* and *Enteromorpha compressa* grow in open coastal waters and in estuary proper only members of the Chlorophyceae like *Enteromorpha* and *Chaetomorpha* were reported from Vellar estuary (Kannan and Krishnamurthy, 1978). Open shore macroalgae like *Ulva fasciata, Enteromorpha intestinalis, Chaetomorpha linum, Gracilaria verrucosa* and *Hypnea musciformis* from the mouth or marine zone and other forms like *Enteromorpha compressa, Rhizoclonium sp., Catenella impudica, Caloglossa liprieurii* and *Bostrychia tenella* from the upstream low salinity mangrove areas of the Mandovi-Zuari estuary were reported (Jagtap, 1985). From Godavari estuary *Chaetomorpha sp., Caloglossa liprieurii, Catenella impudica, Bostrychia tanella, Polysiphonia* sp. and members of blue-green algae mostly *Oscillatoria* (Cyanophyceae), *Microcoleus* sp. and *Lyngbya* sp. were reported (Umamaheswara Rao, 1987).

It is reported that members of the Florideophyceae (Red algae) are abundant in high salinity zones than the members of Chlorophyceae. As the salinity decreased there is a reduction in the numbers of red algae and the Chlorophyceae has become more abundant in low salinity upstream zones. Similarly members of Cyanophyceae were not observed or less abundant in the marine zones and there was progressive increase in their numbers in the upstream areas.

In the mangrove region of the estuaries, algal members of the family Florideophyceae (Red algae), such as, *Caloglossa, Catenella, Bostrychia, Polysiphonia* and blue-green algae are found on the pneumatophores of *Avicennia* and proproots of *Rhizophora* and other mangrove plants in the infralittoral fringe and only *Chaetomorpha* sp. were seen in the midlittoral zone of Godavari estuary (Umamaheswara Rao, 1987).

Phytoplankton : As in neretic or coastal waters, diatoms and dinoflagellates are most common groups in the phytoplankton of the estuaries. In addition to these, members of Chlorophyceae, Cyanophyceae and Euglenophyceae occur as major components in the estuarine ecosystems. Since salinity influences the composition of phytoplankton members of the green and blue green algae these are not found amongst the phytoplankton of the Mandovi-Zuari estuary (Devassy and Bhargava, 1978) at its mouth area while they form 12-25% of the phytoplankton of the upstream waters of the Tapti and Narmada estuaries (Ragothaman and Reddy 1982, Ragothaman and Patil, 1986).

In general the estuarine phytoplankton is composed of diatoms, (93-70%), dinoflagellates (20-2.5%), green algae (25-5%), blue green algae (13-10%) and Euglenoids (10-5%). Abundance of planktonic green, and blue green algae was more in the interior parts of backwater than at the mouth. In Asthamudi estuary, green and blue-green algal groups are numerous in the brackishwater regions and multicellular algae like *Enteromorpha, Ulothrix, Oedogonium, Spirogyra* and *Rhizoclonium* were recorded in large numbers as planktonic forms in this zone (Mathew and Nair. 1983).

As in the macroalgae populations, progressive reduction was observed in the number of species of diatoms and dinoflagellates from marine to brackishwater zones and further to upstream areas and this reduction was more prominent in dinoflagellates. Krishnamurthy and Santhanam (1980) reported reduction in species number of diatoms and dinoflagellates from neretic zone to mangrove areas. They reported 81 species of diatoms and 40 species of dinoflagellates from neretic region, 63 and 19 in backwater zone, 52 and 15 in estuarine area and 50 and 8 species only from mangrove areas at Porto Novo.

In total about 290 species of diatoms from east coast are reported, of which 12 species form the bulk of estuarine phytoplankton. Large population of diatoms and other microalgae occur in the upper 1 cm of mudflats of the estuaries although living diatoms are found up to 18 cm depth in sediments. On the mudflats large mats of macroalgae belonging to Chlorophyceae, Cyanophyceae and Florideophyceae are seen abundantly, of which *Enteromorpha* is very common.

Seagrasses: Among the sea grasses *Halophila ovalis* and *H. beccari* were reported from the mudflats near to the sea coasts of Godavari and Krishna estuaries (Venkanna, 1991).

Mangroves and associated plants: The perennial supply of freshwater along the deltaic coast and the admixture with sea water through the tides at the mouths of rivers resulted in the formation of extensive mudflats which are congenial for the growth of variegated canopy of mangrove forests. The vast deltaic mangroves of the Bay of Bengal owe their luxuriant growth to the alluvial deltas of the coastline formed by the rivers, such as, the Ganga, Mahanadi, Godavari, Krishna and Cauvery. The diversity of species composition evolved as a varying degree of adaptation to the salinity of the sea water and brackishwater mix. The physiological requirements of the plant species to withstand equally silt laden flood water, freshwater, euryhaline estuarine water, tolerance to sea water, etc., determine the composition and the distribution of mangrove vegetation super-imposed upon suitable coastiline geomorphology. The eastern sea coasts covers about 70% of total mangrove area of our country.

The flora occurring at the river mouths and its adjoining vast mudflats, swamps and marshy areas can be grouped into true mangroves, mangrove associates, halophytes and seagrasses. Alternately in the mangrove vegetation, two categories may be recognised, *viz.*, 1) the core mangrove species belonging to genera *Rhizophora, Avicennia, Bruguiera, Kandelia, Ceriops, Excoecaria, Sonneratia, Nypa, Lumnitzera, Aegiceras, Heritiera, Aegialitis*, etc., and 2) the associated and peripheral vegetation belonging to genera *Sesuvium, Suaeda, Salicornia, Acrostichum, Brownlowia, Salvadora, Clerodendrum, Hibiscus, Phoenix, Derris, Proterasia, Aeluropus, Urochondra*, etc.

Fig. 2 : Mangroves of Krishna Estuary during high tide

Fig. 3 : Collection of Mangrove associated fauna

The important role played by estuarine plants including algae, halophytes, mangrove forests and swamps in the production of detritus, and dissolved organic matter and its recycling of nutrients is being increasingly realised. Their importance in the recycling of organic matter and enrichment of coastal waters is of immense potential.

3.1.2. Fauna : Estuaries are richer in nutrients than either freshwaters or the sea so that the flora is highly productive and animal life is prolific. Surprisingly few freshwater animals invade estuaries and most of the species are of marine origin. Even then, these include only a small fraction probably less than a tenth of those found in the sea nearby. Thus an estuary is rich in individuals, but poor in species; however, the varied habitats in the estuarine ecosystems is inhabited by diverse faunal groups.

Based on the salinity tolerance the estuarine fauna can be classified into different components, such as, stenohaline-marine, euryhaline-marine, true estuarine, euryhaline-freshwater, terrestrial and migratory. However, for better understanding of the estuarine faunal diversity it can be grouped basing on their habit, *i.e.*, plankton, nekton and benthos.

Plankton : This refers to the free floating aquatic life in the estuaries which has feeble or no power of movement and, as such, moves along with water currents. It consists of plants (phytoplankton) and animals (zooplankton) and the former has already been dealt under flora.

Zooplankton comprises representatives of most of the invertebrate phyla, few protochordates and, eggs and larvae of fishes. The composition is mainly medusae, ctenophores, polychaetes, mysids, ostracods, copepods, invertebrate larvae of different phyla, foraminiferans, tintinids (ciliates), rotifers, chaetognaths, crustacean larvae, fish eggs and larvae. Among the different groups of the zooplankton, copepods form the major component forming 58-92% of the total zooplankton consisting of about 60 species in the Godavari estuary while 53 species are reported from Hugli estuary and 58 species from Bahuda estuary. The qualitative and quantitative nature of zooplankton varies during different seasons as well as at different locations of estuary. However, zooplankton is found to be rich in bulk in the middle reach of the estuary compared to the head and mouth. This is due to the fact that greater turbulence at the mouth due to tides and freshwater condition is dominant at the head of the estuary.

Nektons: These are the free swimming forms in the water columns of the estuary. This group constitutes mainly quantitatively rich fish fauna along with its large juvenile populations, followed by different species of prawns mainly penaeids and palaemonids, shrimps and some other forms. Occasionally snakes, turtles, crocodiles and dolphins at the mouth of the estuaries are also found.

Benthos: These constitute the major component of estuarine organisms both in variety and in numbers. These are either crawling on or burrowing in the sediments or sessile or live within the interstitial spaces between particles (meiobenthos) of estuarine bottom sediments formed by admixture of silt, clay and sand in various proportions. Depending on the nature of the sediment texture, faunal composition and their quantity varies. Further, the mangrove forests and the vast mudflats of the estuaries also harbour a rich variety of fauna. The benthic fauna consists of coelenterates, polychaets, planarians, nematodes, isopods, amphipods, Cumacea, Tanaidecea, crabs and hermit crabs, shrimps, Echiura, sipunculids, Mollusca, Brachiopoda, Echinodermata and few protochordates; fishes, such as, ophichthid eels, gobioid fishes inhabit as burrowing forms or mud-dwellers in the estuary commonly.

The meiobenthos are smaller in size (less than 0.5 mm) inhabiting the interstitial spaces between the sediment particles of the bottom and intertidal region comprises Nematoda, harpacticoid copepoda, Ostracoda, Kinorhyncha, Turbellaria, Mollusca, Polychaeta, Tardigrada, crustacean larvae and Amphipoda. Nemotoda (90.05%) is the most dominant group followed by harpacticoid copepods (3.7%) and Ostracoda (3.6%) in Godavari estuary (Murthy and Rao, 1987). Similarly situation is reported from Mandovi estuary (Ansari and Parulaker, 1993).

The estuarine fauna occurring as plankton, nekton and benthic forms belong to a wide spectrum of animal groups as detailed below.

Protozoa: Among the estuarine protozoans, foraminiferans are the major component followed by flagellates and ciliates. About 80 species of foraminiferans have been recorded from Godavari and Krishna estuary, of them 57 in living condition (Narappa *et al.*, 1982). Flagellates, such as, *Ceratium* and *Noctiluca* are common dinoflagellates in zooplankton of estuaries. Among ciliates, 23 species of tintinids are reported from Bahuda estuary.

Porifera: Among sponges, 8 species belonging to 6 genera are reported from Indian estuarine waters and lagoons. However, *Cliona vestifica* is reported from Godavari, Mahanadi and Zuari estuaries while *Tetilla dactyloidea* var *lingua* was reported from Godavari estuary. *Donotella acustella* was reported from Mahanadi estuary.

Coelenterata: Medusae and siphonophores as planktonic and sea anemones and pennatulids as benthic forms are common coelenterates in the estuaries. So far, 23 species of hydro- and scyphomedusae and 5 species of siphonophores are reported from Godavari estuary (Sai Sastry and Chandra Mohan, 1989), while 16 species of medusae are reported from Hugli-Matla estuary (Halder and Choudhury, 1995). The Pennatulid *Pteroides esperi* and Sea pen *Virgularia* sp. are reported from the Godavari estuary (Radhakrishna and Ganapati, 1969). Among sea anemones 13 species are reported from Indian estuaries, of which the genera *Edwardsia* and *Metridium* are the common forms.

Nematoda : Large populations of nematode occur in the sediments of the intertidal region to the abysal depths of seas as well as the estuaries. Majority of the nematodes in the sediments of aquatic habitats are small and less than 0.5 mm and occur in between the interstitial spaces of sediment particles. Hence, these are considered as meiobenthos. Nematodes form the dominant group of about 90.5% in the Godavari estuary and about 64.5% in the Chilka lagoon and 75% in the Mandovi Estuary among the meiobenthos. Qualitatively also estuarine nematodes are highly diverse as about 35 spp. are reported from Hugli estuary.

Echiura and Sipuncula : These members of the minor phyla are tubular, cylindrical and highly contractile forms and inhabit the intertidal to the abysal depths of seas and also tropical estuaries. Though they are of marine origin a few species adapt to the estuarine environment. Seven species of Echiura belonging to three genera inhabit Indian esturies, of which genus *Anelassorhynchus* commonly occurs. Two species of sipunculids belonging to *Siphonosoma* and *Phascolasoma* are also reported from Indian estuaries.

Polychaeta : Though these are mostly of marine nature, they invade the estuaries and lagoons and form a major constituent of the benthic fauna. Polychaetes inhabit mostly as crawling, burrowing and tube dwelling forms in the estuarine sediments as well as mangrove associated fauna. Polychaete fauna from various Indian estuaries and lagoons has been very well studied and 69 species from Hugli-Matla estuary (Mishra, 1995), 44 species from Vasista-Godavari estuary (Rao and Ramasharma, 1978), 33 species from Mahanadi estuary (Rao, C.A.N., 1998), 25 species from Pulicat lake (Sunder Raj and Sanjeev Raj, 1985), and 31 species from Chilka lake (Rao, C.A.N., 1995) are reported. About 124 species belonging to 95 genera of polychaetes are reported from Vellar estuary and near-shore water of Parengipettai, consisting of planktonic as well as benthic forms, of which some are purely marine. Among the estuarine polychaetes, members of the families belonging to Pilargidae, Nereidae, Nephthididae, Glyceridae, Eunicidae, Spionidae and Capitellidae are commonly occurring in estuaries.

Mollusca : Members of the group are the important constituent among benthos of the estuaries, lagoons and backwaters. These mostly lie buried in the estuarine sediments of sand/mud and some are seen attached to substratum, such as, rock, timber, mangrove stems and some are seen crawling. The molluscs of the estuaries along east coast of India are well studied. A total of 72 species of Gastropoda, 53 species of Bivalvia, 3 species of Cephalopoda and one species of Scaphopoda are reported from Hugli-Matla estuary and 149 species of molluscs from Mahanadi estuary. The most common forms found in estuaries of India are of genera *Littorina, Nerita, Assiminea, Cerithidea, Telescopium, Murex, Nassarius* and *Thais* among gastropods and *Anadara, Modiolus, Saccostrea, Crassostrea, Mactra, Solen, Tellina* and *Meretrix* among bivalves. Wood boring molluscs belonging to genera, *Martesia, Pholas, Bankia, Nausitora* and *Nototeredo* are reported from estuaries. Cephalopods which are generally marine are also sometimes encountered in estuarine water. Four species, belonging to the genera *Sepia, Sepiella, Loliolus* are reported from Indian estuaries.

Crustacea : This group forms the dominant constituent of the estuarine fauna, both qualitatively and quantitatively, since this group includes copepods, isopods, amphipods, mysids, stomatopods, cirripeds, prawns, shrimps, crabs and hermit crabs. Crustacea also assumes significance due to the commercial importance of prawns and crabs and their aquaculture in the estuarine waters and its environs.

(i) **Copepoda**: These microscopic crustanceans are very rich in diversity and form the bulk of estuarine zooplankton, contributing 48.5-91.5% of the zooplankton in Hugli estuary (Khan., 1995), 76% in Godavari estuary, represented by 40 species (Chandramohan, 1977) and 57-90% in Bahuda estuary consisting of 58 species (Mishra and Panigrahy, 1996). Goswami and Selvakumar (1971) reported 47 species of copepods from the estuaries of Goa. Harpacticoid copepods also from the second dominant group after nematodes among the meiobenthos of estuaries. About 27 species of Harpacticoid copepods belonging to 22 genera are reported from the Godavari estuary. (Murthy and Rao, 1987). Several species of copepods are also reported as external parasites attached to the gills and fins of estuarine fishes.

(ii) **Isopoda and Amphipoda**: Isopods occur as benthic, parasitic and few as planktonic forms in estuaries. About seven species of isopods are reported from Hugli estuary (Ghatak, 1995) among which *Sphaeroma* sp. and *Exosphaeroma* sp. are common parasitic forms. Amphipods, commonly called as "beach fleas", occur as benthic forms in the sediments of the estuaries and also associated with algae, sea grasses and mangroves. *Leucothoe spinicarpa* is reported among planktons of Bahuda estuary (Mishra and Panigrahy, 1999). Six

Fig. 4 : Exposed mudflat near the mouth of Krishna Estuary

species each of amphipods and isopods are reported from Chilka Lagoon, (Rao, G.D. 1987).

(iii) Cumacea and Tanaidacea : These are mostly benthic organisms of marine origin. However, they also invade estuaries. Tanaids are small, cylindrical, dorsoventrally compressed burrowing crustaceans in the estuarine sediments. One species of Tanaid is reported among meiobenthos of Chilka Lagoon (Rao, G.D., 1987). Cumaceans are small marine burrowing crustanceans and majority of them inhabit waters less than 200 m depth and some are found in intertidal regions of estuaries and brackishwater. Though they are essentially benthic inhabitants, a number of them are found in planktons also. About 6 species belonging to 5 genera were reported from Indian estuaries and backwaters, among which *Iphinoe* sp. and *Paradiastylis* sp. are commonly encountered.

(iv) Mysidacea : These are mostly shrimp-like epibenthic and pelagic forms of marine nature; however, they are commonly found in the estuarine zooplankton. About 12 species of mysids are reported from Godavari estuary, of which *Rhopalopthalmus kempii, Mesopodopsis orientalis* and *Gastrosaccus muticus* are commonly found (Chandramohan and Rao, 1972).

(v) Stomatpoda : These are primarily marine, but recorded from estuaries also. Only 12 species belonging to 7 genera are recorded from Hugli-Matla estuary (Ghosh, 1995). At times they are captured along with prawns.

(vi) Cirripedia : These are sedentary crustaceans of marine nature, with only a few species occurring in estuaries either as freeliving, commensals and filter feeders or as highly specialised parasities. They are mostly found attached to wooden logs, mangrove stems, underneath boats and dry shells. A total of 15 species of cirripedia have been reported from Hugli-Matla estuary at Sandheads while only five species are found in estuarine region.

(vii) Prawns and shrimps : Prawns and shrimps constitute the dominant group of animals among the nektonic forms next to fishes of the estuarine water. Majority of the prawns found in estuaries spend some time of their life cycle in estuaries and rest in marine waters for breeding (Penaeidae) and larvae and juveniles to the freshwater (Palaemonidae). The prawn fauna of the estuary includes fresh water, brackishwater and marine forms, of which many are migratory, staying in the estuary only for short period for the purpose of feeding and growth or breeding as the case may be. Therefore, the composition of prawn fauna varies from time to time depending on the season. The estuarine prawn fauna mainly belong to the families Penaeidae, Palaemonidae, Sergestidae, and Alphidae etc. At least 38 species of prawns and shrimps belonging to 15 genera are reported from Godavari estuary, while 21 species from Hugli estuary and 12 from Mahanadi estuary. The important prawn genera encounterd in the Indian estuaries are *Penaeus, Metapenaeus, Parapenaeopsis, Solenocera, Acetes, Palaemon, Macrobrachium* and shrimps *Alphaeus* and *Hipolysmata* etc.

(viii) Crabs and Hermit Crabs : Large crab populations are a common sight at the supratidal and the intertidal areas of the estuaries, mudflats and mangrove forests. The intertidal areas with sand content is dominated by crabs of family Ocypodidae (ghost crabs and fiddler crabs) while mudflats are inhabited by huge populations of portunid crabs. Mangrove forests also inhabit large populations of crabs either of crawling or burrowing nature. About 73 species of crabs of families Portunidae, Graspidae, Xanthidae and Ocypodidae from Gangetic delta, 29 species from Mahanadi estuary and 18 species from Godavari estuary are reported. The common crabs found in Indian estuaries belong to genera, *viz., Uca, Ocypoda, Scylla, Charybdis, Portunus, Sesarma, Varuna* and *Metaplax*. The mud crab *Scylla serrata* found in brackish waters and esturaies of east coast is of highly economic importance as it is the mostly preferred edible crab. Hermit crabs are very common in the intertidal areas of the estuaries living inside the dead gastropod shells. These are mostly terrestrial forms living near water line and 14 species are reported from Hugli-Matla estuary, of which the genera *Clibanarius*, *Diogenes* and *Spiropagurus* are common.

Brachiopoda : These members of the minor phyla commonly called "Lamp shells" are also of marine origin but found burried in the intertidal sediments of backwaters and estuaries which are exposed during low tides. These animals look like bivalves with two shells; however, the shells are dorsoventral with a long lophophore. One species belonging to genus *Lingula* is reported from Indian coasts near the river mouths.

Chaetognatha : These are popularly called as "arrow worms" and generally marine, but they form a component of the plankton community of the estuary. Though 24 species are known to occur in Indian seas only nine species belonging to three genera are reported from Indian estuaries, of which *Sagitta bedoti* and *Sagitta enflata* are commonly seen in estuaries.

Echinodermata : Though these forms are basically marine, some are found occasionally in the esturaine waters where salinity is higher. Some euryhaline forms also live in estuaries where higher salinity prevails. A total of 21 species of echinoderms are recorded from Indian estuaries (Sastry, 1995). Twenty species are reported from Hugli-Matla estuary (Sastry, 1995). Five species belonging to 5 genera, *i.e.*, *Molpadia* and *Synapta* (Holothuroidea), *Astropecton* (Asteroidea), *Temnopleurus* and *Echinodiscus* (Echinoidea) are reported from Godavari estuary.

Protochordata : Among protochordates, the burrowing and mud dwelling hemichordate *Saccoglossus* sp. was reported from mangrove mudflats of Sundarbans (Singh and Choudhury, 1984). Among urochordates (Tunicata) the planktonic forms, *viz.*, *Salpa* sp., *Oikopleura* sp., *Doliolata* sp., and *Fritillaria* sp. are reported from Indian estuaries, (Mishra and Panigrahy, 1999).

Fishes : A majority of estuarine fishes are marine migrants; their juveniles enter estuaries for food and shelter. Fishes of the families Mugilidae, Clupeidae. Engraulididae, Sciaenidae and Gerreidae are of this category. There are few migratory fishes found in estuaries, such as, anadromous fishes, *viz.*, *Tenualosa ilisha* and the catadromous fish, freshwater eels *Anguilla bengalensis* for maturation. There are few permanent residents of estuaries, such as, gobioids, syngnathids, ambassids, clupeoids, engraulids, pearl spots, etc. Very few freshwater forms, such as, *Channa punctata*, *Oreochoomis mossambica*, *Oryzias melastigma* are also encountered in the estuaries.

About 250 species of fishes are considered to be estuarine (Talwar, 1985). Ichthyofaunal studies pertaining to different estuaries indicate the presence of 156 species in Hugli-Matla estuary, 180 species in Mahanadi estuary (Venkateswarlu *et. al.*, 1998), and 314 species in Godavari estuary (Krishnan and Mishra, *in press*). Gobioids contribute maximum number of species to the estuarine fish fauna, followed by clupeoids. Some eels, *viz.*, *Moringua raitaborua*, *Bascanichthys deraniagalai*, *Pisodonophis boro*, *Lycodontis sathete*, and *Thrysoidea macrura* are commonly found in estuaries. From fishery point of view *Tenualosa ilisha*, *Setipinna* sp., *Thryssa* sp., *Mystus gulio.*, *Arius jella*, *Lates calcarifer*, *Chanos chanos*, *Sillago sihama*, *Eleutheronema tetradactylum*, *Polynemus paradasius*, *Polydactylus indicus*, *Terapon* sp., *Johnius* sp. and specially several species of mullets, *viz.*, *Mugil* sp., *Valamugil* sp., which occur through out the year in the estuaries are of highly economic importance.

Amphibia : Very few amphibians are reported to be inhabiting estuarine waters. One species of frog *Rana cyanophlyctis* from the mangroves of Vellar estuary has been reported (Pillai, 1985). However, 5 species of amphibians are reported from Hugli-Matla estuary (Chanda, 1995).

Reptilia : Several reptiles, such as, crocodiles, turtles and snakes are found in estuarine/brackish waters. The estuarine crocodile *Crocodylus porosus* is common in Gangetic delta as well as Mahanadi estuary. Among turtles, 7 species are reported from Gangetic delta, of which the Olive ridley *Lepidochelys olivacea* deserves special mention as these are found commonly on beaches close to river mouths during their egg laying season. Among lizards, the Water monitor *Varanus salvator* is reported from Chilka lake and Hugli-Matla estuary. Snakes of genera, *viz.*, *Xenochrophis*, *Cerberus*, *Enhydris* and *Fordonia* are reported from Hugli-Matla estuary (Sanyal *et* al., 1995). Along with the first two genera, the poisonous snakes belonging to the genera *Enhyndrina* and *Hydrophis* are reported from Mahanadi estuary (Venkateswarlu, 1998).

Aves : Large population of birds is found in the estuarine shallow waters, exposed mud flats near river mouth and mangroves during low tide, feeding on the benthic fauna. About 175 species of birds are observed in and around the environs of Chilka lagoon (Chattopadhyaya, 1995). A total of 46 species of birds were observed from the areas near Mahanadi estuary (Mahapatra, 1998).

Mammals : None of the mammals are exclusively confined to estuarine habitats. However, some of the marine and freshwater mammals enter estuaries. Eight species of mammals (Dolphins and Porpoises) are reported from estuaries of India (Agrawal, 1985). The Gangetic Dolphin, *Platinesta gangetica* is reported from river mouth of Gangetic delta. Of the four other species of dolphins *Orcaella brevirostris* and *Stanella malayana* are reported from Sundarbans, the Propoise *Neophocaena phocaenoides* from Hugli river near Calcutta and *Dugong dugon* from back waters of Gulf of Mannar and Gulf of Kutchch.

4. VALUE

Since the estuaries are known for their high productivity, these help in large scale production of fishery wealth, both shell-fish and fin-fish, thus sustaining the fisherman population around these areas and helping in making available protein rich food to the populations around. Estuaries are the feeding and nursery grounds for several species of coastal marine organisms and thus contributing in maintaining faunal diversity of coastal waters. Since estuarine areas are inhabitated by varied fauna along with the associated fauna of the mangroves in their environs these areas assume high significance in respect of biodiversity.

The large quantity of biomass production in some of the estuaries in the form of mangrove forests provide fodder, fuel wood along with other material useful for making fishing crafts and gears. Estuaries are also of great value, since these help in navigation to enter the seas easily for fishing and commerce.

The vast mangrove forests developed along many of the estuarine areas act as breakers

Fig. 5 : Common fish catch from Krishna Estuary

for coastal habitats to check wind speed during cyclones and high velocity land ward winds. These areas also act as buffer zones capable of receiving heavy river discharges during monsoons. These areas gained importance during recent times with the advent of brackish water aquaculture for fish, prawn and crabs in a big way. These areas not only provide the natural seed for aquaculture practices, but also provide requisite quality of culture medium easily.

Fig. 6 : Shooting nets in operation in Krishna Estuary mouth for collection of prawn seed

The estuarine areas are also of recreational significance to the neighbouring urban population, since they provide water front along with sea, thick greenaries of mangroves, thus promoting tourism.

5. THREATS

During the recent times, many of the estuaries have been subjected to ruthless rampage, extensive damage and even total destruction as a result of great pressure of population, industrialization at the adjacent areas along the river bank and urbanisation. Furthermore, man made changes in upstreams, *viz.*, construction of dams and barrages upsets the free flow of water thus effecting the ecological balance. Indiscriminate deforestation in catchment areas, removal of vegetation along river banks and urbanisation caused heavy siltation of estuaries. Erosion and sedimentation are thus constantly reshaping estuaries for better or worse. Dredging operation and reclamation of land in estuarine areas near the mouth also contribute significantly in the stability of the estuaries.

Aquaculture activities near estuaries taken up in recent times brought about multiple threats to this environment, *viz.*, conversion of mangrove areas to aquaculture ponds by cutting them, large scale prawn seed collection practices in the coastal areas and estuaries leading to destruction of larval forms and juveniles of different coastal organisams resulting in depletion of coastal faunal resources. It is estimated that the seed

Fig. 7 : Krishna Estuary : Prawn seeds in Thermocole container

collectors are destroying 181.4 million seed of economic and uneconomic varieties of brackish water in fish along with much higher number of other crustacean and invertebrate larvae after retaining only the seeds of tiger prawn in Sunderbans (Bhowmick *et al.*, 1992). The aquaculture activities around estuaries resulted in accumulation of organic and inorganic wastes to estuaries causing eutrophication.

6. CONSERVATION AND FUTURE DIRECTION

Anthropocentric activities around the estuarine environment resulted in the degradation of this ecosystem in recent times as is seen in other ecosystems. Increasing population, urbanisation and the industrialization has had its share in degrading this fragile ecosystem by large scale reclamation of land near estuaries, swamps, marshes and mangroves for various purposes, dredging activities in the estuaries for navigation, reducing the river discharges to a very less extent for various reasons, discharging untreated urban sewage and industrial effluents and finally the recent brackishwater aquaculture activities.

Perpetuating this pristine habitat for the postereity is not difficult if eco-awareness is practised by policy makers and the stake-holders in the following aspects.

- Banning the reclamation of estuarine areas for all purposes except ecofriendly aquaculture and strict adherence to coastal zone regulations.
- Discharge of urban sewage, industrial effluents and aquacultural wastes to be allowed after proper treatment.
- Stoppage of cutting mangrove forests for converting them into aquacultural ponds and taking afforestation of mangroves where they were already cleared.
- Maintaining optimum levels of river flows for the sustenance of estuaries.
- Creating awareness among fishermen to avoid over fishing of juveniles in estuaries and not do damage numerous larval and juveniles of coastal organisms while collecting prawn seed, thus protecting the coastal biodiversity.

SELECTED REFERENCES

Annonymous, 1985. State of the Art Report: Estuarine Biology. *Workshop on Estuarine Biology, Berhampur (Orissa)., Feb. 1985, Zool. Surv. India.*

Anonymous, 1987. Mangroves in India: Status Report. *Ministry of Environment & Forests; Govt. of India, 150* pp.

Anonymous, 1995. Fauna of Chilka Lake, *Wetland Ecosystem Series* **1**, *Zoological Survey of India,* 672 pp.

Anonymous, 1995. Hugli-Matla Estuary, West Bengal. *Estuarine Ecosystem Series,* part 2, *Zoological Survey of India,* 542 pp.

Anonymous, 1998. Fauna of Mahanadi Estuary. *Estuarine Ecosystem Series No.* B, *Zool. Surv. India,* 218 pp.

Anonymous (in press), Fauna of Godavari Estuary, (Andhra Pradesh) *Estuarine Ecosystem Series No.* **4.** *Zool. Surv. India*

Balakrishnan Nair, N. *(Ed.),* 1987. Proceedings of the National Seminar on Estuarine management. *State Committee on Science, Technology & Environment, Govt. of Kerala.*

Barnes, R.S.K. and Green, J. 1971. *The estuarine environment*. Applied Science publishers Ltd., London, 133 pp.

Day, J.H., *(Ed.)*, 1981. *Estuarine ecology with particular reference to Southern Africa*. A.A. Balkema, Rotterdam, 411 pp.

Donald S. Mclusky, 1981. *The estuarine ecosystem*, Blackie, Glasgow & London, 150 pp.

Kannupandi, T., 1997. Estuaries of India, State of the art Report. *Environmental information system Centre*, CAS in Marine Biology, Annamalai University, Parangipettai, 52 pp.

Natarajan R. (*Ed*.), 1975. *Recent researches in Estuarine Biology*. Hindustan Publishing Corporation, Delhi, 321 pp.

Umamaheswara Rao, M., 1987. Algae of Indian Estuaries. *J. mar. biol. Ass. India*, **29** *(1 & 2)* : 1-9

Venkanna, P., 1991. Present status of the estuarine Flora of the Godavari & Krishna, *J. Bombay nat. Hist. Soc.*, **88** : 47-54.

Mangroves

A. K. DAS

ENVIS–*Zool. Surv. India*
Ecosystems of India : 239-259, 2001

Mangroves

A. K. DAS

Zoological Survey of India
'M' Block, New Alipore, Kolkata 700 053

1. INTRODUCTION

Mangroves represent a characteristic littoral forest ecosystem, dominated by some specially adapted salt-tolerant plant community that grow at land-sea interphase and border sheltered sea-coasts and estuaries of tropical and subtropical regions of the world. The word 'mangro' was originally the common name for a particular plant species, *Rhizophora mangle* in Surinam. In the Spanish 'manglar' signifies the formation of 'mangles' or mangrove formation. In Portugal 'mangle' is used for plant community and 'mangau' for individual trees. In this context and to bring uniformity in usage Macnae (1968) suggested the term 'mangroves' for the plant species and 'mangal' for the mangrove forest community. The same is generally followed by the present day mangrove researchers.

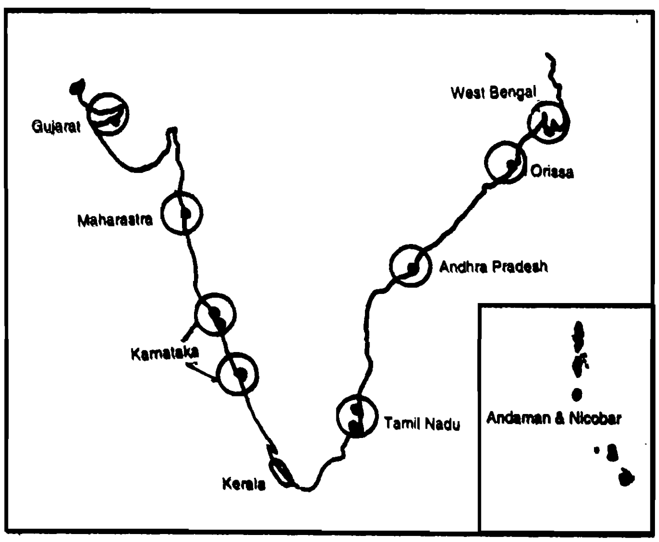


Fig. 1 : Distribution of Mangroves in India

The mangrove forests comprise a diverse composition of trees and shrubs which exhibit unique adaptation to an environment which is periodically innundated by saltwater from one side and fresh water from the other. These plants are well adapted to encounter higher salinity, oppressive heat and tidal extremes. They can grow well in water logged and anaerobic saline soils of coastal environment where no other group of terrestrial plants can survive.

Mangrove ecosystem is highly productive and exchanges matter and energy with adjacent terrestrial and marine ecosystems. This ecosystem constitutes an important reservoir and refuse of rich microbial, floral and faunal components and, feeding and breading grounds of large number of commercially important and ecologically significant animal species. The recent devastating cyclone in Orissa has clearly demonstrated the remarkable role of mangrove vegetation in shore line protection. The supercyclone almost ruined the coastal region of Orissa. But, it had only a marginal impact on the coastal sanctuary of Bhitarkanika which harbours luxuriant mangrove forests.

2. DESCRIPTION AND GEOGRAPHIC DISTRIBUTION

Mangroves grow in sheltered lowlying coasts, estuaries, mudflats, tidal creeks, backwater, marshes and lagoons of tropical and subtropical regions of the world. They fall under two main groups, *viz.*, Old World and New World mangroves. The Old World mangroves extend from East Africa (western limit) to Australia *via* Red Sea and Indian Ocean, then to Philippines and South Japan to the north, New Zealand to the south and finally to Samoa island as their eastern limits. On the other hand, New World mangroves are restricted to west coast of Africa, coasts of North and South America and, West Indies.

In India mangroves are distributed along the east and west coasts and, Andaman and Nicobar islands. Along the east coast mangroves are found in the Gangetic delta in Sundarbans in West Bengal, Mahanadi delta in Orissa, Coringa, Godavari and Krishna deltas in Andhra Pradesh and Cauvery delta and Thanjavur in Tamil Nadu. In West coast mangroves occur in Gulf of Kutchch, Gulf of Khambat, Saurastra and, Narmada and Tapti estuaries of Gujarat; Bombay, Ratnagiri, Malvan, Devgad and Vijaydurg in Maharastra; Mandovi-Zuari estuary in Goa, Coondapur, Hannovar and Malpe in Karnataka and Vembanad, Quilon, Trivandrum, Kozhikode and Kottayam in Kerala. In addition, luxuriant mangroves occur in Andaman and Nicobar islands in tidal creeks and sheltered bays.

Various estimates of state-wise and total mangrove forests of India are presented in Table 1.

Table 1. State-wise estimates of mangrove areas in India

States	Area (in ha)				Area in sq km	
	Mathuda 1957	Waheed Khan 1957	Sidhu 1963	Blasco 1977	Govt. of India* 1987	FSI data** 1998
East Coast						
West Bengal	423,804.1	423,990	418,888	200,000	4,200	2,123
Orissa	12,140.8	—	12,000	5,000	150	211
Andhra Pradesh	18,640.2	—	18,424	10,000	200	383
Tamil Nadu	671.8	—	2,640	1,500	150	21
West Coast						
Gujarat	—	38,074	52,616	20,000	260	991
Maharastra	—	24,864	62,208	20,000	330	124
Goa	—	—	—	—	200	5
Karnataka	—	—	—	—	60	3
Kerala	—	—	—	—	Sparse	Sparse
Islands						
Andaman & Nicobar	116,552.0	120,437	115,200	100,000	1,190	966
Total	571,808.9	607,365	681,976	356,500	6,740	4,827

* Government of India, Status Report

** FSI Remote Sensing Data

Mangroves along the east coast of India are luxuriant and considerably diverse due to the presence of nutrient rich deltas formed by the rivers Ganga, Mahanadi, Godavari, Krishna and Cauvery as well as perennial supply of freshwater along the deltaic coasts. On the other hand, in the west coast mangroves are not so luxuriant or diverse since there is no delta or alluvial soil deposits along that coast. Instead, there are funnel shaped estuaries of Narmada and Tapti rivers, backwater, creeks and inlets where mangroves occur. There is no typical estuary in Andaman and Nicobar islands since there is no perennial freshwater river in this archipelago except in Great Nicobar island. Even then, there are luxuriant mangrove formations in the creeks and sheltered days of these islands.

Fig. 2 : Mangroves showing stilt roots

Mangrove vegetation in India usually grows on soft or firm mud, sandy mud and occasionally on rocks or corals. However, mangroves grown on mud are taller and less crooked. Many environmental factors operate in this ecosystem, of which soil types, nature of substratum, salinity, drainage and water currents significantly influence the composition of plant community and the associated faunal assemblage.

3. BIOLOGICAL DIVERSITY

3.1 Habitat Diversity

Since mangrove ecosystem is located between land and sea it includes several distinct habitats in terrestrial, intertidal and aquatic environs, such as, mangrove dominated forests, litter laden forest floor, tidal flats (muddy, sandy, coralline or rocky), and contiguous water courses which may be rivers, tidal creeks and channels, backwater, neritic inlets and bays. Moreover, several distinct habitats in mangroves can also be demarcated following Berry (1963), *viz.*, tree canopy, higher part of mangroves, lower part of mangroves, forest floors in supra-littoral zone, mud flat/sandy-mud flat in intertidal zone, dead tree and stumps, temporary pools, bank of river channels, *etc* (Table 4). These macrohabitats host diversified micro-habitats, supporting rich and taxonomically diverse microbial, floral and faunal components making this ecosystem a reservoir of rich and unique gene pool.

3.2 Flora

3.2.1. Mangrove species : There is no generally accepted complete checklist of Indian mangrove species. This is mainly due to difference in opinion among the researchers in categorising mangroves into core or exclusive mangroves and nonexclusive mangroves or mangrove associates. By concept, exclusive mangroves are found only in mangrove habitats whereas non-exclusive mangroves or mangrove associates which may be important in the mangrove community are not restricted to mangrove habitats. In order to avoid this confusion the following list of Indian mangrove species (Table 2) includes those taxa which grow on the intertidal area in the mangrove forests only.

The list includes 69 species belonging to 43 genera under 25 families. From the table it is quite evident that 63 species are distributed in the East Coast, 36 in the West Coast and 48 in Andaman and Nicobar islands. As many as 12 species, namely, *Cryptocoryne cilliata* (Family Arecaceae), *Hoya parasitica*, *Sarcobolus carinatus*, *Tylophora tenuis* (Family Asclepiadaceae), *Ipomea tuba* (Family Convolvulaceae), *Dalbergia spinosa*, *Mucuna gigantea* (Family Fabaceae), *Aglaia cuculata* (Family Meliaceae), *Rhizophora annamalayana* (Family Rhizophoraceae), *Merope angulata* (Family Rutaceae), *Heritiera fomes* and *Heritiera kanikensis* (Family Sterculiaceae) are found to occur only along the East coast, 2 species, *viz.*, *Cerbera odollam* (Family Apocynaceae) and *Urochondra setulosa* (Family Poaceae) only along the West coast while 3 species, *Lumnitzera littorea* (Family Combretaceae), *Xylocarpus moluccensis* (Family Meliaceae) and *Acrostichum speciosum* (Family Pteridaceae) only in the Bay islands. In Indian mangroves members of the family Rhizophoraceae are dominant and represented by 11 species followed by Fabaceae with 9 species while all other families have only 1-5 species.

From Table 2 it is quite evident that out of 69 mangrove species only 26 species are common for both the Indian coasts and, Andaman and Nicobar islands, 7 species,

Fig. 3 : Exposed knee roots of mangroves in Andaman Island

common for East and West coasts, 18 species common for East coast and, Andaman and Nicobar islands and only one species, *Acanthus ebracteatus* common for West coast and Andaman and Nicobar islands. This reveals clearly that managrove flora of the Bay islands have closer affinity with those of the Indian East Coast

Considering the extent of innundation Indian mangroves are distinguished under two major types : (i) swampy mangroves which occur below the level of high tides and are innundated by sea water twice a day and (ii) tidal mangroves which are submerged by spring tides and exceptional tides during cyclone.

Several types of mangroves are also recognised considering their location, such as, deltaic, estuarine, backwater estuarine and, coastal and insular. Mangroves of the East coast are of deltaic type while those of the West coast fall under the remaining three types. For example, estuarine mangroves occur in the estuaries of Narmada and Tapti rivers; backwater estuarine mangroves are found along the coast of Saurastra and in the Gulf of Kutchch and, coastal and insular mangroves occur further into the Gulf, inlets and creeks of Pirutan island in Gujarat. The managroves of Andaman and Nicobar islands are also of insular type.

3.2.2. Phytoplankton : Species diversity and distribution of phytoplankton in the mangrove waters of Sundarbans (West Bengal) and Pichavaram (Tamil Nadu) are comparatively well studied. A total of 46 species belonging to Bacillariophyceae, Dianophyceae and Cyanophyceae have been reported from Sundarbans. From Pichavaram mangroves 82 species comprising of 67 species of diatoms, 12 species of dinoflagellates and 3 species of blue green algae have been found. In Sunderbans mangals *Coscinodiscus, Rhizosolenia, Chaetoceros, Biddulphia, Ceratium* and *Protoperidinium* are the predominant genera found almost throughout the year. In Pichavaram mangroves diatoms constitute 72% of the census followed by dinoflagellates with 15%. In Pichavaram 31 species are bloom formers with a predominance of *Rhizosolenia alata f. gracillima*, attaining a maximum bloom concentration $2881 \times 10^7 \mu m^2 l^{-1}$. In the mudflat region 51 species belonging to 23 genera were reported from Pichavaram. These are common during the summer but rare during the monsoon. In mangroves epiphytic diatoms are usually found attached to the submerged roots of woody mangroves, more particularly in *Rhizophora* spp.

Fig. 4 : *Acanthus ilicifolius* interspersed with *Nypa fruticans* in the creeks of South Andaman

3.2.3. Algae and Seagrasses : Only 3 species of seagrasses, *viz., Hatophila ovalis, H. beccari* and *Halodule pinifolva* and 22 species of sea weeds comprising of 11 species of green algae, 9 species of red algae and 2 species of brown algae have been reported from Pichavaram mangrove. Besides these, 20 species of blue green algae have also been reported.

Table 2. List of Mangrove species occurring along the East coast, Andaman & Nicobar Islands and West coast of India

Sl. No.	Family	Genus / Species	East coast	Andaman & Nicobar islands	West Coast
1	Acanthaceae	*Acanthus ebracteatus* Vahl.	-	+	+
2		*Acanthus ilicifolius* L.	+	+	+
3		*Acanthus volubilis* Wall	+	+	-
4	Apocynaccae	*Cerbera manghas* L.	+	+	+
5		*Cebera odollam* Gaertn.	-	-	+
6	Arecaceae	*Nypa fruticans* (Thumb.) Wurmb.	+	+	-
7		*Phoenix paludosa Roxb.*	+	+	-
8		*Cryptocoryne cilliata (Roxb.) Schott.*	+	-	-
9	Asclepiadaceae	*Finlaysonia obovata* Wall	+	+	-
10		*Hoya parasitica* (Roxb.) Wall	+	-	-
11		*Sarcolobus carinatus* Wall	+	-	-
12		*Sarcolobus globosus* Wall	+	+	-
13		*Tylophora tenuis* Bl.	+	-	-
14	Avicenniaceae	*Avicennia alba* Bl.	+	+	+
15		*Avicennia marina* (Forsk.) Vierh. var. *marina* Moldenke	+	+	+
16		*Avicennia marina* (Forsk.) Vierh. var. *acutissima* Stapf. & Mold.	+	-	+
17		*Avicennia officinalis* L.	+	+	+
18	Bignoniaceae	*Dolichandrone spathaceae* (L.f) K. Schum.	+	+	+
19	Combretaceae	*Lumnitzera littorea* (Jack.) Voigt	-	+	-
20		*Lumnitzera racemosa* Willd.	+	+	+
21	Convolvulaceae	*Ipomoea tuba* (Schl.) G. Don	+	-	-
22	Cyperaceae	*Fimbristylis ferruginea* (L.) Vahl	+	+	-
23		*Scirpus littoralis* Schard.	+	-	+
24	Euphorbiaceae	*Excoecaria agallocha* L.	+	+	+
25	Fabaceae	*Caesalpinia bonduc* (L.) Roxb.	+	+	+
26		*Caesalpinia crista* L.	+	+	+
27		*Cynometra iripa* Kostel	+	+	-
28		*Cynomethra ramiflora* Linn.	+	+	+
29		*Dalbergia spinosa* Roxb.	+	-	-
30		*Derris scandens* (Roxb.) Benth.	+	+	-
31		*Derris trifoliata Lour.*	+	+	+
32		*Intsia bijuga* (Colebr.) O. Kuntze	+	+	-
33		*Mucuna gigantea* (Willd.) DC.	+	-	-
34	Flagellariaceae	*Flagellaria indica* L.	+	-	+

Table 2. contd.

35	Meliaceae	*Aglaia cuculata* (Roxb.) Pelleg.	+	-	-
36		*Xylocarpus granatum* Koen.	+	+	-
37		*Xylocarpus mekongensis* (Prain) Pierre	+	+	-
38		*Xylocarpus moluccensis* (Lamk.) Roem.	-	+	-
39	Myrsinaceae	*Aegiceras corniculatum* (L.) Blanco	+	+	+
40	Plumbaginaceae	*Aegialitis rotundifolia* Roxb.	+	+	-
41	Poaceae	*Myriostachya wightiana* (Nees ex steud) Hook. f.	+	+	+
42		*Porteresia coarctata* (Roxb.) Tateoka	+	-	+
43		*Urochondra setulosa* (Trin) Hubh.	-	-	+
44	Pteridaceae	*Acrostichum aureum* L.	+	+	+
45		*Acrostichum speciosum* Willd.	-	+	-
46	Rhizophoraceae	*Bruguiera cylindrica* (L.) Bl.	+	+	+
47		*Bruguiera gymnorrhiza* (L.) Savigny	+	+	+
48		*Bruguiera parviflora* (Roxb.) Wt. and Arn. Ex Griff.	+	+	+
49		*Bruguiera sexangula* (Lour.) Poir.	+	-	+
50		*Ceriops decandra* (Griff.) Ding Hou	+	+	-
51		Ceriops tagal (Perr.) C.B. Rob.	+	+	+
52		*Kandelia candel* (L.) Druce	+	+	+
53		*Rhizophora annamalayana* Kathir.	+	-	-
54		Rhizophora apiculata Bl.	+	+	+
55		*Rhizophora mucronata* Poir.	+	+	+
56		*Rhizophora stylosa Griff.*	+	+	-
57	Rubiaceae	*Scyphiphora hydrophyllacea* Gaertn.f.	+	+	-
58	Rutaceae	*Merope angulata* (Willd.) Swingle	+	-	-
59	Salvadoraceae	*Salvadora persica* L.	+	-	+
60	Sonneratiaceae	*Sonneratia alba* J. Sm.	+	+	+
61		*Sonneratia apetala* Buch.-Ham.	+	-	+
62		*Sonneratia caseolaris* (L.) Engl.	+	+	+
63		*Sonneratia griffithii* Kurz	+	+	-
64	Sterculiaceae	*Heritiera fomes* Buch. -Ham.	+	-	-
65		*Heritiera kanikensis* Majmumdar & Banerjee	+	-	-
66		*Heritiera littoralis* Dryn.	+	+	+
67	Teliaceae	*Brownlowia tersa* (L.) Kostern.	+	+	-
68	Verbenanceae	*Clerodendrum inerme Gaertn.*	+	+	+
69		*Premna corymbosa* (Burm. f.) Rottl. & Willd.	+	+	-
		Total mangrove species	**63**	**48**	**36**

* List compiled by K. Kathiresan, CAS in Marine Biology, Annamalai University, Tamil Nadu in consultation with L. K. Banerjee, Botanical Survey of India, Calcutta.

3.3. Fauna

The animals that are associated with the mangroves span a wide range of invertebrates and vertebrates and include both aquatic and terrestrial fauna. The latter mostly comprises mammals, birds, reptiles, insects, spiders and mites while aquatic fauna consists of marine and estuarine zooplanktons, benthic communities and nektonic forms mostly fishes.

Species richness of the mangrove inhabiting fauna reported so far from mangrove areas of different states of India is presented in Table 3 under respective phyla and classes. The table clearly reveals that mangrove fauna in West Bengal, Andaman and Nicobars and, Tamil Nadu are comparatively well studied while those in the West coast are practically unexplored. In the East coast terrestrial components of mangroves in Andhra Pradesh are also unattended till date. In terms of animal species diversity, mangals of Sundarbans in West Bengal ranks first with the record of 1434 species representing 20 phyla. This is followed by the mangroves of the Bay islands and Tamil Nadu with 914 species and 801 species only under 9 phyla and 6 phyla respectively.

The animal communitives in the mangroves include both resident fauna and the visiting or transient fauna. The former category lives entirely on mangrove ecosystem and the latter exploits mangroves for food, refuse/shelter and transit and also as breeding ground and nursery bed but lives elsewhere during the remaining period of their life cycle. In fact, visiting fauna of mangroves are more diverse. The terrestrial fauna of this ecosystem are mostly visiting fauna which enters mangroves from the adjacent forested and nonforested areas. The majority of the visiting fauna are insects among invertebrates and birds, mammals and reptiles among vertebrates. The aquatic visiting fauna mainly belong to fishes and crustaceans besides some other groups like some molluscs and echinoderms. They invade mangroves from the adjacent coral reefs, rocky habitats, estuaries, creeks and bays.

Resident fauna of mangroves are mainly benthic fauna of intertidal habitats which are grouped under two broad categories, *viz.*, infauna and epifauna. Epifauna, *i.e.*, animals which move over the substratum constitute the bulk resident fauna. The commonest forms of these are gastropods, some sessile bivalves like oysters and *Modiolus* spp. and crustaceans represented by barnacles. On the other hand, infauna, *i.e.*, animals which burrow and penetrate the substratum predominantly comprise polychaetes, brachyuran crabs, wood-boring animals, mud burrowing bivalves and gobiid fishes. Some terrestrial faunal components are also reported as mangrove specialists. Birds like Black-

Fig. 5 : Mudflats–typical habitat for Fiddler crabs *Uca* spp.

Table 3. Species richness of mangrove inhabiting fauna in different states of India (WB:West Bengal; ORI : Orissa; ANDR : Andhra Pradesh; TN : Tamil Nadu; AN : Andaman & Nicobar; GUJ : Gujrat; MAHA : Maharastra; KAR : Karnataka; KER : Kerala)

Taxa	Number of species / subspecies									
	EAST COAST				A&N IS	WEST COAST				
	WB	ORI	ANDR	TN		GUJ	MAHA	GOA	KAR	KER
MACROFAUNA										
Phylum Porifera	1									
Phylum Cnidaria	33	3								
Class Hydrozoa	20									
Class Anthozoa	13	3								
Phylum Ctenophora	2									
Phylum Platyhelminthes	41									
Class Turbellaria	1									
Class Monogenea	21									
Class Trematoda	13									
Class Cestoda	6									
Phylum Nemertinea	2									
Phylum Rotifera	4			23						
Phylum Nematoda	68			40						
Phylum Acanthocephala	3									
Phylum Sipuncula	2				2					
Phylum Mollusca	142	54	43	53	100		33	12	11	17
Phylum Echiura	3									
Phylum Annelida	78	36	17	26	8		8			24
Class Polychaeta	69	36	17	26	8		8			24
Class Oligochaeta	6									
Class Hirudinea	3									
Phylum Arthropoda	476	55	45	202	417*	28	17	55	2	18
Class Crustacea	240	55	45	76	100*	28	17	55	2	18
Class Insecta	201			113	311*					
Class Arachnida	33			13	6					
Class Merostomata	2									
Class Myriapoda										

Table 3 contd.

Taxa	Number of species / subspecies									
	EAST COAST				A&N IS	WEST COAST				
	WB	ORI	ANDR	TN		GUJ	MAHA	GOA	KAR	KER
Phylum Bryozoa	3									
Phylum Entoprocta	1									
Phylum Brachiopoda	1									
Phylum Chaetognatha	4									
Phylum Echinodermata	20				7		3			
Phylum Hemichordata	1									
Phylum Chordata	455	304	121	417	324	212	33	12		11
Class Pisces	176	48	69	217	253	65	12	12		4
Class Amphibia	8	5	4	3	3					
Class Reptilia	58	46	12	7	7					
Class Aves	163	174	23	178	53	147	121			7
Class Mammalia	40	31	13	12	8					
MEIOFAUNA		11		40	53					
Phylum Gastrotricha					1					
Phylum Kinorhyncha					1					
Phylum Nematoda					29					
Phylum Annelida					6					
Phylum Arthropoda										
Class Crustacea					16					
MICROFAUNA	104	2								
Protozoa	104	2								
Total	1434	465	226	801	914	240	194	79	13	70

* include 200 species of insects and 21 species of crustacea not identified up to species level

(Source : Das, 1997; Das and Nandi, 1999; Dey Roy and Das, 2000, Ramaiya, 1998; Veenakumanri *et al.*, 1977; K. Kathiresan, personal comm.)

capped Kingfisher (*Halcyon pileata*),Brown-winged Kingfisher (*Halcyon amauroptera*) and Mangrove Whistler (*Pachycephala grisola*) and insects like *Polyura schreiber* (Lepidoptera: Nymphalidae) are such examples.

Resident fauna are found to exploit diversified microhabitats in the mangrove ecosystem. For example, gastropods which are predominantly found on tidal flats also inhabit dead stumps, mangrove roots and even upper part of the mangrove trees. The crabs which usually live in self constructed burrows occupy diversified niches, such as, crevices of mangrove logs, tree holes, understones and puddles, cracked pneumatophores, desserted burrows of marine borers, *etc.*

3.3.1. Terrestrial component : Of the terrestrial animals, birds generally display maximum species diversity among vertebrates and insects among invertebrates. Trunks, branches, foliages and shades of mangrove trees along the coasts, bays and creeks provide ideal sites for birds for feeding, roosting, transit and also nesting in this ecosystem. Majority of the birds use the ecosystem for roosting and transit. On the other hand insects occupy diversified microhabitats from soil and leaf litter on the ground to tree-canopy of the mangrove trees.

Maximum number of mammalian species (40) have been reported from Indian Sunarbans. Amongst these, 5 species of dolphins and porpoises are aquatic and the rest 35 species are terrestrial. The tiger, *Panthera tigris tigris* is the key stone species of the mangal. Interestingly, besides Sundarbans (including its Bangladesh counterpart) no other mangrove areas of the world habour tiger. In all other mangrove forests of India 8-13 species of mammals are known except in Orissa from where 31 mammalian species have been reported. As

Fig. 6 : Estuarine river bank with mangrove vegetation exposed during the low tide, showing benthic fauna

many as 58 species of reptiles are found to occur in Sundarbans, of which saltwater crododile, *Crocodilus porosus*, 3 species of Monitor lizard and 12 species of turtles and terrapines are aquatic while the remaining 40 species belong to snakes and lizards. In rest of the mangrove areas of India 7-12 species of reptiles are found to occur except in Orissa mangroves which harbour 46 reptilian species. Only 3-8 species of amphibians have so far been reported from Indian mangals, which includes only one species of tree frog, *Rhacophorus maculatus*, that too, from mangroves of West Bengal, Orissa and Tamil Nadu.

Insects of Andaman mangroves have been extensively surveyed. So far 311 species belonging to 10 orders, *viz*, Orthoptera, Dictyoptera, Isoptera, Hemiptera, Thysanoptera, Neuroptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera were reported (Das and Dev Roy, 1989; Veenakumari *et al*, 1997). Out of these, 43 species are hymenopterous parasitoids, 36 species are predators and the rest are herbivores. Das and Dev Roy (1989) listed 13 species of insect borers belonging to the orders Coleoptera and Lepidoptera. They also recorded 11 types of gall causing organisms belonging to insects and mites from Andaman mangroves. Of the herbivore insects of Andaman mangroves more than 50% species are 'chewers', while leaf miners, gall makers and saprophages/scavengers appear to be poorly represented.

3.3.2. Aquatic components : Amongst aquatic animals of mangroves, maximum species diversity is represented by fishes followed by crustacea and molluscs. Fishes are mostly transient fauna which invade mangrove habitats from adjacent water spread mainly for feeding and breeding. Molluscs constitute the resident fauna of mangroves as mentioned earlier. Amongst crustaceans a bulk belong to plankton community and the remaining are mostly benthos which conspicuously represented by crabs. Besides these, invertebrates belonging to Sipuncula, Echiura, Annelida (mainly Polychaeta) and Echinodermata are also found to inhabit intertidal area of mangrove habitat. However, from Sundarbans invertebrates belonging to several other phyla *viz.* Porifera, Cnidaria, Ctenophora, Platyhelminthes, Nemertinea, Rotifera, Acanthocephala, Bryozoa, Ectoprocta, Brachiopoda and Chaetognatha and, one species of mud dwelling hemichordate, *Saccoglossus* sp. are also reported (Table 3). Amongst these, Platyhelminthes are the parasites of mangrove fauna and the others are mainly marine elements.

Meiofauna mainly comprising of Nematoda, Gastrotricha, Kinorhyncha, Annelida and Crustacea have been explored from the intertidal areas of mangroves of Andaman and Nicobar islands, Tamil Nadu and Orissa (Table 3). A total of 104 species and 2 species of microfauna belonging protozoa are reported from Sundarbans and Bhitarkanika (Orissa) respectively.

3.4 Microbial community

Microbial community which includes bacteria and fungi plays a significant ecological role in mangroves. These microorganisms decompose organic matter and recycle nutrients, resulting fertility of mangrove water.

3.4.1. Bacterial community : Nitrogen fixing bacteria *Azotobacter* spp. are common in mangrove sediments. Their counts are found to be more in mangrove habitats than in marine backwaters and estuarine systems. In Sundarbans nitrogan fixing bacterial counts are found high in inundated swamps and low in occasionally inundated ridges and degraded areas of mangroves. Nitrogen fixing *Rhizobium* strains have been isolated from the root nodules of *Derris scandens* and *Sesbania* sp. growing along the mangrove swamps of Sundarbans. These are well adapted to saline stress. Several nitrogen fixing cyanobacteria belonging to *Aphanocapsa* spp., *Nodularia* spp. and *Trichodesmium* spp. have been isolated from Pichavaram mangroves. Cyanobacterial species, more particularly *Phormidium* spp. are also salt-tolerant.

Photosynthetic bacteria of mangrove sediments are of two major groups : purple sulphur bacteira (family Chromatiaceae) and purple nonsulphur bacteria (family Rhodospirillaceae). The sulphate reducing bacteria are isolated from the mangrove swamps of Goa. In addition to these, iron oxidising and iron reducing bacteria also occur in mangrove habitats. Besides these, epiphytic bacteria are also found attached to the surface of green algae and, roots and stems of other plants.

Human pathogenic bacteria, such as, total coliforms, faecal coliforms, faceal *Streptococci, Salmonellae* and *Vibrios* are found in mangrove waters.

3.4.2 Fungal Community : The common mycoflora of Sundarbans mangals belong to the genera *Aspergillus, Collectotrichium, Fusarium* and *Helminthosporium.* A total of 163 species of fungi have been listed from Sundarbans (Chaudhury and Choudhury, 1994). From Pinchavaram some 23 species of fungi have been reported, of which *Aspergillus* spp. and *Penicillium* spp. are predominant (Kathiresan, 2000). Majority belong to Deuteromycetes and some are Actinomycetes. Fungi were isolated from decaying leaves, stems, roofs and pneumatophores of mangroves. They are also associated with leaf litters and mangrove sediments. Lower group of aquatic fungi *(e.g., Thraustochytrium* sp.) occurs in decaying mangrove leaves as reported from Goa. Higher groups of fungi from mangrove woods in Maharastra have been reported. They belong to Ascomycetes, Basidiomycetes and Deuteromycetes with predominance of *Massarina velataspora*. Most of the fungi collected from Maharastra coasts were decomposers of mangrove plants.

4. SPECIAL FEATURES

Mangroves are the ideal examples of ecotone, bordering two very distinct ecosystems, *viz.,* terrestrial and aquatic (marine) as mentioned earlier. Mangrove areas are also treated as wetlands and are usually estuarine especially when they occur under tidal ebb and flow along the tidal river banks,

Table 4. Principle habitats and 'key' species in mangroves of Andaman and Nicobar islands

Sl. No.	Principal habitat	'Key' faunal species/groups
1.	Tree canopy	Bats, birds, insects, spiders and mites
2.	Higher part of mangroves	*Littorina scabra,* Lampyrid beetles
3.	Lower part and roots of mangroves	*Littorina scabra, Onchidium* spp., *Sesarma* spp.
4.	Mud flat	*Terebralia palustris, Cerithidea alata,* Fidder crabs *(Uca* spp.)
4a.	Sandy-mud flat	*Nassarius* spp, *Ocepode ceratophthalma, Dotilla myctiroides,* Fiddler crabs
4b	Coralline/rocky flat	*Cerethium corallinum, Planaxis sulcatus, Grapsus strigosus, Thalamita* sp.
5.	Coast mud of mangrove edge	Polychaetes, bivalves *(Batissa* spp., *Geloina* spp.)
6.	Sea-ward mangroves	Sessile fauna *(Modiolus striatulus, Isognomon ephippium,* oysters, barnacles and Serpulid worms)
7.	Dead trees and stumps	Marine wood borers, Sessile fauna (barnacles)
8.	Edge of streams and rivulets	*Scylla serrata, Periophthalmus* spp., *Boleophthalmus boddarti* and *Cerberus rhynchops*
9.	Creeks and bays	Shrimps, prawns and fishes

mud flats, backwater creeks, shallow lagoons and depressed basins. Mangroves are not simply a forest type as categorised by some workers like Champion and Seth (1968). Rather they constitute a 'guild' with special mode of life and striking adaptive features to encounter saline and water-logged condition. Some such adaptive features are : (i) breathing roots and pneumatophores which are negatively geotropic, (ii) supporting roots like stilt, prop and knee-roots, (iii) succulent leaves with water storage tissue and (iv) viviparous germination. They also exhibit physiological adaptations for salt regulation by developing salt exclusion, salt excretion and salt accumulation mechanisms with the help of their roots and leaves. Further they provide diversified microhabitats for terrestrial, intertidal and marine biota.

4.1 Distribution pattern

In mangroves distribution of animals can not be dealt with by considering simply the tidal expanse and tidal amplitude as is usually done in case of shore animals. Because mangrove ecosystem comprises two main series of zones as mentioned by Berry (1963): (i) horizontally from the landward mangroves towards the sea and (ii) vertically from the tree canopy of mangroves down to the soil. Horizontal zones like the sea-shores include supra-littoral, littoral and sub-littoral areas. Vertical zones which may little bit vary in different mangrove areas embrace, in general, tree canopy, higher part of mangroves, lower part including roots of mangroves, forest floor of supra-littoral zone, tidal flat, dead trees and stumps, edge of streams and rivulets, *etc.* In each of these habitats some 'key' faunal species/faunal groups are distributed as presented in Table 4 which include principal habitats and 'key' species of Andaman mangroves (Das, 1996).

Distribution pattern of brachyuran crabs in relation to tidal amplitude has been studied in some mangrove areas in India. In Andaman mangroves it has been observed that *Macrophthalmus convexus* occurs in the lower littoral zone and is found to be distributed up to Mean Low Water Spring (MLWS) well below mangrove tree zone. *Metaplax crenulata* is distributed above this zone sometimes with *Uca vocans.* Fiddler crabs (*Uca* spp.) are dominant and abundant from Mean Tide Level (MTL) and upwards. Grapsid crabs more particularly *Sesarma* spp. inhabit land-ward mangrove forests. The gecarcinid crab, *Cardisoma carnifex* construct mound or castle in the mangroves even on supra-littoral forest floor. The fiddler crabs in the mangroves display more district distribution pattern in both shaded and unshaded areas of this ecosystem (Dev Roy and Das, 2000).

Fig. 7 : Mangroves in coastal region of Kutchch, Gujarat (*Courtsey :* P. L. Kankane, ZSI)

4.2 Faunal zonations

Various zonations in mangroves have been demarcated by several workers in respect of flora and fauna of this ecosystem. For example, Macnae (1968) and Chapman (1976) demarcated several zonations in the mangroves of Indo-Malaysia, Australia and New Zealand and termed them after the dominant mangrove trees, *viz.*, *Rhizophora*-zone, *Bruguiera*-zone, *Ceriops* thicket, land-ward *Avicennia* fringe and sea-ward *Sonneratia alba* and *Avicennia marina* zone. Earlier to this, Verway (1930) proposed mangroves zonations in Indonesia based on dominant crab species that inhabit the area. He identified five zones, *viz.*, *Sesarma taeniolata*-zone, *Uca consobrinus*-zone, *Uca signatus*-zone, *Metaplax elegans* zone and *Scylla serrata* zone. These mangrove zonations cever mangrove areas horizontally.

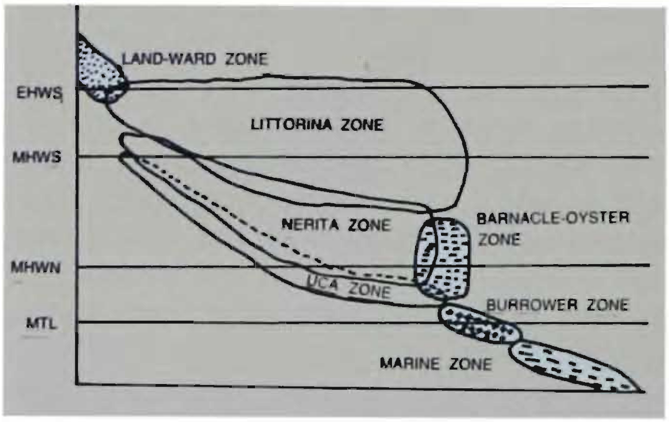


Fig. 8 : Diagrammatic representation of faunal zonations in Andaman mangroves

In order to explain vertical distribution of mangrove associated fauna in Singapore Berry (1963) identified five zones, such as, High Tree zone, Lower Tree zone, Sea-ward fringe and Coastal bank. He also proposed five faunal zonations in mangroves, following shore-

Fig. 9 : Mangroves in South Andaman

Table 5. Faunal zonations in the mangroves of Andaman islands

Sl No.	Name of the zone	Limit	Key faunal components
1.	Landward zone	Landward mangrove forests, at times extending below Extreme High Water Spring (EHWS)	Terrestrial fauna like bats, birds, insects, etc.
2.	*Littorina*-zone	From EHWS to little below Mean High Water Spring (MHWS)	Gastropode : *Littorina scabra, Cerethidia quadrata;* crab: *Cardisoma carnifex;* Hermit crab: *Coenobita cavipes.*
3.	*Nerita*-zone	From the lower limit of the above zone (Fig 1) to little below Mean High Water Neap (MHWN)	Gastropods: *Nerita semirugosa, N. articulata, N. planospira.*
4.	Barnacle-oyster zone	Seaward fringe, vertically between well above MHWS and well below MHWN (Fig 1) and horizontally from near the lowest limit of *Nerita*-zone	Mainly sessile fauna, *viz.,* barnacles *(Balanus* sp.) bivalves *(Crassostrea sp., Saccostrea cucullata, Isognomon epippium, Modiolus striatulus, etc.*
5.	Uca-zone	Vertically from near the lowest limit of *Nerita*-zone (extending from MHWS) to about middle of MHWN and horizontally touching Barnacle-oyster zone and Burrower zone	Fiddler crabs: *Uca dussumieri, U. lactea, U. tetragonon, U. vocans*
6.	Burrower zone	Vertically extending from about middle of MHWN to little below Mid Tide Level MTL) and horizontally from the lowest limit of *Uca*-zone	Polychaetes and mud burrowing bivalves (*e.g., Geloina* spp., *Batissa* spp.),
7.	Marine zone	Sub-littoral areas and adjacent water courses of mangroves	Migrating prawns, shrimps and fishes.

animal zonation pattern of Stephenson and Stephenson (1949). The faunal zonations proposed by Berry are: (i) *Littorina*-zone, (ii) *Nerita* zone, (iii) Bivalve-zone, (iv) *Uca*-zone and Burrower-zone. These zonations of Berry have been mostly followed subject to marginal modification.

So far, faunal zonations of Indian mangroves have been studied only in Goa (Dwivedi et al, 1974) and Andaman islands (Das and Dev Roy, 1989 and Das, 1996). Dwivedi *et al.* (*op. cit.)* recognised five zonations in the mangroves of Goa, such as, *Littorina*-zone, *Nerita*-zones Barnacle-Oyster-zone, *Uca*-zone and Polychaete-zone. Das (1996) has demarcated 7 zonations in Andaman mangroves as presented in Table 5. The diagrammetic representation of these zonations (Fig. 9) reveals that these zonations are not exclusive. Rather, they touch and invade one another.

5. VALUE

Mangrove ecosystem provides many "functions", "services" and "goods" to mankind in general and coastal populations in particular. The ecosystem function refers to its biological or system properties or process of ecosystems. These functions generate "goods" (such as, food) and "services" (such as, natural defence against storms and tidal waves). Such goods and services have an economic value, some of which can be traded using some market value while many others of equal or more value

Table 6. Goods and ecological services of mangrove ecosystem
(after Costanza *et al.*, 1997 and Moberg and Folke, 1999)

Sl No.	Ecosystem functions of mangroves	Corresponding goods and services
1.	Habitat for resident and transient population	Refusia (*exs.*, nursery and habitats of rich floral, faunal and microbial taxa)
2.	Portion of gross primary production extractable as food	Food production (*exs.*, sea-weeds, fin fish, shell fish and other sea-food products)
3.	Portion of gross primary production extractable as raw material	Raw materials (*exs.*, poles, charcoal, wood chips, domestic fuel wood, wood for house construction, material for medicine and curio)
4.	Tropic-dynamic regulations of populations	Biological control (*exs.*, feeding places within and between ecosystems)
5.	Capacity, damping and integrity of ecosystem in response to environmental fluctuations	Disturbance regulation (*exs.*, shore line protection, sediment retention and buffer to storm)
6.	Recovery of mobile nutrients and removal or breaking down excess or xenic nutrients and compounds	Waste treatment (waste assimilation and Nitrogen fixation)
7.	Providing opportunities for recreational activities	Recreation (*exs.*, tourism, recreation, viewing and studying wildlife)
8.	Providing opportunities for non-commercial use	Social and cultural (*exs.*, aesthetic value, artistic inspiration and support of cultural and religious value)

Fig. 10 : Mangroves with pneumatophores

can not be evaluated straight forward through market mechanism (Table 6).

It has now been well established that mengrove ecosystem is a vital resource in terms of wood and wood products, fishery, nursery bed and feeding and breeding ground of many commercially important animals like fin fishes and shell fishes. Mangroves are also ecologically significant for their role in shore line protection, as buffer to storm (which is well evidenced during the recent devastating cyclone in Orissa as mentioned earlier), for supplying nutrient flows to pelagic food webs and as important reservoirs of rich biodiversity.

Following Costanza *et al.* (1997) and Moberg and Folke (1999) ecosystem functions of mangroves and corresponding goods and services are presented in Table 6.

6. THREATS

Mangrove areas in India have been reduced to more than 50% during the last forty years (Table 1), revealing clearly that mangrove ecosystem is under considerable threat in this country. Threats to mangroves may be natural or human induced. Natural threats generally include cyclone, soil erosion and soil sedimentation due to natural cause. Anthropogenic threats mainly include tree felling primarily for fuel and timber, conversion of mangrove areas for agriculture and aquaculture, human settlement, cultivation, fragmentation, cattle grazing, introduction of exotic plant species, over exploitation of mangrove resources, harvesting for various purposes and trades. Moreover, developmental activities like development of port and harbour, erection of dykes and embankment, mining, oil and industrial effluent discharge as well as discharges of domestic sewage, agricultural pesticides and insectisides are also the considerable threats to this ecosystem affecting both habitat and biotic components.

Every mangrove area in India may have some specific and unique threats. For example, in Sundarbans unregulated use of shooting nets of small mesh-size for the collection of tigher prawn (*Penaeus monodon*) seeds for trade results in tremendous loss of faunal diversity. It has been estimated that for the collection of a single seed of tiger prawn 208 juveniles on average mostly belonging to fishes, molluscs, crabs and other prawns are destroyed. The construction of Farraka Barrage in the upper reaches and erection of dykes and embankments in the lower reaches of the Hugli estuary has greatly altered the pattern of freshwater flow and thus affected the salinity, siltation pattern and natural equilibrium of the ecosystem. In the coastal and inland region of Gujarat excessive grazing of camels, cutting of wood for fuel and timber, construction of dam across the rivers and oil spillage from oil tankers and ships cause considerable threat to mangroves of this state.

7. CONSERVATION

Government of India promulgated time to time a number of acts like, the Wildlife Protection Act, 1972, the Forest Conservation Act, 1980 and the Environment Protection Act, 1986 with their various amendments. These acts provide substantial legal and policy framework for the protection and conservation of forests including the mangroves. A number of protected areas have been declared in mangrove areas for the conservation of their biotic resources. For example Sundarbans (West Bengal), the largest mangrove areas in India is protected as a Biosphere Reserve which in turn hosts one National Park, one Tiger Reserve and three wildlife Sanctuaries in Sajnekhali, Haliday island and Lothian island. It has also been declared as World Heritage Site for its conservation. Mangroves of Andaman and Nicobar islands, the second largest mangrove areas of India are also mostly brought under the network of Protected areas for conservation. The Great Nicobar Biosphere Reserve with two National Parks hosts luxuriant mangrove formation of Great Nicobar island.

Under the Environment Protection Act, 1986 mangrove areas have been declared as ecologically sensitive areas, prohibiting developmental activities within mangroves and waste disposal of industries through mangrove areas. Ministry of Environment and Forests, Government of India has set up a National Committee of Mangroves and Coral Reefs headed by the Secretary of the concerned Ministry. The Committee comprises of experts and representatives of concerned departments. Steering Committees at State Level headed by the Chief Secretary of the respective state have also been set up.

The Action plans initially covered the following basic components: (i) survey and demarcation of mangrove areas to be conserved; (ii) mapping of the areas, (iii) study of biotic status, aquaculture, pollution, *etc.*; (iv) remedial measures to be adopted including regeneration and afforestation; (v) promotion of environmental awareness through publication of literature, films, organisation of environmental camps, *etc.*, for the mangrove dependant human population.

So far, 30 mangrove areas have been demarcated and Action Plans of many of them have also been prepared for their conservation. But, level of implementation involving the local communities is not satisfactory in majority of mangrove areas. Moreover, information regarding extent of forest cover and status of forests derived from satellite data remains hazy since less than 25 ha could not be mapped and mixed-up mangroves with adjoining forest areas could not be resolved in several places by satellite application. Over exploitation of mangrove resources and conversion of mangrove areas for agriculture, aquaculture and human settlement are being continued mainly due to human population pressure and poor socio-economic development of mangrove dependant people. Although efforts are being made for natural regeneration and afforestation of mangrove plants in many mangrove areas, monitoring activities ensuring their long term viability are very much neglected. In view of above, these weak areas are to be made strengthened through proper Action Plan for the proper conservation and management of Indian mangroves.

8. FUTURE DIRECTION

From the fore-going discussion it is evident that increasing peripheral human population in mangrove areas coupled with their poor socio-economic condition, lack of environmental awareness and inadequate conservation measures are the important limiting factors for management and sustainable use of mangrove resources. As pointed out earlier considerable measures are being taken up for conservation of this fragile but genetically unique ecosystem. Now, gaps and weak areas of earlier Action Plans are to be recognised and remedial measures through future Action plans are to be adopted. It is therefore suggested:

- To prepare an updated inventory of biotic resources of each mangrove area.
- To carry out community base survey of the user groups and the local people to assess extent of their dependance (pressure) on the ecosystem and resultant threat to it.
- To identity specific and unique threats (if any) of each mangrove area and remidial meausres.
- To improve infrastructural facilities and surveillance safe-guards involving local communities in the form of participatory forest management.
- To prepare proper environmental awareness programmes for the local people and implement the same regularly.
- To prepare an integrated data base for formulating conservation and management plan of the region.

9. SELECTED REFERENCES

Anon., 1997. Mangroves of India, State of the art report. *ENVIS Centre, CAS in Marine Biology, Annamalai University,* Parangipettai, Tamil Nadu : 61 pp.

Berry, A. J. 1963. Faunal zonation in mangrove swamps. *Bull. Nat. Mus. Singapore,* **32 : 90-98.**

Chada, S. K. and Kar, C. S. 1999. *Bhitarkanika: Myth and Reality.* Nataraj Publishers, Dehra Dun : 1-388.

Champion, H. G. and Seth, S. R. 1968. *A revised Survey of forest types of India.* i-xx vii+1-404. Manager of Publ. Govt. of India, New Delhi.

Chapman, U. J. 1976. *Mangrove vegetation :* i-viii+1-447. Ed J. Cramer.

Chaudhury, A. B. and Choudhury, A. 1994. *Mangroves of the Sundarbans volume one: India,* IUCN, Bangkok, Thailand : 1-247.

Costanza, R., d' Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Neem, S., O'Nill, R.V., Paruelo, J., Raskin, R. G. and Sutton, P. 1997. The value of the world's ecosystem services and natural capital. *Nature,* **387** : 253-260.

Das. A. K. 1996. Faunal diversity, distribution pattern and zonations in the mangrove ecosystem of Andaman and Nicobar islands. *Proc. zool. Soc., Calcutta,* **49** (2):57-65.

Das, A. K. 1997. Mangrove associated fauna and their sustainable use with special reference to the Sundarbans and Andaman mangals. *Proc. zool. Soc., Calcutta,* **50** (1) : 54-57.

Das, A. K. and Dev Roy, M. K. 1989. A general account of the mangrove fauna of Andaman and Nicobar islands. *Fauna of Conservation Areas :* **4**, *zool. Surv. India*: 1-173.

Das, A. K. and Nandi, N. C. 1999. Fauna of the Indian Sundarbans mangal and their role in the ecosystem. In : *Proc. Sir Willium Roxburgh Memorial Seminar on Sundarbans Mangal,* eds. D. N. Guha Bakshi, P. Sanyal and K. R. Naskar. Naya Prakash, Calcutta : 417-427.

Das, A. K. and Nandi, N. C. 1999. Fauna of Sundarban Biosphere Reserve. *ENVIS Newsletter, Zool. Surv. India,* **5** : 4-9.

Dev Roy, M. K. and Das, A. K. 2000. Taxonomy, ecobiology and distribution pattern of the brachyuran crabs of mangrove ecosystem in Andaman islands. *Occ. Paper No.* **185**, *Zool Surv. India :* 1-211.

Dwivedi, S. N., Parulekar, A. H., Goswami, S. C. and Untawale, A. G. 1974. Ecology of the mangrove swamps of the Mandovi estuary, Goa, India. *Symp. on Biology and Management of Mangroves.* East West Centre, Honolulu, Hawai : 115-125.

Kathiresan, K. 2000. A review of studies on Pichavaram mangrove, Southeast Asia. *Hydrobiologia,* **430** : 185-205.

Macnae, W. 1968. A general account of the fauna and flora of mangrove swamps and forests in the Indo West Pacific region. In: *Adv. mar. Biol.,* **6** : 73-270. Eds. F. S. Russel and M. Younge.

Mandal, A. K. and Nandi, N. C. Fauna of Sundarban mangrove ecosystem, West Bengal, India, *Fauna of Conservation Area :* **3**, *Zool. Surv. India,* Calcutta : 1-116.

Moberg, E. and Folke, C, 1999. Ecological goods and services of Coral reef ecosystems *Ecological Economics,* **29** : 215-233.

Pandav, B. 1996. Birds of Bhitarkanika mangroves, eastern India. *Forktail,* **12** : 9-20.

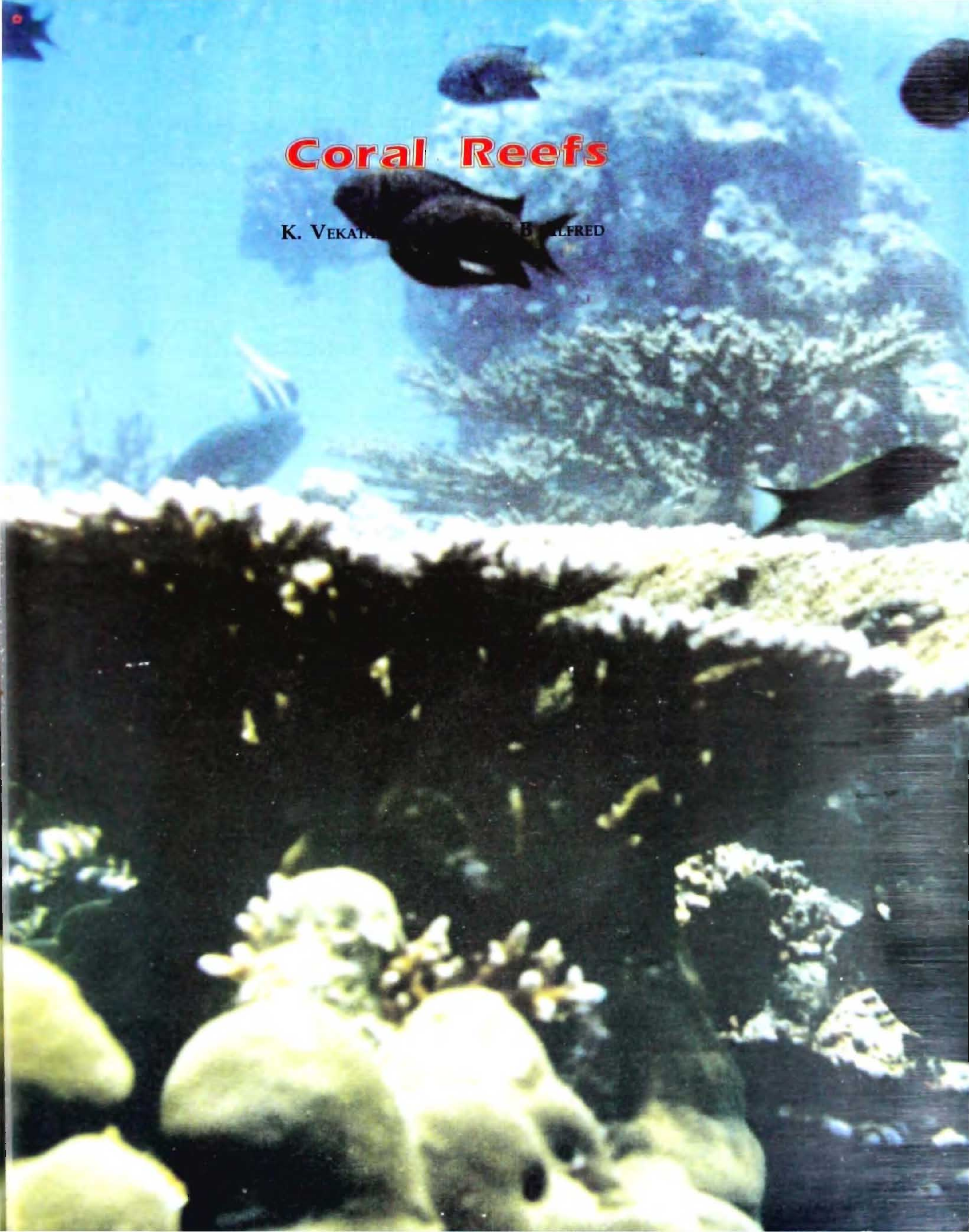
Ramaiyan, V. 1998. Finfishes. In : *GIS-based Information System for Critical Habitats in India, Manual on methodology for biological parameter.* Eds. D.O.D. Chennai.

Veenakumari, K., Mohanraj, P. and Bandyopadhyay, A. K. 1997. Insect herbivores and their natural enemies in the mangale of the Andaman and Nicobar islands. *Jour. nat. Hist.,* **31** : 1105-1126.

Verway, J. 1930. Einiges uber die Biologie Ost-Indischer Mangrove-Krabben. *Treubia,* **12** : 169-261.

Coral Reefs

K. VEKATA ... B ... ILFRED



ENVIS–*Zool. Surv. India*
Ecosystems of India : 261-290, 2001.

Coral Reefs

K. VEKATARAMAN AND J.R.B ALFRED*

Marine Biological Station
Zoological Survey of India, Chennai 600 028

1. INTRODUCTION

Coral reefs form the most dynamic ecosystem providing shelter and nourishment to thousands of marine flora and fauna. They are the protectors of the coastlines of the maritime states. A few genera of corals are supposed to be older than prairies. This unique ecosystem is most productive because of its symbiotic association with algae called zooxanthellae. Though they are the builders of the most massive structures ever created by living beings in the world, they are very fragile and vulnerable to natural disturbances and human activities. Maritime states and the coastal populations mostly depend upon the coral reef ecosystem for their day to day life.

Fig. 1 : Distribution of Coral Reefs in India

Coral reefs are tropical, shallow water ecosystems, largely restricted to the area between the latitudes 30° N and 30° S; the exact arial extent of coral reefs in the world is unknown and extremely difficult to estimate. However, Smith (1978) has produced a figure of 600,000 sq km for reefs to a depth 30 m. About 60% of the world's reefs occur within the area covered by the Indian Ocean region estimated as 73,600 000 sq km, according to IUCN.UNEP (1985) about half of which are in the Indian Ocean, Red Sea and Gulf and half in the "Asiatic Mediterranean" an area bounded by Indonesia to the west, northern Australia to the South, the Philippines to the east and mainland Asia to the north (Smith, 1978).

In India, all the three major reef types (atoll, fringing and barrier) occur, and the region includes some of the most diverse, extensive and least disturbed reef areas of the Indian Ocean, many of which are scientifically least known (Fig. 1). The mainland coast of India has two widely separated areas containing reefs: the Gulf of Kutchch in the northwest which has some of the most northerly reefs in the world and Palk Bay and, Gulf of Mannar in the southeast.

* Zoological Survey of India, M-Block, New Alipore, Kolkata-700 053

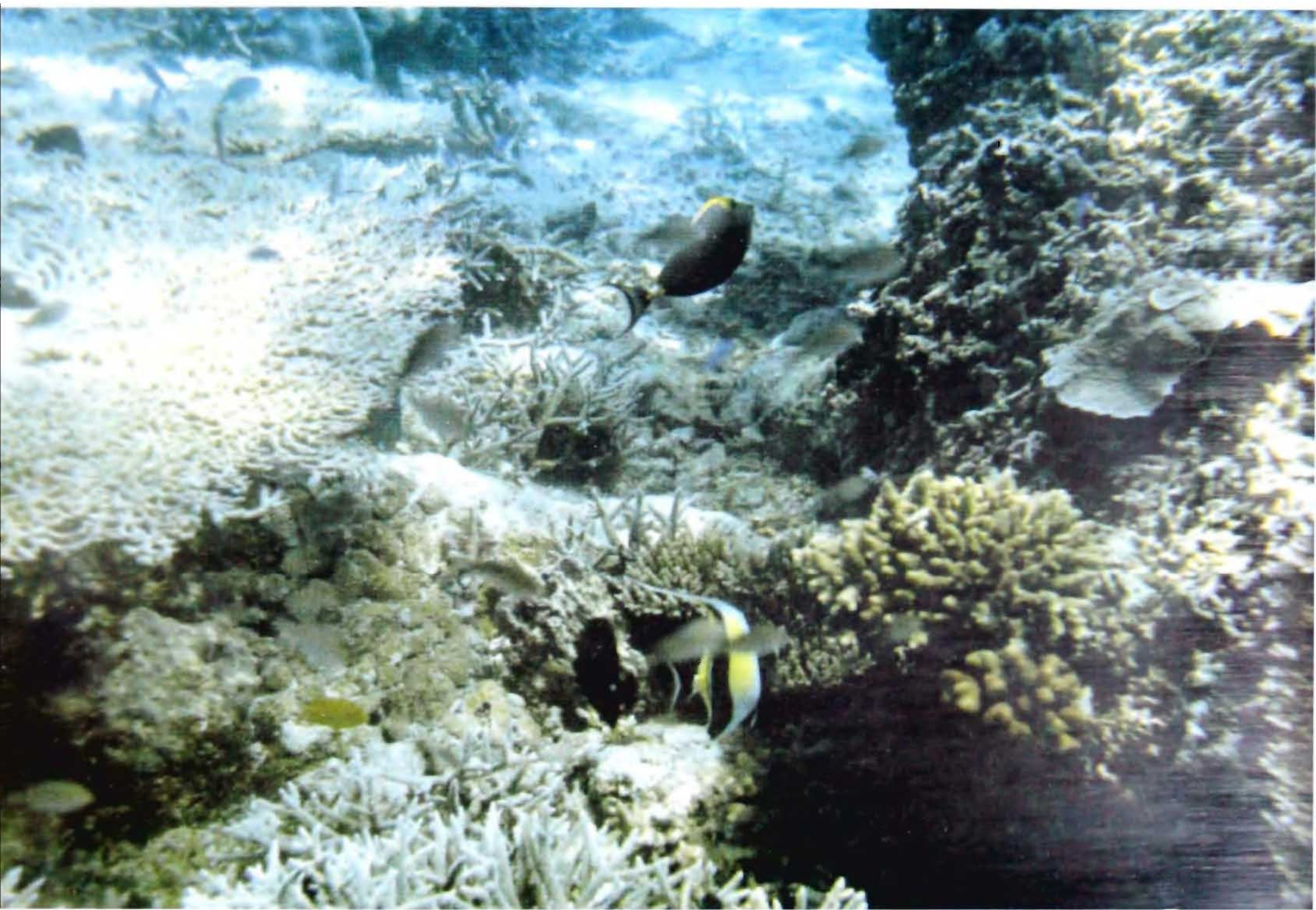
There are patches of reef growth on the west coast, for example coral reefs at Malvan. The Andaman and Nicobars have fringing reefs around many islands, and a long barrier reef (329 km) on their west coast. The reefs are poorly known scientifically but may prove to be the most diverse in India and in the best condition. The Lakshadweep has extensive reefs but these are equally poorly known.

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

2.1 Coral Biology

The term 'coral' has been used to describe a variety of different invertebrate animals from the Phylum Cnidaria including hard corals, soft corals, precious corals and hydrocorals. However, 'coral' is most often used as the common name for hard corals from the Order Scleractinia. Scleractinian corals are divided into reef-building corals (hermatypic corals) which form the primary structure of coral reefs, and non-reef building corals (ahermatypic corals) which do not contribute significantly to reef formation (Veron, 1986). Hermatypic corals usually contain millions of tiny algal cells, called zooxanthellae, within their tissues. These algae are a primary energy source for the reef-building activities of hermatypic corals. Most coral species have a colonial growth form. These species grow in colonies and consist of living polyps which grow together and are interconnected. Other coral species exist as solitary polyps. The solitary corals found in

Fig. 2 : A view of huge populations of *Acropoa* in Andaman and Nicobar Islands



India are of different types, of which some of them are huge and bell shaped *(Halomitra pileus)*.

Corals that contain zooxanthellae are termed 'zooxanthellate species' In contrast, some species lack these algae and are termed 'non-zooxanthellate' corals. Both the zooxanthellae and the corals benefit from their relationship, which is termed a 'mutualistic symbiotic association' Zooxanthellae gain protecton, get access to sunlight and a stable environment by living in the coral tissue and obtain vital nutrients from the waste products of the coral. In return, the coral gains access to energy-rich compounds leaked from the zooxanthellae and benefits from the removal of wastes. The interaction of coral tissues and zooxanthellae also enhances the rate at which corals calcify and grow. Thus, the symbiosis of corals and algae is ultimately responsible for the development of coral reefs. Zooxanthellae represent a nonmotile resting stage of the single-celled dinoflagellate *Symbiodinium microadriaticum*. Vast numbers of zooxanthellae live inside the gastrodermal cells of zooxanthellate corals and give these corals their distinctive brown colouration. Zooxanthellae are also found in some other cnidarians and giant clams and other molluscs.

2.2 Reef Origin

The origin of coral reefs has been debated by oceanographers for over a century. Since corals do not grow below about 65 ft and can survive only for brief periods above water, the question arises as to how coral reef formations of several hundred feet in thickness could have occurred. Charles Darwin, as a result of his voyage abroad in the Beagle in 1831, suggested that such reef growth was made possible by the gradual subsistence of the pedestal upon which the reef first began to grow. In other words, the reef organisms grew upward to compensate for the gradual submergence of their platform. More recently, at the end of the last Ice Age, gradual rising of the sea level because of the melting of glaciers has added to the subsistence mechanism, is a possible explanation.

2.3 Types of reef

2.3.1 Fringing reefs : These grow along the edges of continents and around islands close to shore but sometimes separated from it by a shallow lagoon. Fringing reefs are common in the Gulf of Mannar and, Andaman and Nicobar Islands. Where there is murky water caused by soil run-off, fringing reefs rarely grow to any substantial depth.

2.3.2 Barrier reefs : These develop along the edges of continental shelves or around islands that have become partially submerged, and are separated from the mainland or island by a wide, deep lagoon. More corals that are fragile grow on the lagoon side of the barrier than on the open side where they would have to withstand the force of larger and more violent waves. This type of reefs can be found in Andaman and Nicobar Islands. However, its best known example is the Great Barrier Reef which extends for nearly 2000 km 'along the east coast of Australia and represents about three percent of the total of the world's reefs.

2.3.3 Atoll reefs : These generally begin as fringing reefs around volcanic islands. As the island subsides, because of the sea floor sinking or the sea level rising, the fringing reef forms a circular barrier reef separated from the island by a lagoon. When the island finally disappears, the circle of reefs is left, sometimes capped with small coral islands, enclosing lagoon. The whole structure is called an atoll. Atoll varies in size from tiny Bitra, the smallest of just 0.10 sq km, to the largest, Andrott of 4.84 sq km in Lakshadweep.

Apart from these, there are a few minor reef types as follows : Platform reef, Patch reef, Coral pinnacle, Reef flat, Coralline shelf, Coral heads and Live coral platform.

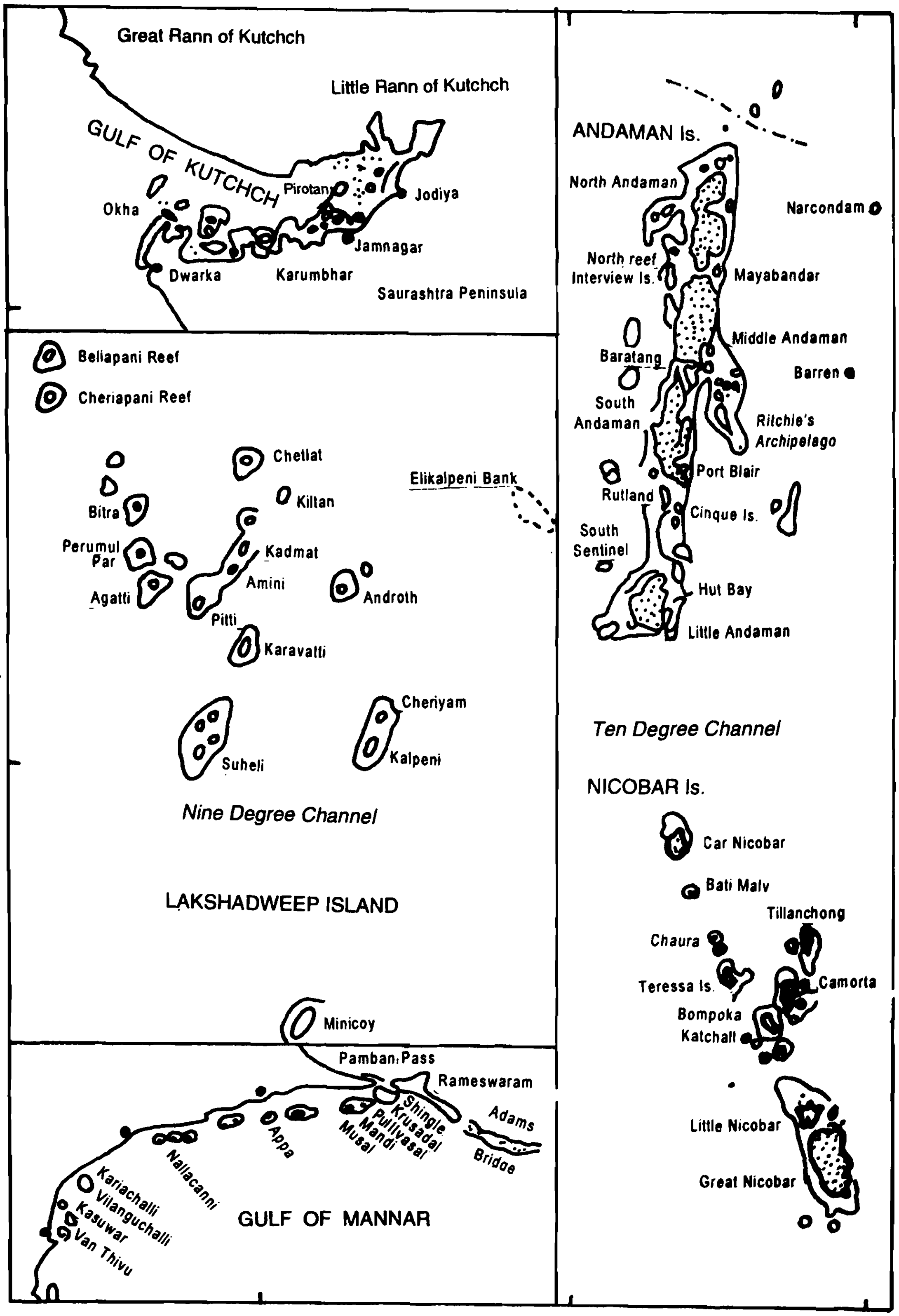


Fig. 3 : Four major coral reef areas in India

2.4 Coral Reefs in India

Indian subcontinent with its coastline extending over 8,000 km and subtropical climatic condition has very few coral reef areas when compared to other regions of the world. In India, the reefs are distributed along the east and west coasts at restricted places. However, all the major reef types are represented. Fringing reefs are found in Gulf of Mannar and Palk Bay. Platform reefs are seen along the Gulf of Kutchch. Patchy reefs are present near Ratnagiri and Malvan coasts. Fringing and barrier reefs are found in Andaman and Nicobar Islands. Atoll reefs are found in Lakshadweep. The absence of reef in Bay of Bengal (North-east Coast) is attributed to the immense quantity of freshwater and silt brought by the rivers such as Ganga, Godavari and Krishna. Satellite imagery (SAC, Ahmedabad) shows scattered patches of corals in the intertidal areas and occasionally at subtidal depths along the west coast of India notably at Ratnagiri, Malwan and Rede Port.

The mainland coast of India has the Gulf of Kutchch in the North-west (Gujarat state) and Palk Bay and the Gulf of Mannar in the South-east (Tamil Nadu state). Other than these, important off shore island groups of India, the Andaman and Nicobar in the Bay of Bengal and Lakshadweep in the Arabian Sea also have extensive reef growth. The total area of coral reefs in India is estimated to be 2273.8 sq km.

2.4.1 South-east Coast of India

Palk Bay : Coral reefs on the Tamil Nadu coast are located in Palk Bay near Rameswaram and in the Gulf of Mannar. Mandapam peninsula and Rameswaram islands separate Palk Bay from the Gulf of Mannar. The reef is centered at 9°17′ N and 79°15′ E. There is only one fringing reef in the Palk Bay, which lies along the mainland from the Pamban channel at the Pamban end of the bridge to Rameshwaram islands. This reef is 25-30 km long and generally less than 200 m wide; maximum depth is around 6 m. Visibility is poor due to siltation and it is influenced by the north-east monsoon. The reef flat is relatively broad from Pamban channel to the southern end near Ramnad and narrow from Pamban to south of Rameswaram.

Gulf of Mannar : The Gulf of Mannar reefs on the other hand are developed around a chain of 21 islands that lie along the 140 km stretch between Tuticorin and Rameswaram in Tamil Nadu. These islands are located between latitude 8°47′ N and 9°15′ N and longitude 78°12′ E and 79°14′ E. The islands lie at an average of about 8 km from the main land. They are a part of the Mannar Barrier reef, which is about 140 km long and 25 km wide between Pamban and Tuticorin. Different types of reef forms, such as, shore, platform, patch and fringing types are also observed in the Gulf of Mannar. The islands have fringing coral reefs and patch reefs around them. Narrow fringing reefs are located mostly at a distance of 50 to 100 m from the islands. On the other hand patch

Fig. 4 : *Montipora foliosa*, a common foliose coral in Gulf of Mannar and other reefs of India

Table 1. Area estimates of Coral reefs in India (km²)				
Category	Gujarat	Tamil Nadu	Lakshadweep Islands	Andaman & Nicobar Islands
Reef flat	148.4	64.9	136.5	795.7
Sand over reef	11.8	12.0	7.3	73.3
Mud over reef	117.1	-	-	8.4
Coraline shelf	-	-	230.9	45.0
Coral heads	-	-	6.8	17.5
Live coral platform	-	-	43.3	-
Algae	53.8	0.4	0.4	-
Sea weeds	-	-	0.7	-
Sea grass	-	-	10.9	-
Reef vegetation	112.1	13.3	-	8.9
Vegetation over sand	17.0	3.6	0.4	10.5
Lagoon	-	0.1	322.8	-
Sandy substrate	-	-	(67.4)	-
Reef patch	-	-	(13.4)	-
Deep	-	-	(98.5)	-
Uncertain	-	-	(143.5)	-
Total	460.2	94.3	760.0	959.3

reefs rise from depths of 2 to 9 m and extend to 1 to 2 km in length with width as much as 50 meters. Reef flat is extensive in almost all the reefs in the Gulf of Mannar. Reef vegetation is richly distributed on these reefs. The total area occupied by reef and its associated features is 94.3 sq km. Reef flat and reef vegetation including algae occupies 64.9 and 13.7 sq km respectively. (DOD & SAC, 1997). Visibility is affected by monsoons, coral mining and high sedimentation load. These reefs are more luxuriant and rich than the reefs of Palk Bay.

2.4.2 West Coast of India

Malvan : The west coast of India between Bombay and Goa is reported to have submerged banks with isolated coral formations (Nair and Qasim, 1978). Coral patches have been recorded in the intertidal regions of Ratnagiri, Malavan and Rede, south of Bombay (Qasim and Wafer, 1979) and at the Gaveshani bank, 100 km west to Mangalore (Nair and Qasim, 1978).

Malvan coast forms part of Western Ghats where Sahyadri ranges gradually meet the Arabian Sea. From Vengurla point the coast trends towards north for about 22 km. From Malvan bay a chain of submerged and exposed rocky islands extends straight towards south up to 15°53′ N and 73°27′ E. In this chain, several islands exist including Vengurla Rocks at the Southern tip and Singhudurg Fort at the northern tip. Other small islets around Sindhudurg Fort are Mandel Rock, Malvan Rock, *etc.* There are numerous exposed rocky outcrops in this area. Sindhudurg is a low fortified island on the coastal reef, which is pointed to the mainland by a fringing reef. Kalarati and Kolamb rivers flank the Malvan coast in the north and Karli river in the south. The coast mainly consists of granites and genisses and in a few genissic interruptions the rocks are covered by laterite beds. Behind these marine coastal tertiaries, there are genisses up to 16°15′ N and further North Deccan lava starts. Sandy beaches and rocky cliffs interrupt the coastline near Malavan. Most of the marine flora and fauna from the intertidal area is exposed during any low tide. However, during lowest low tides (particularly minus tides), the coral reefs get exposed. Siltation is of high rate and salinity may drop to 20 ppt during monsoon in some habitats, which may restrict the growth of ecologically sensitive forms of ramose corals.

Gulf of Kutchch : The Gulf of Kutchch in Gujarat is the richest source of floral, faunal and marine wealth of India as it gives favourable conditions for breeding and shelter to all marine life in the 42 islands. Extensive mangroves are present in the Indus River Delta forming several islands. The tidal range in the Gulf is reported to be as great as 12 m, but may have seasonal changes with extreme low tides at certain times of the year (Brown, 1997). The corals in the Gulf of Kutchch survive through extreme environmental conditions, such as, high temperature, salinity changes and high-suspended particulate loads (Wafar *et al.*, 2000).

Fig. 5 : *Pavona decussata*, a common submassive coral in India except Gulf of Kutchch

2.4.3 Andaman and Nicobar Islands

The Andaman and Nicobar group of islands is located in the South-east of the Bay of Bengal, between 6°-14° N latitudes and 91°-94° E longitudes. They are the emerged part of a mountain chain and lie on a ridge that extends southward from the Irrawaddy delta area of Myanmar, continuing the trend of the Arakan Yoma range.

The Andaman and Nicobar consist of more than 500 islands and islets, of which only 38 are inhabited. The coral reefs are of fringing type and except for a few investigation reports, the reefs of the area still largely remain unknown. A deep oceanic ridge along 10° N separates the Andaman group from the Nicobar group of islands. The orientation of the chain of islands groups is north-south.

2.4.4 Lakshadweep Islands

The Lakshadweep islands lie scattered in the Arabian Sea about 225-450 km from Kerala coast. Geographically, the islands lie between 8°N-12°30′ N latitudes and 71°E-74°E longitudes. The islands consist of coral formations built up on the Laccadive-Chagos submarine ridge rising steeply from a depth of about 1500 m to 4000 m off the west coast of India. The union territory of Lakshadweep along with the Maldives and the Chagos Archipelagoes form an interrupted chain of coral atolls and reefs on a contiguous submarine bank covering a distance of over 2000 km. This ridge is supposed to be a continuation of the Arravali Mountain, and the islands are believed to be remnants of the submerged mountain cliffs. There are 36 islands including 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 km^2 with lagoons occupying about 4200 km^2. Only 11 of the 36 islands are inhabited. They are Andrott, Amini, Agatti, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kiltan, Minicoy and the headquarters at Kavaratti. The

Fig. 6 : Diversity of coral species in the reef slope of Chidiatappu, Andaman

Minicoy Island is separated from the rest of the islands by a 180 km wide stretch of sea known as the nine degree channel.

The islands are flat and scarcely rise more than two meters. They are made up of coral sand and boulders that have been compacted into sandstone. Coral reefs of the islands are mainly atolls except one platform at Andrott. The reef flat occupies 136.5 sq km area. Sea grass occupies 10.9 sq km and lagoon occupies 309.4 sq km (Bahuguna and Nayak, 1994). The depth of the sea increases outside the coral reef and can reach up to 1500-3000 m. Andrott is the largest island with an area of 4.84 sq km and the only island that does

Fig. 7 : The branching coral, *Acropora aspera* abundant in Lakshadweep and, Andaman and Nicobar

not have a lagoon. Birta with an area of 0.10 sq km is the smallest in land area but perhaps has the most magnificent lagoon. All the islands lie north to south, excepting Andrott that lies east to west. The distance between them varies from 11 km to 378 km.

3. BIOLOGICAL DIVERSITY

Reefs are home to more species than any other ecosystem in the sea. The total number of reef species in the world is still unknown, but up to 3,000 species can be found together on a single reef in south-east Asia and over 1,000 species on a single Caribbean reef. Only tropical rainforests estimated by some to be home of a staggering 30 million insects, have a greater number of species, although due to the vast number of fish that inhabit them, reefs contain a larger number of vertebrates than rainforests. Reefs also contain many more major animal groups (Phyla) than any other ecosystem on land or in the sea.

The richest reefs, with the greatest diversity of plants and animals are in the region bounded by Indonesia, Malaysia, the Philippines and southern Japan. Of the 700 or so reef corals that are known in the world, 600 are found in this region; over 400 are found in the Philippines and Japan, and about 350 in Indonesia, although there are probably many more to be discovered here. Up to 200 corals may occur on a single reef in South East Asia. This high diversity extends equally to other reef associates and is partly because of the greatest area of reefs found here and partly because of its geological history. When the sea level was lower, the region comprised of three separate basins, within each of which numerous species evolved. The variety of species on a reef decreases eastwards across the Pacific.

3.1 Ecosystem/Habitat Diversity

Taken in the context of geological time, the coral reefs have undergone remarkable changes. They have survived continental drift, consequences of the Ice Ages, repeated dramatic temperature fluctuations and rapid changes in rainfall and soil run-off, among the other environmental factors. All these mean that the shape, structure and distributions of modern reefs probably have less to do with the particular species that built them than geological history : the depth and shape of the ocean floor, the geology of the area and past sea level changes.

A fundamental distinction can be made among shelf reefs which form on continental shelters, as in the Gulf of Mannar, continental island reefs as in Andaman and Nicobar islands and oceanic reefs which develop in deep waters mostly in the Pacific. Within these three broad divisions, there are a number of different reef types as discussed earlier.

3.2 Species Diversity

Hard corals belong to the Order Scleractinia which includes all the true corals, which secrete a solid calcium carbonate skeleton. There are more than 600 living species of scleractinian reef-building corals worldwide, and each of these coral species is classified and described scientifically to allow each coral to be correctly identified.

In colonial corals, individual corallites are joined together by perithecal skeletal elemets termed 'coenosteum', which are secreted by coenosarc tissues between the polyps. The most common colony forms are plocoid where corallites have septate walls and are united by coenosteum *(Cyphastrea)*, ceriod where adjacent corallities share common walls *(Favites)*, meandroid where a series of corallities form valleys *(Platygyra)* and phaceloid where corallites have separate walls and form branched clumps *(Dendrophyllia)*. The growth form of the colony can be encrusting where the skeleton adheres closely to the substratum *(Siderastrea)*, massive *(Porites lutea)*, column *(Goniopora)*, branching *(Acropora, Stylopora)*, foliaceous *(Turbinaria reniformis)* or plate-like (*Turbinaria peltata*). In some species, the growth form does not vary much among individuals in the population whereas in many species, the growth form can change greatly depending upon the amount of light, wave action, water depth, sediment and other environmental factors. In most coral species, the corallites of each polyp are nearly identical; however, in branching *Acropora* species, two distinct types of corallites are developed. Relatively large axial polyps are present at the tip of each growing branch while the main structure of the branch is formed by a series of smaller radial corallites.

Fig. 8 : Close view of the exposed massive corals during low tide

3.2.1. Coral Fauna : A total of 199 species divided among 71 genera are hither to recorded from India, including Lakshadweep, the Gulf of Kutchch, Palk Bay and the Gulf of Mannar and, Andaman and Nicobar Islands (Table 3). Out of these, 155 species belonging to 50 genera are hermatypes and 44 species divided among 21 genera are ahermatypes (Table 2). The Indian Ocean as a whole is known to harbour 88 genera of hermatypes (Scheer, 1984) which means 56.8 percent of the total known hermatypic genera of the Indian Ocean is present in Indian waters. A comprehensive list of species from the Indian Ocean is not yet available. Based on the present record a numerical list of genera and species is drawn up in Table 2.

The hermatypes constitute 77.8% of the coral fauna and the ahermatypes form 22.2%. Among the hermatypes *Acropora* alone forms 20% and *Montipora* 13% and these two are numerically rich genera. The members of the suborder Astrocoeniina constitute 34.7%, Fungiina 25.7%, Faviina 22.6%, Caryophylliina 8% and Dendrophylliina 9% of the coral fauna of India. (hermatypes and ahermatypes included). No genus is endemic to India. The

Table 2. Numerical list of genera and species of corals from Indian Ocean

Area	Corals					
	Hermatypes (A)		Ahermatypes (B)		Total (A+B)	
	genus	species	genus	species	genus	species
Lakshadweep	27	69	4	9	31	78
Gulf of Kutchch	20	34	4	3	24	37
South-east Coast	28	84	9	10	37	94
A. & N. islands	47	100	12	35	59	135
Whole of India	50	155	21	44	71	199

Fig. 9 : *Pocillopora verucosa*, a common species in the coral reefs of India

coral reefs of southeast India, Andaman and Nicobar Islands and Lakshadweep harbour *Acropora* community (Pillai, 1971a, 1986). The coral growths in Gulf of Kutchch are mostly found scattered and are in a juvenile stage.

A recent study conducted by the Zoological Survey of India, Chennai during the GCRMN Coral training workshop at Port Blair (December, 1998) found that the total number of genera and species of scleratinian corals may increase up to 265 species. This includes the already published list of corals by many authors and the recent findings (ZSI, unpublished data) by Zoological Survey of India, Chennai.

3.2.2 Coral Reef Associated Fauna : In Indian Coral reefs sponges, molluscs, crustaceans, echinoderms and fishes constitute major components of reef associated fauna (Table 4). Besides these, a few species of reptiles and mammals are found in reefs in India.

Sponges : Sponges are asymmetrical benthic animals and are strikingly coloured. They represent a major component of reef communities. A total of 275 species has been recorded from Gulf of Mannar and Palk Bay. Other areas with numerical abundance are Gulf of Kutchch with 25 species, Andaman and Nicobar group with 112 species and Lakshadweep with 109 species. Recent studies have revealed that sponges contain several peculiar chemical compounds that are not found in any other animals. Arabinose nucleosides isolated from *Tethya crypta* have proven cancer inhibiting properties and this

Table 3. List of scleractinian corals of India

Sl. No.	List of taxa	Lakshadweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
	Order : SCLERACTINIA				
	Family : THAMNASTERIIDAE				
	Genus : *Psammocora* Dana				
1.	*P. contigua* (Esper)	+	-	+	+
2.	*P. digitata* Milne Edwards & Haime	+	+	-	-
3.	*P. haimeana* Milne Edwards & Haime	+	-	-	-
4.	*P. profundacella* Gardiner	+	-	-	+
	Family : POCILLOPORIDAE				
	Genus : *Stylophora* Schweigger				
5.	*S. pistillata* (Esper)	+	-	-	+
	Genus : *Seriatopora Lamarck*				
6.	*S. crassa* Quelch	-	-	-	+
7.	*S. hystrix* Dana	-	-	-	+
8.	*S. stellata* Quelch	-	-	-	+
	Genus : *Pocillopora* Lamarck				
9.	*P. brevicornis* Lamarck	-	-	-	+
10.	*P. damicornis* (Linneaus)	+	-	+	+
11.	*P. ankeli* Scheer and Pillai	-	-	-	+
12.	*P. ligulata* Dana	+	-	-	-
13.	*P. meandrina* var. *nobilis* Verrill	-	-	-	+
14.	*P. verrucosa* (Ellis and Solander)	+	-	+	+
15.	*P. eydouxi* Milne Edwards and Haime	+	-	+	+
	Genus : *Madracis* Milne Edwards & Haime				
16.	*Madracis* sp.	-	-	+	+
	Family : ACROPORIDAE				
	Genus : *Acropora* Oken				
17.	*A. intermedia* (Brook)	+	-	-	-
18.	*A. formosa* (Dana)	+	-	+	+
19.	*A. valenciennesi* Milne Edwards & Haime	-	-	+	-
20.	*A. abrotanoides* (Lamarck)	+	-	-	-
21.	*A. gravida* (Dana)	-	-	-	+
22.	*A. efflorescens* (Dana)	+	-	-	+
23.	*A. conigera* (Dana)	+	-	-	+
24.	*A. obscura* (Brook)	-	-	+	-
25.	*A. teres* Verrill	+	-	-	-
26.	*A. nasuta* (Dana)	+	-	-	-
27.	*A. secale* (Studer)	-	-	-	+

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
28.	*A. corymbosa* (Lamarck)	+	-	+	-
29.	*A. hyacinthus* (Dana)	+	-	+	+
30.	*A. indica* (Brook)	+	-	+	-
31.	*A. millepora* (Ehrenberg)	-	-	+	+
32.	*A. pinguis* Wells	-	-	-	+
33.	*A. brevicollis* (Brook)	-	-	+	-
34.	*A. palifera* (Lamarck)	+	-	-	+
35.	*A. nobilis* (Dana)	-	-	+	+
36.	*A. humilis* (Dana)	+	+	+	+
37.	*A. diversa* (Brook)	-	-	+	+
38.	*A. hebes* (Dana)=*A. aspera*	+	-	-	-
39.	*A. variabilis* (Klunzinger)=*A. vlida*	-	-	+	+
40.	*A. squarrosa* (Ehrenberg)	+	-	-	-
41.	*A. hemprichi* (Ehrenberg)	+	-	-	-
42.	*A. forskali* (Ehrenberg)	+	-	-	-
43.	*A. rambleri* (B. Smith)	+	-	-	+
44.	*A. granulosa* Milne Edwards and Haime	+	-	-	+
45.	*A. dumosa* (Brook)	-	-	-	+
46.	*A. echinata* (Dana)	+	-	-	-
47.	*A. multi-acuta* Nemenzo	-	-	-	+
	Genus : *Astreopora Blainville*				
48.	*A. myriophthalma* (Lamarck)	+	-	+	-
49.	*A. listeri* Bernard	-	-	-	+
	Genus : *Montipora* Quoy & Gamiard				
50.	*M. subtilis* Bernard	-	-	+	-
51.	*M. granulosa* Bernard	-	-	+	-
52.	*M. explanata* Brueggeman	-	+	+	-
53.	*M. exserta* Quelch	-	-	+	-
54.	*M. digitata* (Dana)	-	-	+	+
55.	*M. divaricata* Brueggeman	-	-	+	+
56.	*M. cocosensis* Vaughan	-	-	-	+
57.	*M. turgescens* Bernard	-	+	+	+
58.	*M. manauliensis* Pillai	-	-	+	-
59.	*M. monastriata* (Forskai)	-	+	+	-
60.	*M. venosa* (Ehrenberg)	-	+	+	-
61.	*M. spumosa* (Lamarck)	-	-	+	-
62.	*M. tuberculosa* (Lamarck)	+	-	+	-
63.	*M. jonesi* Pillai	-	-	+	-
64.	*M. verrucosa* (Lamarck)	-	-	+	-

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
65.	*M. peltiformis* Bernard	-	-	-	+
66.	*M. verrilli* Vaughan	-	-	+	-
67.	*M. hispida* (Dana)	-	+	+	-
68.	*M. foliosa* (Pallas)	-	+	+	+
69.	*M. composita* Crossland	-	-	-	+
	Family : AGARICIIDAE				
	Genus : *Pavona* Lamarck				
70.	*P. explanulata* (Lamarck)	-	-	-	+
71.	*P. xarifae* Scheer and Pillai	-	-	-	+
72.	*P. varians* (Verrill)	+	-	+	+
73.	*P. decussata* (Dana)	-	-	+	+
74.	*P. praetorta* (Dana)	-	-	+	-
75.	*P. clavus* (Dana)	-	-	-	+
76.	*P. maldivensis* Gardiner	+	-	-	-
77.	*P. duerdeni* Vaughan	+	-	+	+
78.	*P. divaricata* (Lamarck)	-	-	+	-
	Genus : *Pachyseris* Milne Edwards & Haime				
79.	*P. rugosa* (Lamarck)	-	-	+	+
80.	*P. speciosa* (Dana)	-	-	-	+
	Genus : *Leptoseris* Milne Edwards & Haime				
81.	*L. papyracea* (Dana)	-	-	-	+
82.	*L. fragilis* Milne Edwards & Haime	-	-	-	+
	Genus : *Gardineroseris* Scheer & Pillai				
83.	*G. planulata* (Dana)	+	-	-	+
	Genus : *Coeloseris* Vaughan				
84.	*C. mayeri* Vaughan	-	-	-	+
	Family : SIDERASTERIDAE				
	Genus : *Siderastera* Blainville				
85.	*S. savignyana* Milne Edwards & Haime	-	+	+	-
	Genus : *Pseudosiderastrea* Yabe & Sugiyama				
86.	*P. tayami* Yabe and Sugiyama	-	+	+	+
	Genus : *Coscinaraea* Milne Edwards & Haime				
87.	*C. monile* (Forskal)	-	+	+	-
	Family : FUNGIIDAE				
	Genus : *Cycloseris* Milne Edwards & Haime				
88.	*C. cyclolites* (Lamarck)	-	-	+	-
89.	*C. sinensis* Milne Edwards and Haime	-	-	-	+

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
90.	*C. distorta* (Michelin)	-	-	-	+
91.	*C. hexagonalis* Milne Edwards and Haime	-	-	-	+
92.	*C. costulata* (Ortman)	-	-	-	+
	Genus : *Fungia* Lamarck				
93.	*F.* scutaria Lamarck	+	-	-	+
94.	*F. paumotensis* Stutchberry	-	-	-	+
95.	*F. somervilli* Gardiner	+	-	-	+
96.	*F. echinata* (Pallas)	-	-	-	+
97.	*F. repanda* Dana	-	-	-	+
98.	*F. danai* Milne Edwards & Haime	+	-	-	+
99.	*F. horrida* Dana	-	-	-	+
100.	*F. fungites* (Linneaus)	+	-	-	+
	Genus : *Fungiacyathus* Sars				
101.	*F. symmetrica* (Pourtales)	-	-	-	+
	Genus : *Herpolitha* Eschscholtz				
102.	*H. limax* (Esper)	-	-	-	+
	Genus : *Polyphyllia* Quoy and Gaimard				
103.	*P. talpina* (Lamarck)	-	-	-	+
	Genus : *Podabacia* Milne Edwards & Haime				
104.	*P. crustacea* (Pallas)	+	-	-	-
	Family : PROTIDAE				
	Genus : *Goniopora* de Blaniville				
105.	*G. stokesi* Milne Edwards and Haime	+	-	+	+
106.	*G. tenuidens* (Quelch)	-	-	-	+
107.	*G. nigra* Pillai	-	+	+	-
108.	*G. minor* Crossland	+	+	-	-
109.	*G. planulata* (Ehrenberg)	-	+	+	+
	Genus : *Porites* Link				
110.	*P. solida* (Forskal)	+	-	+	+
111.	*P. lobata* Milne Edwards & Haime	-	-	-	+
112.	*P. minicoiensis* Pillai	+	-	-	-
113.	*P. lutea* Milne Edwards & Haime	+	+	+	+
114.	*P. lichen* Dana	+	+	+	-
115.	*P. exserta* Pillai	-	-	+	-
116.	*P. andrewsi* Vaughan	+	-	-	-
117.	*P. eridani* Umbgrove (=*P. cylindrica)*	-	-	-	+
118.	*P. compressa* Dana	-	+	+	-
119.	*P. mannarensis* Pillai	-	-	+	-
	Genus : *Alveopora* Blainville				
120.	*A. daedalea* (Forskal)	-	-	-	+

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
	Family : FAVIIDAE				
	Genus : *Plesiastrea* Milne Edward & Haime				
121.	*P. versipora* (Lamarck)	+	+	-	+
	Genus : *Favia Oken*				
122.	*F. stelligera* (Dana)	+	+	+	+
123.	*F. pallida* (Dana)	+	-	+	+
124.	*F. speciosa* (Dana)	+	+	+	+
125.	*F. flavus* (Forskal)	+	+	+	+
126.	*F. rotumana* (Gardiner)	-	-	-	+
127.	*F. valenciennesi* Milne Edwards & Haime	-	-	+	+
	Genus : *Favites* Link				
128.	*F. abdita* (Ellis and Solander)	+	-	+	+
129.	*F. halicora* (Ehrenberg)	+	-	+	+
130.	*F. complanta* (Ehrenberg)	+	+	+	+
131.	*F. flexuosa* (Dana)	-	-	-	+
132.	*F. pentagona* (Esper)	+	-	+	-
133.	*F. melicerum* (Ehrenebrg)	+	+	+	-
	Genus : *Goniastrea* Milne Edwards & Haime				
134.	*G. retiformis* (Lamarck)	+	-	+	+
135.	*G. pectinata* (Ehrenberg)	+	+	+	+
	Genus : *Platygyra* Ehrenberg				
136.	*P. daedalea* (Ellis and Solander)	+	-	+	+
137.	*P. sinensis* (Milne Edwards and Haime)	+	+	+	+
	Genus : *Leptoria* Milne Edwards & Haime				
138.	*L. phrygia* (Ellis and Solander)	+	-	+	+
	Genus : *Oulophyllia* Milne Edwards & Haime				
139.	*O. crispa* (Lamarck)	-	-	-	+
	Genus : *Hydnophora* Fischer de Waldheim				
140.	*H. microconos* (Lamarck)	+	-	+	+
141.	*H. exesa* (Pallas)	-	+	+	+
142.	*H. laxa* (Dana)	-	-	-	+
	Genus : *Diploastrea* Matthai				
143.	*D. heliopoa* (Lamarck)	+	-	-	+
	Genus : *Oulastrea* Milne Edwards & Haime				
144.	*O. crispata* (Lamarck)	-	-	-	+
	Genus : *Leptastrea* Milne Edwards & Haime				
145.	*L. bottae* (Milne Edwards and Haime)	+	-	-	+
146.	*L. purpurea* (Dana)	+	+	+	+
147.	*L. tarnsversa* Klunzinger	+	-	+	-
	Genus : *Cyphastrea* Milne Edwards & Haime				

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
148.	*C. microphthalma* (Lamarck)	-	-	+	+
149.	*C. serailia* (Forskal)	-	+	+	+
	Genus : *Echinopora* Lamarck				
150.	*E. lamellosa* (Esper)	-	-	+	+
151.	*E. horrida* Dana	-	-	-	+
	Family : TRACHYPHYLLIDAE				
	Genus : *Trachyphyllia* Medward & Haime				
152.	*T. geoffroyi* (Audouin)	-	-	-	+
	Family : RHIZANGIIDAE				
	Genus : *Culicia* Dana				
153.	*C. rubeola* (Quoy and Gaimard)	-	-	+	+
	Genus : *Cladangia* MED & H				
154.	*C. exusta* Luetken	West coast of Kerala only			
	Family : OCULINIDAE				
	Genus : *Galaxea* Oken				
155.	*G. fascicularis* (Linneaus)	+	-	+	+
156.	*G. clavus* (Dana)	-	-	+	+
	Family : MERULINIDAE				
	Genus : *Merulina* Ehrenberg				
157.	*M. ampliata* (Ellis and Solander)	+	-	-	+
	Genus : *Scapophyllia* MED & H				
158.	*S. cylindrica* Milne Edwards & Haime	-	-	-	+
	Family : MUSSIDAE				
	Genus : *Lobophyllia de* Blainville				
159.	*L. corymbosa* (Forskal)	+	-	-	+
	Genus : *Acanthastrea* MED & H				
160.	*A. simplex* Crossland	-	+	-	-
161.	*A. echinata* (Dana)	+	-	-	-
	Genus : *Symphyllia* MED & H				
162.	*S. nobilis* (Dana)	+	-	+	+
163.	*S. radians* Milne Edwards & Haime	+	+	+	+
	Family : PECTINUDAE				
	Genus : *Mycedium* Oken				
164.	*M. elephantotus* (Pallas)	-	+	+	+

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
	Genus : *Pectinia* Oken				
165.	*P. lactuca* (Pallas)	-	-	-	+
	Family : CARYOPHYLLIIDAE				
	Genus : *Caryophyllia* Lamarck				
166.	*C. clavus* Scacchi	+	-	-	+
167.	*C. arcuata* Mine Edwards & Haime	+	-	-	-
168.	*C. acanthocyathus grayi* MED & H	-	-	-	+
	Genus : *Deltocyathus* MED & H				
169.	*D. andamanesis* Alcock	-	-	-	+
	Genus : *Paracyathus* MED & H				
170.	*P. indicus* Duncan	-	-	-	+
171.	*P. profundus* Duncan	-	-	+	-
172.	*P. stokesi* Milne Edwards and Haime	-	+	-	-
	Genus : *Polycyathus* Duncan				
173.	*P. verrilli* Duncan	-	+	+	+
174.	*P. andamanensis* Alcock	-	-	-	+
	Genus : *Heterocyathus* MED & H				
175.	*H. aequicostatus* MED & H	-	-	+	+
	Genus : *Stephanocyathus* Seguenza				
176.	*S. nobilis* (Moseley)	+	-	-	-
	Genus : *Euphyllia* Dana				
177.	*E. glabrescens* (Chamisso & Eysenhardt)	+	-	-	+
	Genus : *Plerogyra* MED & H				
178.	*P. sinousa* (Dana)	-	-	-	+
	Genus : *Physogyra* Quelch				
179.	*P. lichtensteini* MED & H	-	-	-	+
	Family : FLABELLIDAE				
	Genus : *Flabellum* Lesson				
180.	*F. pavonium* Alcock	+	-	-	-
	Genus : *Placotrochus* MED & H				
181.	*P. laevis* Milne Edward & Haime	-	-	-	+
	Family : DENDROPHYLLIIDAE				
	Genus : *Balanophyllia* S. Wood				
182.	*B. imperialis* Kent	-	-	-	+
183.	*B. scabra* Alcock	-	-	-	+
184.	*B. affinis* (Semper)	-	-	+	-
	Genus : *Endopsammia* MED & H				

Table 3. contd.

Sl. No.	List of taxa	Laksha-dweep	Gulf of Kutchch	Gulf of Mannar and Palk Bay	Andaman & Nicobar Islands
185.	*E. philippinensis* MED & H	-	-	+	-
	Genus : *Heterpsammia* MED & H				
186.	*H. michelini* MED & H	-	-	+	+
	Genus : *Tubastrea* Lesson				
187.	*T. aurea* (Quoy and Gaimard)	-	+	+	+
	Genus : *Dendrophyllia* Blainville				
188.	*D. coarctata* Duncan	-	-	+	-
189.	*D. arbuscula* V. der Horst	-	-	-	+
190.	*D. minuscula* Bourne	-	+	-	+
191.	*D. micranthus* (Ehrenberg)	-	-	-	+
192.	*D. indica* Pillai	-	-	+	-
	Genus : *Enallopsammia* Micheloti				
193.	*E. amphelioides* (Alcock)	-	-	-	+
194.	*E. marenzelleri* Zibrowius	-	-	-	+
	Genus : *Turbinaria* Oken				
195.	*T. crater* (Pallas)	-	+	+	+
196.	*T. undata* Bernard	-	-	+	-
197.	*T. peltata* (Esper)	-	+	+	+
198.	*T. mesenterina* (Lamarck)	+	-	-	-
199.	*T. veluta* Bernard	-	-	-	+

Note : + recorded, Not yet recorded

discovery has triggered off a worldwide interest in the biochemistry of this group. In India too, several institutions have taken up the extraction and characterization of several pharmacologically active compounds from sponges. So far, no species of sponges are exploited commercially in India.

Crustacea : Crustaceans of Indian coral reefs are least studied. So far, little more than 586 species and 97 species of this group are reported from Andaman and Nicobar islands and Lakshadweep respectively. The crustaceans rank second in the diversity of fauna in the coral reef ecosystem in the world and many of them are exploited for commercial purposes.

Mollusca : Coral reefs of Andaman and Nicobar Islands have a rich molluscan diversity, which include about 1000 species. Gulf of Mannar including the Coramandal coast and Lakshadweep have 428 and 424 species of Mollusca respectively. Though, the molluscan diversity is supposed to be the highest among all the invertebrates in the coral reef ecosystem, they are threatened by habitat alternation and indiscriminate exploitation by man. Eight species of oysters, two species of mussels, 17 species of clams, six species of pearl oysters, four species of giant clams, one species of window-pane oyster and other gastropods, such as, Sacred chank, *Trochus*, *Turbo* as well as 15 species of cephalopods are exploited from the Indian coral reefs.

Echinoderms : About 257 species of echinoderms are known from Andaman and Nicobar islands alone (James, 1987). Lakshadweep has 77 species and Gulf of Mannar 108 species. Economically only

Table 4. Diversity of coral reef associates of all the four major reefs of India.

Faunal Groups	Gulf of Mannar	Gulf of Kutchch	Andaman and Nicobar	Lakshadweep
Sponges	272	25+	112+	109
Crustacea	?	?	586+	97+
Mollusca	428+	?	1000	424+
Echinoderms	108+	?	257	77+
Fishes	538+	?	750+	603+
Corals	96+	37+	135+	105+
Total	1442+	62+	2840+	1415+

Holothuroidea (12 species) are exploited on a commercial scale for export. Sea urchins play a very important role in creating reef sediments and keeping seaweed growth on the reef at bay, but when in very large numbers, they can damages reefs. Perhaps the most notorious echinoderm is the Crown-of-Thorns starfish that can devastate reefs in the course of its coral consumption.

Fishes : The distribution of marine fishes is rather wide and some genera are common to the Indo-Pacific and the Atlantic regions.

Fig. 10 : A school of fish feeding near a massive coral colony of *Porites lutea* on the reef slope at Mahatma Gandhi Marine National Park, Andaman

57 percent of the Indian marine fish genera are common to the Indian seas and to the Atlantic and Mediterranean. The exact number of species associated with coral reefs of India is still to be known. However, the number of fishes in Indian Ocean is 1367. The Lakshadweep Islands have a total of 603 species of fishes (Jones and Kumaran, 1980), about 750 species are found in the Andaman and Nicobar Islands (Rajan, Zoological Survey of India, Port Blair, personal communication) and in Gulf of Mannar Biosphere Reserve these are 538 (Unpublished, Zoological Survey of India, Chennai). The category of fishes occurring in coral reef ecosystem includes groups, such as, the damsel fishes, butterfly fishes, trigger fishes, file fishes, puffers, snappers, hawk fishes, triple fins and most of the wrasses, groupers and gobies. Another 20% are composed of cryptic and nocturnal species that are confined primarily to caverns and reef crevices during daylight periods. This assemblage includes such families as the cusk eels, some groupers and their relatives, most of the moray eels and some scorpion fishes, wrasses and nocturnal families including the squirrel fishes, cardinal fishes and sweetlips. Another 10% of fishes dwell primarily on reefs covered with sand and rubble including snake eels, worm eels, various rays, lizard fishes, grab fishes, flat fishes, and some wrasses and gobies. A relatively small percentage (about 5%) of the fauna is composed of transient mid water reef species that roam over large areas. This group includes most sharks, jacks, fusiliers, barracudas and a scattering of representatives of other families.

Reptiles and Mammals : Few marine reptiles and mammals can be described as the reef animals but several species are often spotted near reefs and many visit them to feed on. Sea snakes are still common and are often encountered streaking over reefs, but most large marine vertebrates are now comparatively rare, their populations heavily reduced by human exploitation. Turtles are often seen on reefs. The hawksbill is most closely associated with coral reefs and found all round the reefs of India, nesting on small beaches and coral cays and feeding on sponges and invertebrates on nearby reefs. Other than this, green turtles, the Loggerhead, Olive Ridley and Leatherback turtles are also seen swimming and feeding in coral reef environments.

The dugong found in Gulf of Mannar and Andaman and Nicobar Islands feed entirely on sea grasses and other rich vegetation and are found near reefs, though rarely seen, as they prefer the better protection and more plentiful food afforded by silt laden waters. Dugongs are now endangered. They were hunted extensively in the past and are now threatened both by the disappearance of their shallow-water habitats and by the human activities. Dolphins and some of the whales that live or breed in tropical waters, such as, humpbacks are occasionally seen near reefs.

4. SPECIAL FEATURES

4.1 Endemicity of Corals and Coral Associates

Unlike terrestrial animals, fewer marine animals are endemic or restricted to a small area since their larvae float freely in the oceans. The exceptions are those species that do not have floating larvae or have larvae that float in the currents for a very short time around isolated reefs or in semi-enclosed seas. Although most coral species are very wide-ranging, ten corals are unique or endemic to Brazil, several are endemic to the Red Sea and Chagos Archipelago and at least two are endemic to India (probably many more to be discovered).

Up to 20% of corals and 30% of fishes in Hawaii are thought to be endemic, although further work on the many remote and unstudied reefs in the Pacific may show that they have wider distributions. In Indonesia about 150 corals are rare and about a third of all corals found in Japan are also rare or have restricted distributions. However, in India, studies on the coral associates are far from complete and a comprehensive account on this is difficult at this stage.

One of the most striking features of a coral reef is the immense concentration of different creatures that live on, around and within its complex three-dimensional frame. Immediately noticeable are the fish and, of course, the corals themselves, but many other annimals including a seemingly infinite variety of invertebrates are largely hidden amongst the cracks and crevices of the reef. Only on close inspection are the secret lives of tiny crabs, worms and sea slugs revealed. In this crowded community, every vacant living space is strongly contested, and some species have gone to extraordinary distance to find a home. Very recently Zoological Survery of India has initiated studies on the coral reefs combined with specialisation on underwater diving. Probably during the coming years many more new discoveries on the fauna of the coral reefs of India are expected to emerge.

5. VALUE

Due to India's location on the Indian Ocean, Arabian Sea and Bay of Bengal, the people of India have traditionally had a close relationship with the sea. This has resulted in strong cultural and economic links with maritime activities, such as, fishing, pearl diving, shipbuilding and international maritime trading. India's coral reefs provide habitats for many commercially important fish species. These reefs and some of the associated islands are becoming increasingly popular sites for recreation and are strategically important for India. It would also provide the significant potential for numerous pharmaceutical compounds, which are yet to be discovered.

The coral reefs have a large variety of direct and indirect uses that benefit man and society. Among the dominant and most valued uses, the large yield is obtained from marine fisheries supported by the reef system. Reef's resources have traditionally been a major source of food for local inhabitants and of major economic value in terms of commercial exploitation. Reefs in India provide economic security to the communities that live alongside them. There are millions of poor fishermen in India whose livelihood depends on coral reefs. Reefs provide up to 25% of the total fish catch in India and up to 75% of the animal protein consumed. This yield includes a large variety and quantity of organisms caught elsewhere but whose existence is dependent upon the reef. As a source of lime production, mining of the living reef and back-reef areas is still common in many part of the world. As coral reefs tend to be positioned perpendicularly to the mean direction of wind generated swell currents flowing over the reef, they can serve to weaken incoming waves, thereby minimising erosion and coastal hazards behind the reef.

6. THREATS

There are varying levels of degradation which can be observed on coral reefs, from the extreme and obvious (mortality) to more sublime changes in characteristics including competitive dominance among organisms, decreased growth rates, break down of organisms association, reduced fecundity, reproductive failure and declining recruitment of larvae. Essentially, whether a coral reef is killed with in a week due to sediment burial or over a ten-year period due to attrition and lack of recruitment, the result is the same. The loss of the coral reef community results in the loss of all the benefits that it offers.

Recent reports indicate that coral reefs are under considerable stress and are experiencing considerable damage. Coral reefs have been resilient ecosystems since the Mesozoic (about 200 million years ago), surviving major environmental events such as ice ages, meteor strikes and large changes in solar activity. Not withstanding these events, coral reefs have recovered to form the extensive reefs we see today, although recovery may have taken thousands to hundreds of thousands of years. Coral reefs also have the capacity to regenerate rapidly after catastrophic tropical storms, plagues of the coral-eating Crown-of-Thorn starfish and servere bleaching. Recovery often takes 15 to 20 years. However, over the past 50 years, there has been major increase in stresses on coral reefs from direct and indirect human activities. These stresses are threatening the existence of reefs in some areas and will diminish the extent of reefs in other areas.

6.1 Natural Stresses to Coral Reefs

The major stresses on reefs are storms and waves, particularly tropical storms and cyclones. These cause major intermittent damage to reefs, particularly to those reefs that rarely experience these storms. Cyclone disturbances develop during certain months (October-November) along the Indian sea coasts and elsewhere in the tropical region.

These cyclones have sustained winds with speed ranging from 65 to 120 km per hour. High-speed winds cause extreme wave action that break corals into rubbles and sometimes large amounts of sand and other materials may be dumped on to the coral reef. Due to 1969 cyclone a large area of corals was buried under the sand in Rameswaram area of Gulf of Mannar. Likewise, the cyclone of December 1987 in Bay of Bengal devastated the coral reefs of the Mahatma Gandhi Marine National Park of Port Blair, Andaman, that resulted in large quantities of broken coral colonies, getting heaped and scattered near the shore.

Freshwater run off damages reefs in semi-enclosed bays and lagoons (a channel near the Mahatma Gandhi Marine National Park entrance) by lowering salinity and depositing large amounts of sediments and nutrients. Reefs are also damaged by volcanic activities (earthquakes, volcanic lava flows, severe uplifting) in the Andaman Islands, for example, in Barren Island. The major biological stress on reefs are predation by Crown-of-Thorns starfish and coral diseases have been particularly devastating in Andaman and Nicobar reefs (*e.g.*, Mahatma Gandhi Marine National Park in 1989) and Lakshadweep respectively. There is now considerable speculation that the incidence of both these stresses has been exacerbated by human activities.

6.2 Anthropogenic Impacts on Coral Reefs

Varied man's activities which are a cause for concern includes runoff and sedimentation from development activities, eutrophication from sewage and agriculture, physical impact from maritime activities, dredging, collecting, and destructive fishing practices, pollution from industrial sources, golf courses and oil refineries and the synergistic impacts of anthropogenic disturbance on top of natural disturbance.

6.2.1 Sedimentation : Sedimentation which is the most well studied impact may affect corals in three different ways: photosynthetically, physically, and chemically. As most reef-building corals obtain the majority of their nutritional requirements through translocation of metabolites from their photosynthetic partners (zooxanthellae), any reduction in the availability of light will affect coral nutrition, growth, reproduction and depth distribution.

Physically, sediments also interfere with coral nutrition by coating the feeding surfaces responsible for catching prey items needed to supplement the energy provided by zooxanthellae. While corals do have the ability to cleanse themselves using a combination of mucus secretion and ciliary action, chronic sedimentation may end up in a high energetic cost, adding to the overall impact on the colony. Sedimentation can alter species composition of reefs through photosynthetic and physical effects. Changes in relative abundance of morphological types as well as individual species are an important reflection of how sedimentation as a disturbance affects community structure. The standing examples are the coral reefs of Gulf of Mannar islands and the reefs of Little Andaman. So far, the presence of sediment load in the coral reef areas has been confirmed in Gulf of Mannar and Andaman and Nicobar Islands. However, quantitatively these are not reported. Venkataraman and Rajan (1994) reported the amout of silt carried by the rainwater from Port Blair city into the sea. Only few studies have focussed on the effects of sedimentation and siltation on the damages the reef quantitatively.

Sedimentation can also physically interfere with recruitment of coral larvae which require a solid substratum to settle and metamorphose. Dredging projects have been particularly damaging to reefs, (Sethu Samudram project, Gulf of Mannar region) primarily through the initial physical disturbance, habitat alteration and the subsequent problems associated with sedimentation. Sand mining in Andaman islands and coral quarrying in Gulf of Mannar (Tuticorin group of islands) cause a lot of sedimentation and siltation on coral reefs.

Very few studies have focussed on the chemical effects of sediment on corals that may be important. Dumping of fly ash near Pandian Island at Tuticorin may contain a variety of heavy metals particularly detrimental to coral reefs.

6.2.2 Runoff/Chemical Pollution/Water Quality : A general rule for coastal zone: whatever is used on land today ends up in the aquifer or coastal zone tomorrow. Salinity changes alone have proven to affect corals, especially on shallow water reef flats which are most likely to be affected by freshwater runoff. The amount of sediments and chemicals the runoff water carries to the sea has profound effects on fertilization of eggs of coral species. Likewise, the quality of runoff water can affect the metamorphosis of the larvae of corals. Many experiments have demonstrated that the actual coastal surface water quality above reefs during coral spawning events has sufficiently reduced reproductive failure. Many areas in Andaman and Nicobar islands and Gulf of Mannar area have large quantities of sediment laden freshwater runoff impinged on coastal reefs, causing high levels of coral mortality, rapid growth of fleshy algae species, and large areas of reduced salinity/quality seawater. Local fishermen of Gulf of Mannar have complained of decreased fisheries and reef vitality not only on these coastal reefs, but also on off shore islands and reefs not directly affected by contact with the sediment. Inspection of these reefs by the Zoological Survey of India, Chennai revealed live adult coral colonies, but there was no sign of larval recruits with increased levels of sedimentation.

Oil pollution is an extreme example of how chemicals, in this case hydrocarbons, can affect reefs. Research performed in many areas have documented coral mortality, decreased fecundity and recruitment failure in response to chronic oil pollution.

Industrial waste discharged into the sea near Tuticorin islands and Chattam Saw mill wastes in Port Blair are the standing examples of how pollution deteriorates the reef ecosystem. All the near shore reefs and island reefs of Tuticorin, Gulf of Mannar and Port Blair area, Andaman and Nicobar area have become barren rocks.

6.2.3 Sewage : The overall impact of sewage on a coral reef community depends on nature of sewage, level of treatment, presence of toxic materials and receiving water characteristics. The effects of sewage-related nutrient enrichment on coral reef communities have been documented and include alteration of competitive interactions, reduction of coral calcification rates from decreased light levels and increased phosphate concentrations and increased mortality from bacterial infection.

Corals are adapted to live in nutrient poor environments and are relatively slow growing compared to algae, sponges, tunicates and other groups of sessile benthic organisms. Nutrients not only increase the biomass of phytoplankton, affecting light transmission and increasing the biological oxygen demand (B.O.D.) which may have some impact on the corals but also give a competitive advantage to faster growing benthic species. The green algae have formed large mats, covering and killing corals in Keelakarai coast coral reefs in Gulf of Mannar due to sewage pollution from the town. The nutrient enrichment *via* sewage reduces the photosynthetic efficiency of corals, as alga cells increase in density to the point of becoming self-shading. Since the coral zooxanthellae symbiosis evolved under nutrient limited conditions, it is reasonable to assume that the relationship will become altered in response to changes in the level of nutrients available. Further studies of the physiological effects of such changes are needed to determine the sublethal or long-term effects of sewage and nutrient enrichment on coral reefs of Gulf of Mannar islands and Andaman and Nicobar.

While the effects of suspended solids from sewer out falls have been compared to those from terrigenous runoff and sedimentation, the two types of sediment differ in physical, chemical and toxicological characteristics, which must be considered when assessing impacts. Sewage suspended solids primarily organic, can contain absorbed toxins and increase B.O.D more than inorganic sediment associated with runoff. The toxic component of sewage depends on the sources of input and is primarily a concern in industrial or agricultural areas where industrial wastes and pesticides are included in the effluent.

6.2.4 Temperature stress and Bleaching: The negative impacts of increased temperature on corals have been documented from both anthropogenic and natural sources. There are many documented evidences for coral mortality associated with the hot water discharge from a cooling system of a power plant and wide spread mortality with increased temperatures accompanying the *El Nino* event. In both cases, the cause of mortality appeared to be the breakdown of the symbiotic association between the zooxanthellae and the coral host (bleaching).

There has been unprecedented bleaching of hard and soft corals throughout the coral reefs of the world from mid-1997 to late-1998. Much of the bleaching coincided with a large *El Nino* event followed by a strong *La Nina* but bleaching in all the coral reefs is uncorrelated. During this event bleaching and mortality were most pronounced in shallow water (less than 15 m) and particularly affected staghorn and plate *Acropora* and other fast growing corals. Many of the massive, slow-growing species bleached, but many recovered within one or two months. This bleaching event has resulted in poor coral cover (recent study by Zoological Survey of India, Chennai) and possibly fewer new coral recruits on many reefs in India for next 10 years until recovery gains speed. In short terms this will affect adversely the economics of India, particularly fisheries. There will be a shift in the composition of coral communities; some will have greater dominance of slow growing massive corals, whereas other reefs will lose century old colonies. Nevertheless, such shifts have occurred in the past and are part of the normal variability of many coral reefs. If however, the recent bleaching event is linked to global climate change, and will be repeated regularly in the immediate future, the consequences would be serious for many coral reefs if sea temperatures show a continuing upward trend.

The relationship between bleaching events and ozone depletion/global warming is presently being studied by several groups of researchers. If the connection can be proven, it will be an example of global rather than local anthropogenic impacts on coral reefs.

6.2.5 Coral diseases : Four types of coral diseases have been "identified": white band disease, black band disease, bacterial infection and shutdown reaction. While there is a degree of uncertainty over the causes responsible for each disease, they all appear to be stress-related. Synergism is believed to play an important role as stressed corals seem to be the most susceptible for the above diseases. Sediment, sewage, pesticides, heavy metals, bleaching and other human impacts have stressed tumors, bacterial attack and parasitic worms. White Band Disease has been reported from Andaman and Nicobar and Lakshadweep islands. In addition, a new disease called Pink Line disease is also reported from Lakshadweep.

6.2.6 Destructive fishing practices : The use of destructive fishing practices has been responsible for the destruction of coral reefs throughout the world. Destructive fishing practices have seriously damaged many of the Gulf of Mannar's richest and most diverse coral reefs, giving an urgent warning that immediate and far-reaching action is needed. The Gulf of Mannar stands out as one of the hardest hit areas, with 60% of its reef in varying stages of deterioration. Because of the large size of the areas concerned (Gulf of Mannar and, Andaman and Nicobar Islands or other areas in India) and the general lack of resources for enforcement, education appears to be more successful than legislation in controlling these practices. Poverty reduces the alternatives for fishermen who must feed their families and rely on fishing as a source of protein and income. The same problem has lead to another anthropogenic disturbance on reefs : over fishing. The use of fish traps made of long-lasting materials with small mesh sizes results in the capture of pre-reproductive juveniles, affecting future populations and the death of fish when traps become dislodged during storms, yet continue to capture fish which eventually starve. Several types of net fishing have also been responsible for over-exploitation of reef. With all biological communities in a coral reef, each species plays an important role in the dynamics of balance. Therefore, depletion of grazers, for example, may eventually lead to an overgrowth of alga as in the case of Gulf of Mannar reefs.

Blast Fishing : Although it is now illegal, blast fishing has been a widespread and accepted fishing technique in some of the reef areas in India (*e.g.*, Gulf of Mannar). Schooling reef fishes are located visually, after which the capture boat moves within close range and a lighted bomb is thrown into the middle of the school. After the bomb is exploded, fishermen enter the water to collect the fish that have been killed or stunned by the resulting shock wave. Due to blasting, branching, tabulate and foliose hard corals are shattered while massive and columnar corals are often fractured. Although this effect of blasting is quite localized, reefs subject to repeated blasting are often to little more than shifting rubble fields, punctured by the occasional massive coral head. In addition to damaging the reef framework, blast fishing results in side-kills of non-target and juvenile fishes and invertebrates.

Trap Fishing (Koodu) : The use of bamboo mesh traps, locally known as koodu, is wide spread throughout Gulf of Mannar islands reef fisheries. In Ramanathapuram alone 3,312 (37% of the total trap in the Tamil Nadu state) traps are found. Although this gear is not intrinsically destructive, the process of setting and retrieving the trap is largely responsible for the destruction of the reef. These traps set by simply lowering the trap from boat-side *via* a buoyed rope are responsible for the most reef damage. The traps are often heavily weighted with wooden runners or stones and can destroy entire stands of branching and foliase corals on the reef during their installation and especially removal (by pulling on the rope). If the current trend continues, Koodu trap activities will become an increasingly important cause of reef damage in Gulf of Mannar.

Ola Valai and Shore Seine: Ola valai is a type of drive-in net fishing technique where by a line of fishermen in the water use scare-lines, lines with palm leaves tied off at regular intervals to drive fish down a bag net. The scare lines are rhythmically lifted and dropped into the shore areas, often breaking live corals while the fish are driven ahead. Next to this, the shore seines form the major gear of Gulf of Mannar. There are about 1523 numbers of shore seines found in Ramanathapuram district alone, forming about 33% of the total shore seines in the state. Although this gear is not intrinsically destructive, the process of shore seines is largely responsible for the destruction of new colonies emerging near lagoon.

While it is simple to prove how damaging destructive fishing practices are to the productivity of fisheries, the economic realities of day-to-day life in Gulf of Mannar and Andaman and Nicobar islands make the solution difficult to obtain.

Crown-of-Thorns starfish phenomenon: The coral eating starfish, *Acanthaster plancii* has been the focus of a debate on the fate of coral reefs since out breaks were observed in the late 1980s and early 1990s at Andaman and Nicobar Islands (Mahatma Gandhi Marine National Park). While it has been documented that hundreds of km^2 of coral reefs of Australia and other areas have been devastated by population blooms of starfish, the debate centers on the out breaks of natural events, having occurred repeatedly over geologic time and whether the situation has arisen as a result of man's activities. Although sediment core data have indicated that *Acanthaster* out breaks occurred 10,000 years ago, recent studies have shown a relationship between nutrient input and recruitment success of the larvae. Studies of echinoderm reproduction have demonstrated that the success of recruitment of their planktonic larvae depends on phytoplankton availability following spawning. Events that increase nutrient availability on coral reefs can affect reproduction and recruitment in *Acanthaster*, while out breaks may be considered natural, an increasing number and/or the persistence of these events may be linked to anthropogenic nutrient input.

7. CONSERVATION

The Federal Government Coastal Regulation Zone Notification 1991 regulates onshore development activities, which affect coastal environments and strictly prohibits the collection and trade of corals. Wildlife Protection Act 1972 provides protection for protected areas and certain marine species. Efforts continue to bring corals under this act and to encourage enforcement that is more stringent. Coral reef conservation is also included in the Environmental Protection Act (1986), the National Conservation Strategy and Policy Statement on Environmental Development (1992) and the Action Plan of the Ministry of Environment and Forests. The conservation and management of coral reef resources is within the mandate of the Ministry of Environment and Forests, the focal point for the Indian Coral Reef Monitoring Network and the National focal point of ICRI.

India has 5 marine protected areas : the largest is the Gulf of Mannar Biosphere Reserve (GOMBR), which encompasses 10,500 sq km. Other areas are Gulf of Kutchch Marine National Park (GOKMNP) with 400 sq km., Mahatma Gandhi Marine National Park (MGMNP) also known as the Wandoor Marine National Park in Andamans with 28,150 ha, Great Nicobar Biosphere Reserve (GNBR) with an area of 885 sq km and Rani Jansi Marine National Park (RJMNP) in Ritchie's Archipelago in Andamans. Although several marine protected areas exist in India their management is weak, particularly those adjacent to the subcontinent where human impacts from resource use and urban and industrial development is high. There is a growing concern that some areas of the Gulf of Kutchch Marine National Park may be denotified for industrial development. The reefs there have been neglected and there is no systematic monitoring of the status of the reefs except for occasional EIA studies for development activities (Wafar *et al.*, 2000). Protected areas on Andaman and Nicobar Islands and in Lakshadweep are in better condition due to less human impact. However, these may be more vulnerable to other impacts, such as, from the Crown-of-Thorns and from stresses caused by bleaching. There is a great need for training of conservation officers to manage the protected areas and funding for infrastructure development.

Coral Reef Monitoring Action Plans (CRMAP), prepared under the first phase of the GCRMN, have been launched within the framework of the ICRMN for all reef areas except the Gulf of Kutchch. Government support has been extended for the implementation of the CRMAP and to build capacity to monitor reefs through training. However, activities are still at a beginning and overall the capacity for monitoring and management is lacking. Other significant international initiatives on the Indian coral reefs underway and under development include : UNDP/GEF DPE B Projects on the Gulf of Mannar and, Andaman and Nicobar Islands, the Coral Reef Degradation in the Indian Ocean project (CORDIO), an Integrated Coastal Zone Management Training Project (ICZOMAT) funded by the UK Department for International Development (DFID) and an India-Australia Training and Capacity Building (IATCB) programme.

8. FUTURE DIRECTION

Coral reefs in India are under increasing pressure. In many cases, the sources of stress due to human pressure are known. However, the etiology of a growing number of diseases and pathologies now being reported in corals is not widely understood, highlighting the need for more search to unravel the complex interactive effects between natural and anthropogenic forms of stress and their effects on coral reefs. The inability of scientists to predict with any certainty where the critical thresholds of resilience to stress lie along the continuum of human-induced and natural disturbances, make it inherently difficult to manage reefs sustainably. Solutions to these conservation and management problems will need to incorporate effective science, robust economic analysis and sound policies and laws. Participatory actions grounded in the cultural and social reality of local people who depend on and benefit directly from coral reefs must be part of the solution. Creating political will, through communication and environmental education, will be essential in mobilising and sustaining conservation efforts.

Studies, such as, qualitative and quantitative estimation of biodiversity, percentage cover of live and dead coral estimation by standard methods, estimation of standing crops of reef resources, their recruitment, growth, mortality, standing stock and level of exploitation to suggest norms for judicious exploitation are essential. These aspects need intense and long-term study in India. In general, the percentage cover of live coral estimation is not the only criteria for the health of reefs but also the ratio of dead and live coverage.

Presence or absence of indicator species may be an index of environmental stress or pressure on reefs. The extensive taxonomic surveys of sessile organisms, such as, sponges, alcyonarians and polychaetes can give clue to the state of art environmental conditions. Assessment of heterotrophic macro-invertebrates, such as, sponges, barnacles, hydroides, tunicates, echinoderms, etc., may yield clue to stress conditions due to pollution. Such studies are very important for management of coral reefs.

We cannot control nature, but with adequate and accurate data, we can take appropriate decisions to control the impacts of man's activities on coral reef communities.

9. SELECTED REFERENCES

Alfred, J.R.B., Das, A.K. and Sanyal, A.K. 1998. Faunal Diversity in India. *ENVIS Centre, Zool. Surv. India.,* Calcutta, 497 pp.

Allen, G.R. and Steene, R.C. 1987. Reef Fishes of the Indian Ocean, *T.F.H. Publications Inc.* USA. 240 pp.

Bahuguna, A. and Nayak, S. 1998. Coral reefs of the Indian Coast. *Space Application Centre (ISRO),* Ahmedabad, 54pp.

Bakus, G.J. 1994. Coral reef Ecosystem, *Oxford and IBH Publishing Co. Pvt. Ltd,* New Delhi, 232 pp.

DOD and SAC, 1997. "Coral reef maps of India", Department of Ocean Development and Space Application Centre, Ahmedabad, India.

Gosliner, T.M., D.W. Behrens and Williams, G.C. 1996. Coral Reef animals of the Indo-Pacific. *Monterey, California,* 314 pp.

Menon, N.G. and Pillai, C.S.G. 1996. Marine Biodiversity Conservation and Management, *CMFRI,* Cochin, 205 pp.

Pillai, C.S.G. and Scheer, G. 1974. Report on the Scleractina from the Nicobar Islands, E. Schweizerbart'sche Verlagsbuchhandlung (Nagele u. Obermiller), Stuttgart 75 pp.

Pillai, C.S.G. 1986. Recent corals from the southeast coast of India. In : *Recent Advances in Marine Biology.* Today & Tomorrow publishers, New Delhi. 107-201.

Pillai, C.S.G. 1996. Coral reefs of India, their conservation and management. In: Marine Biodiversity, Conservation and Management (N.G. Menon & C.S.G. Pillai eds). *Central Marine Fisheries Research Institute, Cochin,* 16-31.

Pillai, C.S.G. and Venkataraman, K. 1999. Status, Conservation and Management of Corals and Coral Reefs of Andaman and Nicobar Islands. *Report submitted to GOI/UNDP/GEF Project on Management of Coral Reef Ecosystem of Andaman and Nicobar Islands.* 19 pp.

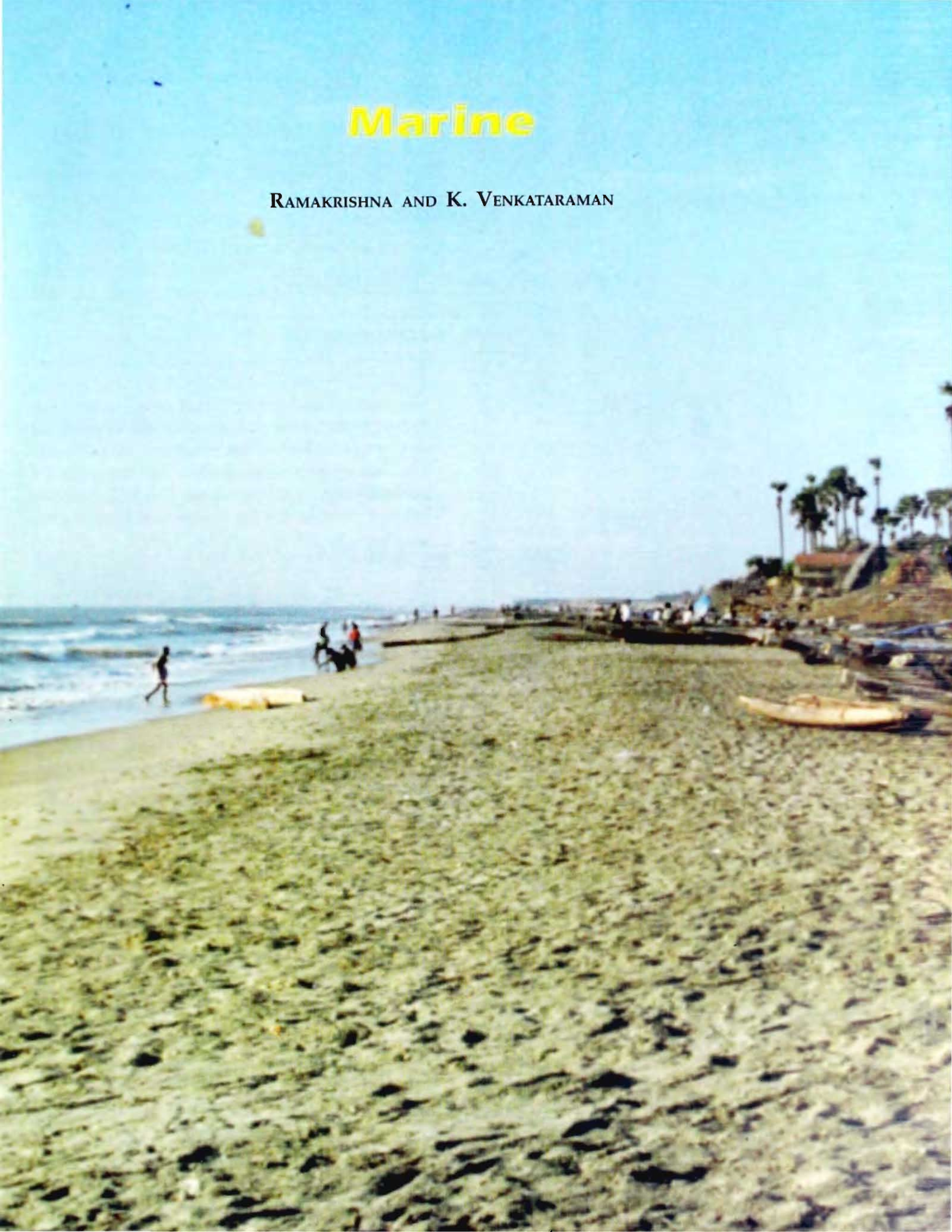
Saldanha, C.J. 1989, Andaman, Nicobar and Lakshadweep: An environment impact assessment. *Oxford & IBH Publishing Co. Pvt. Ltd.,* New Delhi. 114 pp.

Wells, S. and Hanna, N. 1992. The Green Peace Book of Coral Reefs. *Blandford,* 160 pp.

Wilkinson, C. 1998. Status of Coral Reefs of the World: 1998. Australian Institute of Marine Science. 184 pp.

Marine

RAMAKRISHNA AND K. VENKATARAMAN



ENVIS–*Zool. Surv. India*
Ecosystems of India : 291-315, 2001.

Marine

RAMAKRISHNA AND K. VENKATARAMAN*

Zoological Survey of India
'M' Block, New Alipore, Kolkata-700 053

1. INTRODUCTION

Marine and coastal biological diversity encompasses the enormous variety of marine and coastal species and their genetic variety, the global oceans' cornucopia of living resources, myriad coastal and open sea habitats and ecosystems, and the wealth of ecological processes that support all of these. The oceans cover over 70% of the planet's surface area and account for 99% of the volume that is known to sustain life. Coastal

Fig. 1 : Katchal Island, Nicobar

* Zoological Surve of India, Marine Biological Station, Chennai 600 028

ecosystems, such as, tidal flats (sea-shores), coastal wetlands, *viz.*, backwaters, estuaries, lagoons and mangrove forests also harbour significant diversity and are highly valuable for coastal communities.

Much of the world's of biodiversity is found in highly diverse marine and coastal habitats. These habitats range from tidal flats and shallow coral reefs to the dark ocean floor's soft sediments thousands of meters below the water surface. While the total number of described marine species is smaller than that found on land, scientists are continually discovering new concentrations of diversity. Coral reefs are already known to be among the richest habitats in species diversity on the planet. The deep sea bottom, dark and subjected to tremendous pressure, is now thought to be a dwelling pace for thousands, perhaps millions of species of small invertebrate animals including crustaceans, molluscs and worms. In recent years, scientists exploring the dim middle depths have discovered numerous new species that compose almost unknown, yet apparently productive ecosystems (De Fontaubert *et al.*, 1996).

Until today marine biodiversity is less well known than terrestrial biodiversity due to the difficulty in access and expense. We know astonishingly little about marine life, even in the most familiar seascapes. For instance, scientists have identified twenty-two phyla of meiofauna, two of which were identified only in the past two decades. These animals, barely visible to the naked eye, live on grains of coastal and ocean-bottom sands. Up to 10,000 such animals can be found in single handful of wet sands. Thousands of species may live in soft bottom sands off the Atlantic coast of Canada. Yet only recently have scientists begun to suspect the important role they play in marine ecosystems. They are a major source of food for shrimp and bottom feeding fish and they consume detritus and pollutants in seawater that filters through coastal and near shore sands.

2. DESCRIPTION, GEOGRAPHICAL DISTRIBUTION AND PHYSIOGRAPHY

2.1 Indian coast line and Exclusive Economic Zone (EEZ)

India has a long coastline, of about 8000 km, stretching along nine states and two archipelagos. The coast is indented by a number of rivers which form estuaries at their confluence with the sea. The complex coastal ecosystems comprise of estuaries, lagoons, mangroves, backwaters, salt marshes, mud flats, rocky shores and sandy stretches. Besides, there are three gulfs, one on the East coast, Gulf of Mannar and two on the West coast, Gulf of Kutchch and Gulf of Khambhat. The two island ecosystems Lakshadweep and, Andaman and Nicobar Islands add to the ecosystem diversity in India. Gulf of Mannar, Gulf of Kutchch and the two island ecosystems have rich coral reefs harbouring valuable marine biodiversity.

The extension of land into the sea is continental shelf and it is variable along the Indian coasts. The continental shelf area is the sea bed and submarine area extending from coast up to 200 m depth. The shelf has an average width of 32 km along Andhra coast, but it is wider, being 175 km, off Maharashtra coast. The total shelf area which is divisible into inshore (up to 50 m depth) and offshore regions (between 50 m and 200 m depth) occupies an area of about 4,14,686 sq km (including Islands). The total shelf area of India represents about 0.55% of the surface area of the Indian Ocean. Exclusive Economic Zone (EEZ) is an area beyond and adjacent to territorial waters with a limit of 200 nautical miles from the base line. The Indian EEZ has 1.8 million sq km area and represents about 2.7% of the Indian Ocean. In India the EEZ on the West coast (including Lakshadweep) constitutes maximum (42.5%) followed by Andaman and Nicobar Islands (29.7%) and East coast (27.8%).

2.2 Indian Ocean

The Indian Ocean is the smallest of the three 'great' oceans and geologically much of which is rather youthful. Following the International Hydrographic Bureau, its boundaries are as follows: western limits : the meridian of Cape Agulhas to Antarctica; eastern limits: south of Australia, Bass Strait, Cape Grim, Tasmania to Antarctica; north of Australia Torres Strait; north, there is the Asian landmass. Marginal seas of the Indian Ocean include, the Red Sea, Gulf of Aden, Persian Gulf, Gulf of Oman, Arabian Sea, Laccadive Sea, Bay of Bengal, Andaman Sea, Malacca Straits and Singapore Straits. The two additional seas are the Mozambique Channel and the Great Australian Bight. The area covered by the Indian Ocean (excluding Arafura Sea) 74,917,000 km^2, with a mean depth of 387 m. The maximum depth recorded is 7,.437 m (24,444 feet).

2.3 Oceanography

The Indian landmass forms a major physical division between the Arabian Sea and the Bay of Bengal. Oceanographically, the Bay of Bengal differs from the Arabian Sea in maintaining clockwise circulation of major currents during both the northeast and southwest monsoons. The circulation in the Arabian Sea reverses; with surface water masses circulating counter clockwise during the northeast monsoon and clockwise during the southwest monsoon. There is also a major difference in salinity. In the Arabian Sea, evaporation exceeds precipitation and runoff, leading to the formation of highly saline water masses that flow south. The Bay of Bengal has comparatively low salinity due to high runoff and precipitation; during the southwest monsoon, maximum salinity is found at depths of about 500 meters as highly saline water moves into the Bay from the Indian Ocean.

The general current patterns are as follows. Along the Indian coast the currents follow a general clockwise circulation during the southwest monsoon and counter-clockwise circulation during the northeast monsoon. In January, when the northeast monsoon is at its peak, the currents follow the coastline, having a southerly component off the East coast and a northerly component off the West coast of India. In June and July, as the southwest monsoon reaches its peak, the flow is generally in the opposite direction. In the Andaman Sea there is a general flow from east to west, or southeast to northwest during the northeast monsoon and in the opposite direction during the southwest monsoon period.

The surface layer of the Andaman Sea is generally well mixed to a depth of 100 m, but a sharp decrease in temperature may occur in the eastern side of the Andaman and Nicobar Islands at depth of 25 to 50 m. There is a wide fluctuation in surface salinity in the Andaman and Nicobar Islands, low salinity occurring during May to November, a recovery period in December and January, and high salinity from February through April. Upwelling occurs in both the Lakshadweep and Andaman Seas, included by wind stress and Coriolis force. Upwelling ceases in October in the Lakshadweep region. Tides in the Indian Ocean are mainly semidiurnal, sometimes mixed. Spring tides range from 0.3 to 1.0 m in south India and the Lakshadweep and Maldive Islands and from 1.0 to 2.0 m in the Andaman Islands.

2.4 Temperature and Salinity

Temperature is probably the most important of the major physical environmental factors, which mediate the life histories of marine organisms. Its effects are expressed in different distribution patterns, rates of growth and in the timing of reproductive cycles. Sea surface temperature around the Indian coast varies considerably through the year and both the range and the pattern of isotherms differ between the west and east. It may be seen that general temperature varies from a minimum 10°C in the southern part to a maximum of 27° C or even higher (>28° C) towards central and northern regions. During the northeast monsoon, water temperature is relatively less (24-26° C) in the Arabian Sea and Bay of Bengal than during other times. Similarly, beyond 30° S latitude the temperature is very low (10-20° C) evidently due to the influence of the Antarctic Ocean. During the winter months the surface temperature gradient for the whole region trends roughly north-south. In the northeastern Bay of Bengal Sea, along the West Bengal and Bangladesh coast, the mean winter surface temperature is typically less than 25°C. And in the summer the temperature gradient runs approximately north-south on both sides of the Indian coasts, with highest values of 32°C and upwards obtained along the south-east coast of the Bay of Bengal Sea, and a summer mean increase from 28-32°C onwards along eastern India.

Salinity is regarded as the second most important physical characteristic of the marine environment. Throughout the Indian coastal area the total concentration of dissolved salts falls in low range of about 35-40‰ (g/kg). However, over much of the Indian marine region, seasonal variation in both surface and bottom salinity is related to the penetration of oceanic water, having a salt concentration in excess of 35‰ This salinity factor has high influence on the fauna of this area.

2.5 Nutrients

The sampling of the Indian Ocean for nutrients (phosphate, nitrate, silicate) was conducted on a widespread basis during the International Indian Ocean Expedition (IIOE) from 1st September 1959 to 31st December 1965. Altogether, 9,536 stations were sampled of which there were 2,982 stations with depths exceeding 1,950 m. In general, the concentration of inorganic phosphate in surface waters varied from a minimum of 0.2 mg.at.l^{-1} (most part of the west, central and east Indian Ocean) to a maximum 1.0 mg.at.l^{-1} (east Somalia, Arabian coast; South Indian Ocean below 40° S latitude). However, exceptionally high values (4 mg.at.l^{-1}, 4000m South Indian Ocean; 12 mg.at.l^{-1}, Andaman-Myanmar coast above Coral Banks) were noticed. The concentration of nitrate varied from a minimum of (0.5 mg.at.l^{-1}) at most parts of the Ocean to a maximum of 10 mg.at.l^{-1}) below 40° S latitude and in one region close to Persian Gulf. The exception was in deep water where the levels were about 40 mg.at.l^{-1}. Silicate ranged from a minimum of 3 mg.at.l^{-1} to a maximum of 10 mg.at.l^{-1}. In Bay of Bengal very high silicate (130-140) was noticed close to river mouths. In all these cases, nutrient levels were appreciably higher during southwest monsoon period (March-October) than at other times. The nutrients in the Indian Ocean are determined to a great extent by the control over circulation exerted in the northern Indian Ocean by monsoon winds which below offshore from Africa directly transport surface waters away with a resulting replacement of deep nutrient rich waters. The high values of inorganic phosphate (0.6-1.0 mg.at.l^{-1}) off Somalia and Arabia coasts during May-October (south-west monsoon) were caused by near shore upwelling at these places. The relatively high (>5 mg.at.l^{-1}) silicate values at the Ganges Head (Bay of Bengal) and off Malaysia are attributable to river runoff during the same period. In general, the concentration of inorganic phosphate, nitrate and silicate increased in the direction of Antarctic Sea particularly around 40° S latitude, in the proximity of sub-tropical convergence. In comparison to other two oceans, namely, Atlantic and Pacific, the concentration of nutrients in the Indian Ocean are about twice found there.

2.6 Dissolved Oxygen

Data collected during IIOE revealed appreciable variations in the dissolved oxygen concentration. Overall the levels remained between 2 and 4 $ml.l^{-1}$. However, in the Arabian Sea (0.25 $ml.l^{-1}$; 200 m) and central equatorial region (0.3-1.25 $ml.l^{-1}$; 1200 m) the observed values were vary low. In contrast, in surface waters in Gulf of Aden and in the south (Mozambique channel and Antarctic bottom water, 4000 m) dissolved oxygen values were maximum (>5 $ml.l^{-1}$). The presence of O_2 minimum layer in the Arabian Sea (100-1250 m) is yet another notable feature of the Indian Ocean. In the upper part of this layer (down to 600 m) free hydrogen sulphide was discovered. A quantitative minimum of plankton was recorded in the whole thickness of the oxygen minimum in this area.

2.7 Tides

Tides are a significant factor in the ecology of marine organisms as well as an important consideration for marine biologists. All coastlines are subjected to regular vertical changes in sea level although in some parts of the world these are so small at times as to be scarcely discernible. Around the Indian coast tidal ranges are variable, sometimes complexly so, and some coastlines experience often spectacular tidal amplitudes. In general, tides in Indian coastal region is semi diurnal, with tidal ranges varying from place to place. While Sundarban, Gulf of Khambhat and Gulf of Kutchch experience large tidal variations exceeding 5 m, the peninsular tip of India is subject to relatively low variation of tides around 0.5 m. The variation of tide level at some places along the Indian coast based on tide tables is shown below (Table 1).

Table 1. Variation of tidal level along the Indian coasts

Place	Spring Tidal Range (m)	Neap Tidal Range (m)
Kandla	5.86	3.90
Mumbai	3.66	0.73
Goa	1.69	0.56
Mangalore	1.22	0.56
Cochin	0.63	0.23
Tuticorin	0.70	0.16
Chennai	1.01	0.41
Visakhapatnam	1.43	0.54
Paradeep	1.87	0.70
Calcutta	4.21	2.10

The current patterns near the river mouths are generally influenced by tides. Wind and seasonal circulation pattern mostly dominate the regions along the coast, 2 km away from the coastline. Currents beyond 2 km distance from the coastline are once again significantly influenced by tides. Surface currents tend to follow the monsoon winds. For several months at the end of each year current comes from the northeast, the Bay of Bengal and along the coast of India, rather than from the open ocean.

3. BIOLOGICAL DIVERSITY

3.1 Ecosystem/Habitat diversity

3.1.1 Sea coasts : The Indian mainland coast is divided into two parts: West coast and East coast. The West coast is fronted by the Arabian Sea and the East coast by the Bay of Bengal. Other than these mainland coasts, there are three island groups, such as, Lakshadweep in the south Arabian Sea and Andaman and Nicobar in the eastern Bay of Bengal. The east and west coasts are markedly different in their geo-morphology. The West coast is generally exposed with heavy surf and rocky shores and headlands. The East coast is generally shelving with beaches, lagoons, deltas and marshes. It is also relatively low lying with extensive alluvial plains and deltas. The physical regime of the Indian coasts is characterised by different types of coastal and shore ecosystems like promontories (near Beypore in Kerala state), sand spits (at Karnataka and Andra Pradesh), barrier beaches (along Kerla coast), embayments (Mirya bay in Maharashtra),

Table 2. State-wise details of coastal length (in km) in India

States	Sandy coast	Rocky coast	Muddy coast	Marsh coast	Approx Total
Gujarat	440	319	444	352	1555
Maharashtra	95	201	250	-	546
Goa	66	31	54	-	151
Karnataka	224	33	41	-	298
Kerala	459	23	88	-	570
Tamil Nadu	574	31	394	-	999
Andhra Pradesh	354	32	512	74	972
Orissa	292	-	171	53	516
West Bengal	-	-	125	121	246
Lakshadweep	-	-	-	-	132
Andaman & Nicobar Islands	-	-	-	-	1962
Total	2504	670	2079	600	7947

Fig. 2 : Rocky Coast, Mahabalipuram, Tamil Nadu

Table 3. Major habitat categories in Indian sea coast

Categories	Area in sq km.
Mudflat	2961
Beach/Spit	1465
Shoal/Bar	93
Coral reef	1270
Mangroves	3979
Marsh vegetation	370
Mudflat with vegetation	6125
Beach vegetation	290
Lagoon/Backwaters	2132
Flood prone area	3437
Coastal dunes	2509
Reclaimed area	1212
Paleo Beach Ridges	434
Paleo Mudflats	6821
Strand plain	1378
Salt affected area	697
Salt pans	1617

Source : Space Application Centre, 1992

estuaries and offshore islands. Indian sub-continent has a long coastline of about 8000 km distributed among 9 coastal states and Union Territories of the Andaman and Nicobar and the Lakshadweep Islands (Table 2). Moreover, there are mud flats, rocky coasts and sandy stretches which are characterised by unique biotic and abiotic properties and processes. More than half of the Indian coastline is sandy. The west coast of India is predominantly rocky consisting of silt covered rocky flats or lime stone rocks, often with overhanging cliffs formed of green to black basalt. Sandy areas, rivers and creeks interrupt the rocky coast and back waters. On the East coast, small stretches of rocky formations occur along Tamil Nadu and Andhra Pradesh.

Major habitat categories in Indian sea beaches are shown in Table 3.

3.1.2 Coastal Wetlands

Coral Reefs : In India, all the three major reef types (atoll, fringing and barrier) occur, and the region includes some of the most diverse, extensive and least disturbed reef areas of the Indian Ocean. The mainland coast of India has two widely separated areas containing reefs: the Gulf of Kutchch in the northwest, which has some of the most northerly reefs in the world, and Palk Bay and Gulf of Mannar in the southeast. There are patches of reef growth on the West coast, for example coral reefs at Malvan. The Andaman and Nicobars have fringing reefs around many islands, and a long barrier reef (329 km) on the West coast. These reefs are poorly known scientifically but may prove to

Fig. 3 : Exposed coral rubble on an island of Gulf of Mannar

be the most diverse in India and in the best condition. The Lakshadweep has extensive reefs but these are equally poorly known.

In India, the reefs are distributed along the east and west coasts at restricted places. However, all the major reef types are represented. Fringing reefs are found in Gulf of Mannar and Palk Bay. Platform reefs are seen along the Gulf of Kutchch. Patchy reefs are present near Ratnagiri and Malvan coasts. Fringing and barrier reefs are found in Andaman and Nicobar Islands. Atoll reefs are found in Lakshadweep. The absence of reef in Bay of Bengal (North-east coast) is attributed to the immense quantity of freshwater and silt brought by the rivers such as Ganga, Godavari and Krishna. Satellite imagery (SAC, Ahmedabad) shows scattered patches of corals in the intertidal areas and occasionally at subtidal depths along the West coast of India notably at Ratnagiri, Malwan and Rede Port.

The mainland coast of India has the Gulf of Kutchch in the northwest (Gujarat state) and Palk Bay and the Gulf of Mannar in the southeast (Tamil Nadu state). Other than these, important off shore island groups of India, the Andaman and Nicobar in the Bay of Bengal and Lakshadweep in the Arabian Sea also have extensive reef growth.

Mangroves : Mangrove forms one of the most extraordinary ecological formations occurring almost exclusively in the tropics.

Mangroves are salt-tolerant forest ecosystems of tropical and subtropical intertidal coastal regions near river mouths. Between latitudes 30°N and 30°S, the shoreline marsh vegetation is replaced by mangals (a community of mangroves is termed as mangal).

Fig. 4 : Mangrove Ecosystem, Wandoor, Andaman

India has only 2.66% of the world's mangroves, 6.42% of mangroves exist in the south and southeast Asia, 9.83% in America. 17.29% in West Africa, 25.69% in Australia and 46.65% of mangroves in East Africa and Middle East. The East coast is endowed with the world's largest mangrove forest, the Gangetic Sundarbans in West Bengal. As per FSI Remote sensing data (1998) the Sundarbans mangroves are of the deltaic type occupying 2123 km^2 area. The mangrove area in Orissa is nearly 200 km^2 in extent. Andhra Pradesh has 383 km^2 of mangrove area. The area under mangrove ecosystem in Tamil Nadu is about 21 km^2. Out of India's total area under the mangroves, about 57% are found on the East coast, 23% on the West coast and remaining 20% on the Bay Islands (Andaman and Nicobar). There are three types of mangroves in India, *viz.*, deltaic, backwater-esturine and insular categories. The deltaic mangroves occur on the east coast (Bay of Bengal) where the mighty rivers make the deltas. The backwater-esturine type of mangroves that exists in the west coast (Arabian) is characterized by typical funnel-shaped estuaries of major rivers (Indus, Narmada, Tapti) or backwaters, creeks, and neritic inlets. The insular mangroves are present in Andaman and Nicobar Islands, where many tidal estuaries, small rivers, neritic islets, and lagoons support a rich mangrove flora.

Estuaries and Lagoon: Estuaries are an integral part of coastal environment. They are the outfall regions of the river, making the transitional zone between the fluvial and marine environs. Historically the term estuary has been applied to the lower tidal reaches of a river.

Ecosystem diversity is reflected in the formation of estuaries at the mouth of 14 major rivers, which together account for 83% of the total catchment area and 85% of the annual runoff into seas around India (Qasim and Sengupta, 1984). These estuaries harbour lush mangrove vegetation which add subsequently to the organic production. In some locations along the coast, backwaters stretch over vast areas and have a few specialized faunal groups. The total estimated area under the estuaries is approximately 2 million hectares and the backwater is 1.9 million hectares. Two lagoons, namely, Chilka and Pulicat on the East coast, are the important wetlands as far as biodiversity is concerned.

The following are the major East coast estuaries: 1. Hugli, 2. Rushikulya, 3. Godavari, 4. Krishna, 5. Edaiyur, 6. Ennore, 7. Cooum, 8. Adyar, 9. Uppanar, 10. Vellar, 11. Kollidam, 12. Kavery, 13. Agniyar and 14. Kallar. The West coast eaturies are 1. Asthamudi, 2. Korapuzha, 3. Beypore, 4. Periyaar, 5. Kaninamkulam, 6. Vembanad, 7. Netravathi and Gurupur, 8. Gangolli, 9. Pavenje, 10. Kali, 11. Amba, 12. Mahim, 13. Purna, 14. Mahi and 15. Madovi and Zurai.

Coastal lagoon is a shallow coastal water body separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets and usually oriented parallel to shore. The ocean entrance(s) can at times be closed off by sediment deposition as a result of wave action and littoral drift. Coastal lagoons are usually found on low-lying coasts and are normally aligned with their largest diameter parallel to the seashore. A number of lagoons are present on the East and West coasts of India. There are 17 noteworthy lagoons (8 on the east and 9 on the west) along the Indian coasts. The East coast of India, extending from the international border of India and Bangladesh in the northeast, to Kanyakumari in the south is 2,545 km long. It covers the states of West Bengal, Orissa, Andhra Pradesh, and Tamil Nadu. It is over 2 million km^2 in extent and acts as the receipent of mighty rivers of the subcontinent, *viz.*, the Ganga and Brahmaputra. The other major Indian rivers that drain into the Bay of Bengal are the Mahanadi in the north, the Godavari and Krishna in the central region and the Kaveri in the south. There are also a number of minor rivers draining into the Bay. The coast is endowed with extensive areas of estuaries, brackish water lagoons, mangroves, coral reefs and seaweed beds. These coastal habitats are ecologically dynamic, rich in species and individuals and have high organic production. Hence, they carry great ecological, social and economic significance. These areas are important for the marine fisheries, serving as nurseries for many species of shellfish and fin fish. Important lagoons on the East coast of India are Chilka, Pulicat, Pennar, Bendi, Nizampatnam, Muttukadu, Muthupet and Gulf of Mannar. The lagoonal ecosystem along the West coast of India are Vembanad, Ashtamudi, Paravur, Ettikulam, Veli, Murukumpuzha Talapady, Lagoons of Bombay coast and Lakshdweep lagoons (Kavaratti and Minicoy lagoons).

3.2 Species Diversity

3.2.1 Flora

Seagrasses and sea weeds : Seagrasses occur in the infratidal and midtidal zones of shallow and sheltered localities of sea, gulf, bays, backwaters and lagoons. They are submerged monocotyledonous plants and adapted to the marine environment for completion of their life cycle under water. They occur along the East and West coasts and Andaman and Nicobar Islands. They form a dense meadow on sandy and coral rubble bottoms and sometimes in the crevices under water. In India the earlier studies revealed that about 14 species of seagrasses are found along the Indian coasts. The dominant species are *Cymodium rotundata, Enhalus acorodies. Halodule pinifolia pinifolia, H. uninervis. H. wightii, Halophila beccarii H. decipiens, H. ovalis, H. ovta, H. stipulacea, Syringodium isoetifolium, Thalassia hemprichii* and others. About 9 species of seagrasses are extensively found in Andaman and Nicobar islands. The unique ecological importance of the seagrasses for the conservation of rare and endangered animals like marine turtles, dugongs, some common echinoderms, juvenile prawns and fishes is very well known.

The seaweed communities prefer somewhat flat and rocky coastal wetlands that gradually slope towards the sea with marked tidal effect of complete submergence during high tide and successive exposure during low tide. Their distribution extends from open shore formation to intertidial lagoons, bays, rock pools, puddles, creeks and inlets beyond the low tide along the infralittoral region of the coast. Different species are abundant along the West coast, Andaman and Nicobar Islands and Lakshadweep including Minicoy. Except the places like Chilka, Pamban and Cape Comorin, their occurrence along the East coast is very scanty.

About 120 species of seaweeds have so far been recorded from the coastal wetlands in India. Some of the important seaweeds are *Enteromorpha compressa, Ulva lactuca, Acetabularia crenulata, Dictyosphaeria cavernosa, Chaetomorpha media, Caulerpa corynephora, C. paltata,*

Fig. 5 : Appa Island, Gulf of Mannar Biospher Reserve

C. tomentosum, Odium iyengarii, Halimeda macroloba; Dictyota atomarica, Ectocarpus breviarticulatus, P. olysiphonia variegata, Grateloupia indica, Sargassum duplicatum and others. These plant communities serve as sustainable life support in the field of food, shelter, fertilizer, production of iodine, potash, glue, agar, algin, vitamin, antibiotic and others.

3.2.2 Fauna

Among coastal wetlands estuaries, mangroves and coastal lagoons are biodiversity-rich areas, whereas the other brackish habitats have only a few specialized species. It is generally commented that there is a reduction in the species number in estuaries compared to adjacent seas and in-flowing river system. However, as far as Indian estuaries are concerned the statement is partly true. There is lesser number of species than in the adjacent seas, but the upper riverine ecosystem does not harbour as many species as in its estuary. It has been observed that as the distance increases from the sea the number of species decreases. Salinity becomes an important regulating factor.

The marine fauna of India is rich and varied. The coastline encompasses almost all types of intertidal habitat, from hypersaline and brackish lagoons, estuaries and, coastal marsh and mudflats to sandy and rocky shores with every degree of exposure and widely varying profile. Subtidal habitats are equally diverse. Each local habitat reflects prevailing environmental factors and is further characterised by its biota. Thus, the marine fauna itself demonstrates gradients of change throughout the Indian coasts.

A total of 199 species of corals divided among 71 genera are recorded from India including Lakshadweep, the Gulf of Kutchch, Palk Bay, the Gulf of Mannar and Andaman and Nicobar Islands. Out of these, 155 species belonging to hermatypes and 44 species ahermatypes. The Indian Ocean as a whole is known to harbour 88 genera of hermatypes (Scheer, 1984), which means 56.8 percent of the total known hermatypic genera of the Indian Ocean is present in Indian waters.

The hermatypes constitute 77.8% of the coral fauna and the ahermatypes form 22.2%. Among the hermatypes *Acropora* alone forms 20% and *Montipora* 13%. These are the two numerically rich genera. The members of the suborder Astrocoeniina constitute 34.7%,

Fig. 6 : Red gorgonid and a pair of associated crustaceans in Andamans

Fungiina 25.7%, Faviina 22.6%, Caryophylliina 8% and Dendrophylliina 9% of the coral fauna of India. (hermatypes and ahermatypes included). No genus is endemic to India. The coral reefs of southeast India, Andaman and Nicobar Islands and Lakshadweep harbour *Acropora* community (Pillai, 1971, 1986). The coral growths in Gulf of Kutchch are mostly found scattered and are in a juvenile stage.

Out of the total 32 animal phyla, 20 are represented in the marine ecosystem of India. In addion to these, 750 species belonging to two phyla of protista, *viz.*, Sarcomastigophora and Ciliophora are also known. (Table 4). These animals may constitute either migratory of resident species. The former includes pelagic crustaceans, coelentrates (medusae), cephalopod molluscs, fishes, reptiles, birds and mammals. Amphibians are generally absent in estuaries. The benthic macrofauna comprises resident species of polychaetes, molluscs, sipunculas and mud-burrowing fishes. Among invertebrates, sponges, phoronids and echinoderms generally do not prefer estuarine ecosystem. In India estuarine species diversity seems to be maximum in molluscs. About 245 species belonging to 76 genera under 54 families were catalouged. Another important taxa, polychaeta are represented by about 167 species belonging to 97 genera under 38 families. Maximum diversity has been observed in the much-studied Hugli-Matla estuary (West Bengal). Microfauna and meiofauna of Indian estuaries are not properly investigated. Estuarine mud may contain rich variety of bacteria, flagellates, ciliates nematodes, ostracodes, harpacticoid copepods, rotifers, gastrotriches, arachnids and tardigrades.

Free swimmers or nektons are important components of marine biodiversity and constitute important fisheries of the world. The dominant taxa in the nekton are fish, others being crustaceans, molluscs, reptiles and mammals. Out of a total 22,000 species of fishes known from the globe, it has been estimated that about 4,000 species occur in the Indian Ocean, of which 1,800 species are from the Indian seas. Majority of the nektonic species are found in the coastal waters.

Among reptiles, sea snakes and turtles are important and represented worldwide by 50 and seven species respectively. These are generally oceanic forms but majorities of these

Table 4. Diversity of marine biota (in number of species) in India

Taxonomic group	No. of species
ALGAE	425
PROTISTA	
1. Sarcomastigophora	750
2. Ciliophora	
ANIMALIA	
1. Porifera	500
2. Cnidaria	790
3. Ctenophora	10
4. Platyhelminthes	350
5. Gastrotricha	88
6. Kinorhyncha	9
7. Annelida	440
8. Mollusca	3370
9. Bryozoa	170
10. Entoprocta	8
11. Phoronida	3
12. Brachiopoda	3
13. Arthropoda	
a) Crustacea	2430
b) Pycnogonida	16
c) Merostomata	2
14. Sipuncula	38
15. Echiura	33
16. Tardigrada	5
17. Chaetognatha	30
18. Echinodermata	765
19. Hemichordata	12
20. Chordata	
a) Protochordata	116
b) Pisces	1800
c) Amphibia	3*
d) Reptiles	31
3) Aves	145
f) Mammalia	30
Total :	12,372

* In estuaries/mangroves.

often swim near to the shore and visit the shore at some part of their life. About 26 species of sea snakes belonging to one family, Hydrophiidae and five species of sea turtles were reported from seas around India. Oceanic islands seem to harbour more reptiles in their marine environment. All the sea snakes and four species of sea turtles are known from islands of Andaman and Nicobar. Nesting sites of an amphibious snake were reported from the shores of North Andaman Islands (Whitaker, 1985). Turtles visit the shore during breeding time to lay their eggs. The shore visit of these turtles especially the Olive Ridley is a spectacular sight on the sandy beach at Gahirmatha near Bitharkanika in Orissa. The Andaman and Nicobar Islands have best nesting beaches for the Leatherback, the Hawksbill and the Green turtle and also the Olive Ridley (Baskar, 1993).

The seashore offers a variable feeding and breeding ground for a number of birds. It is difficult to define precisely the avian component of marine biodiversity. There are some species which are exclusively dependent on marine ecosystem, while a few are generalists without much dependence on it. From the available data it has been inferred that there are 12 families, 38 genera and 145 species of birds which occur in the coastal ecosystem.

Marine mammals belong to three orders, Sirenia, Cetacea and Carnivora. About 120 species are estimated to occur in World seas. Of these, 30 are reported from seas around India. But majority of these are oceanic forms and occasionally a few individuals may get stranded on the shore. Sea cow occurs in near shore waters.

Pelagic and benthic community : The fauna of the marine ecosystem is not evenly distributed throughout the oceans. It is estimated that 90 percent of marine species live in about 50 million sq km of the total 352 million sq km. The patterns of biodiversity are determined by the availability of light in the sea. The pelagic ecosystem is dominated by plankton, which is classified on the basis of size as picoplankton (0.2-2 mm), nanoplankton (2-20 mm) microplankton (20-200 mm) and mesoplankton (>200 mm and below 1 mm). Mesoplankton includes copepods, rotifers etc. Larvae of many benthic invertebrates represent mesoplankton. Sponges, coelentrates, molluscs and echinoderms have planktonic larvae. Copepods, cladocerans, mysiids, rotifers, chaetognaths, hemichordates and protochordates have planktonic adults. Copepods are important primary grazers. About 1925 pelagic copepods have been described from marine waters of India. It is estimated that there are 3500 to 4500 species of marine phytoplankton in the world but we do not have any such data for Indian seas. Planktons occur everywhere in the sea and they differ only in the species composition and relative abundance. The rich nutrient present in the coastal waters forms the basis for the presence of many species of diatoms whereas the nutrient deficient oceanic wates contain dinoflagellates. Also there is generally a gradual decline in phytoplankton abundance from coastal to oceanic water. Plankton plays important role in the primary productivity. It also produces half of the world's oxygen and fixes 27 giga tons of carbon each year. Pelagic life also includes nekton represented by shrimp, squids, cuttle fish, reptiles, whales and sea cows. Pelagic life thus has a tremendous diversity in form and function. Dominant taxa in the nekton are fish represented by about 4000 species in the Indian Ocean, of which about 50% occur in Indian seas. Majorities of these species occur in coastal water supporting valuable fisheries.

Till recently deep sea which constitutes a major part of the ocean was perceived as species poor environment. But now the estimates of the numbers of species in the deep seas range from 5-10 million. This staggering range reflects our attempt to fill up the gap that hitherto exists in our knowledge of marine biodiversity. It is now well established that the oceans are rich in supraspecific categories, especially at the phyletic level. Out of the 32 animal phyla recorded so far from the world, 15 are endemic to the sea and five have predominantly marine occurrence. The taxonomic status of the groups representing the evolutionary branches off Protista is in a fluid state. The kingdom is divided into about 70 phyla. As many as 1000 new species are discovered every year. The assumption that terrestrial ecosystem has more species than the marine ecosystems can no longer be taken as a certainty. From the recent studies it is found that the number of benthic invertebrates include millions of species instead of 60,000.

4. SPECIAL FEATURES

Marine environments encompass an impressive diversity of ecosystems and habitats. Coral reefs, among the planet's largest and oldest structures created by living organisms, are home of dense concentrations of species with complex webs of interspecies interactions. Some coastal systems, such as, marshes, mangrove forests and sea grass beds are characterised by high biological production rather than high diversity of species. They are important both to other marine ecosystems, such as, coral reefs and larger ocean ecosystems, and to human development because of the fisheries and other resources and services they provide (De Fontaubert *et. al.*, 1996).

Regarding species counts, marine animals are more diverse than land animals at the higher, phyletic levels of taxonomic differentiation. All but one of the phyla (or major branches on the tree of life) of animals are found in the sea. In comparison, only about half of all phyla occur on land. Marine animals exhibit a correspondingly greater range of body forms and structures than are found among terrestrial species.

The biota of marine habitats also exhibits a diversity of survival strategies not found on land. The numerous planktonic life forms of the ocean drift passively in the water, relying on ocean currents to transport them to new nutritional sources and new habitats. Filter feeders sieve plankton and other floating material for food. They range from microscopic zooplanktons to barnacles to sea anemones to Baleen whales.

Reefs are home to more species than any other ecosystem in the sea. The total number of reef species in the world is still unknown, but up to 3,000 species can be found together on a single reef in south East Asia and over 1,000 on a single Caribbean reef. Only tropical rainforests estimated by some to be home to a staggering 30 million insects, have a greater number of species, although due to the vast number of fish that inhabit them, reefs contain a larger number of vertebrates than rainforests. Reefs also contain many more major animal groups (Phyla) than any other ecosystem on land or in the sea.

4.1 Faunal Distribution

The marine faunas of the India are not the same everywhere. A survey of a moderately sheltered rocky shore on the east coast will reveal a slightly different suite of species from the west and the island ecosystem which may be equally rich in species, but different groups of species will occur in each haul. Certain familiar species occur commonly on all Indian coasts; certain others may have very limited distributions, being restricted, for example, to northeast or southwest coasts. Many species may simply be more common at one geographical extreme than the other, occurring with diminishing frequency along a north-south or east-west gradient. No marine species is ubiquitous, and even the commonest and most widely distributed species do not occur at constant frequency or density over the whole of their geographical range.

5. VALUE

Coastal zone represents 18% of the earth's surface, providing space for 60% of the human population, since about 70% of the world cities with population more than 1.6 million are located in the coastal zone. 90% of the world fish catch is obtained from this zone. Interestingly, the hydrosphere of the coastal zone is only about 8% but represents about 18 to 33% of total primary production. This zone is biogeochemically more important as it buries and mineralises 80-90% of organic matter and the approximate carbonate deposition is estimated to be 50%. This area also receives discharges of suspended matter associated with elevated levels of pollutants from major rivers and this accounts for 75 to 90%. This zone has high biological potential as it serves as feeding, nursery and spawning grounds with rich biodiversity and as an intermediary biotope between marine and freshwater environments.

Coastal ecosystem plays a vital role in India's economy by virtue of their resources, productive habitats and rich biodiversity. India has a coastline of 7,947 km of which the mainland accounts for 5,853 km, Lakshadweep coast extends 132 km and Andaman and Nicobar islands have coastline of 1,962 km. Nearly 250 million people live within a distance of 50 km from the coast. The coastal area is assuming greater importance in recent years owing to increasing human population, urbanisation and accelerated developmental activities. The coastal regions are thus a place of hectic human activity and the coastal ecosystems are now highly disturbed and very much threatened. Current approaches for the management of coastal resources are not sufficient for sustainable development and the coastal environments and resources are being rapidly degraded and eroded in India.

Like the tropical rain forests, the mangroves have also played a very important role in the economics of our coastal population for thousands of years, providing a wide variety of goods and services including wood production, support for commercial and subsistence fisheries, aquaculture, salt production, shoreline protection and coastal erosion control. Mangroves form highly productive ecosystem since the inorganic nutrients, brought in by the incoming freshwater from land run-off, are trapped to form the source of energy for many organisms. A mangrove ecosystem constitutes a reservoir, refuge, feeding ground and nursery for many useful and unique plants and animals confined to this region. Through the export of decomposable organic matter into adjacent coastal waters, the mangroves provide an important nutrient input and primary energy source for many tropical estuaries. The mangrove ecosystem also protects coastal areas from sea erosion and from the violent effects of cyclones and tropical storms. The warm, calm waterways of mangroves provide shelter and rich food for many juveniles and larvae of finfish and shellfish.

Marine and coastal ecosystems and the diversity of species that compose their structure, provide a wide range of important resources and services. Food from the sea, in particular fishes, crustanceans and molluscs, is a major source of human consumption. Marine fish provided about 84 million tons of human food and livestock supplements in 1993 (FAO, 1995). The fish catch is a major source of employment for many of the world's coastal states. Small-scale fisheries harvest a large proportion of the world's catch. Fish accounts for about 16 per cent of the average individual's intake of animal protein worldwide (FAO, 1993), and the proportion is higher in many developing countries (WRI, 1996).

Marine and coastal ecosystems also provide many critically important services for humanity, such as, a) storing and cycling nutrients, b) regulating water balances, c) buffering land and protecting it against erosion from storms and waves, d) filtering pollutants, e) playing an essential role in regulating planetary balances in hydrology and climate, and f) through the ocean's photosynthetic pump, removing the primary green house gas, carbon dioxide from the atmosphere and producing one third to one half of the global oxygen supply.

Coral reefs, estuaries, lagoons and shallow coastal waters are particularly valuable for human populations because of the goods and services they provide. They are among the most biologically productive systems on the earth. Some like reefs and mangroves provide sea defenses and buffer the impacts of tropical storms, mitigating the erosive effects of waves and storm surges. All of these systems provide nurseries and feeding grounds for many coastal and pelagic species of fish including many of the most important sources of fish for human consumption.

Coral reefs form the most dynamic ecosystem providing shelter and nourishment to thousands of marine flora and fauna. They are the protectors of the coastlines of the maritime states. A few genera of corals are supposed to be older than prairies. This unique ecosystem is most productive because of its symbiotic association with algae called zooxanthellae. Though they are the builders of the most massive structures ever created by living beings in the world, they are very fragile and vulnerable to natural disturbances, and human activities. Maritime states and the coastal populations mostly depend upon the coral reef ecosystem for their day-to-day life.

Marine species provides many other products as well, including edible sea weed, ingredients for food and cosmetics, industrial chemicals and dyes and a host of other products. Medical researches have already identified a number of marine organisms that produce previously unknown bioactive compounds, including antiviral and antitumour agents, which may soon have medical applications. One compound derived from a sea sponge to treat herpes, for example, is worth US $50 to $100 million annually (Norse, 1993).

This diversity of species and ecosystem in the marine and coastal environment is the foundation for the production of goods and services valuable to human communities. While we tend to measure the ocean's value in terms of harvests of particular species used for food or other purposes, marine and coastal ecosystems provide important ecological services that are rarely perceived until they are lost. Species do not live in isolation, but are part of, and dependent upon, vast ecological communities and systems. Thus exploitation of living marine resources even of single stocks is a biodiversity issue. The conservation of biodiversity is therefore an important part of managing economically valuable living resources.

The multiple uses of the coastal zone, in general, and the mangroves in particular, like recreation, tourism, forestry, agriculture, aquaculture, housing and commercial fishing are all well known, as also the fact that this zone is very highly productive and also thickly populated. A major concern with the increasing use of this zone and its resources, not only for the present but also for posterity, relates to coastal pollution by domestic industrial, municipal and agricultural wastes and of late due to oil exploration.

5.1 Coastal and Marine Fisheries in India

Marine fisheries constitute a highly productive sector in India, a source of valuable food and employment and a net contributor to the balance of payment. For India with strong fisheries interests, the largest fish production comes from the coastal capture fisheries, which contribute on an average, 62% of the total fish production (including freshwater fish production). The marine jurisdictional area (the Exclusive Economic Zone; EEZ) is extensive, spanning 2.02 million km^2, which is 38% of the total

(5.30 m km^2) marine, freshwater and land areas of the country. In the 3651 fishing villages situated along the 8129 km coastline, about 1 million people are employed full time in marine capture fisheries. The fishing sector, which is dominated by small scale and semi-industrial operators, supports several ancillary industries, such as, boat building yards, processing plants, *etc.* Of the marine products export of 385,818 t valued at RS 1.1 billion US $ during 1997-1998, about 310,000 t (80%) was from the capture fisheries, but this formed only 11.5% of the marine fisheries contributes essentially to the domestic consumption needs, and in some measure to the export trade. Marine fisheries production, which was only 0.5 million tones in 1950, increased through the time scale and peaked to 2.7 m t in 1997. In 1997, the production (2.2 m t from inshore waters (<50 m depth) has reached the maximum harvest potential (2.2 m t) and hence scope for further increase in production from inshore waters is limited.

5.2 Marine Productivity

The Indian Ocean extending up to Antarctica has an area of about 75 million km^2, which is roughly one fifth of the world oceans. But the fish production from this ocean is only about 5 million tonnes, i.e. about one fourth of the world annual catch. In terms of organic production and yield ratio, Indian Ocean presents a miserably low percentage as compared to that of Pacific and Atlantic Oceans. That means the yield ratio, as percentage of carbon is roughly one third of the Pacific and one fourth of the Atlantic Oceans. This clearly indicates the wide gap in the potential harvestable stock especially in view of the fact that the average carbon fixation is almost similar to the Pacific, Atlantic and Indian Oceans with the western Indian Ocean indicating even slightly higher rate of fixation. The average annual gross production for all seas is estimated to be about 55-70 g/C/m^2. Assuming a 40% loss through respiration and an area of 361 million square kilometers for all the oceans, the total net production per year for all the seas is estimated at about 1.2-1.5 x 10^{10} tonnes of carbon. Ryther (1963) has subsequently modified this value to 2 x 10^{10} tonnes. This value is practically the same as that estimated for the production on land. Of the 74,917 km^2 which is conventionally taken as the Indian Ocean region 3.1 million km^2 is considered as coastal and near shore regions which sustain the major part of the fishery and have an annual net production of 560 x 10^6 tonnes. During the Galathea Expedition it was found that the rate of organic production was practically high anywhere in the tropics in shallow waters, which was at variance with the observations of the earlier expeditions, which indicated a comparatively low productivity in the tropical seas. But with intensive exploration during the International Ocean Expedition (1959-65) it was revealed that some of the world's highest values of primary production are in the upwelling regions of Somalia and South of Arabia. Based on the measurements made by several vessels during different seasons Qasim (1977) estimated the production of the Indian Ocean at about 4 x 10^9 tonnes. But there is quite a large variation both in space and time in the Indian Ocean in general and coastal areas in particular. The reasons for these seasonal and spatial variations can be attributed to various factors.

6. THREATS

Though human impacts on marine and coastal biodiversity are less understood and publicised than those on its terrestrial counterpart, their potential effects are no less threatening. The major direct threats to marine and coastal biodiversity can be divided into five interrelated categories: pollution (from land based and other sources), over exploitation of marine living resources, introduction of alien species, habitat degradation caused by coastal development and, global climate change and ozone depletion.

In India we have a combined river length of 45,000 km comprising of 113 major and minor rivers. The health status and the biological diversity of the Indian estuarine ecosystem is deteriorating day by day due to man-made activities and dumping of enormous quantities of sewage into the estuary has drastically reduced the population of the mature fishes. It has also caused considerable ecological imbalance and resulted in large scale disappearance of their flora and fauna. Further, introduction of untreated municipal waste-water and industrial effluents into these water bodies leads to serious water pollution including heavy metal pollution, which gets biomagnified and reaches man through food-chain implications.

The population influx and increased tourism in some coastal places are responsible for indiscriminate destruction of marine resources. Recent spurt in aquaculture activities increased the demographic pressure and the related environmental manipulation. All the above mentioned reasons leads to biodiversity conservation problems in India, which may be reduced by taking examples from other regions of the world where the marine ecosystem is conserved at a larger scale.

7. CONSERVATION

The belated realisation of the need for action after the damage becomes apparent

Fig. 7 : Catamarans on the sea shore In Gulf of Mannar Biosphere Reserve, Tamil Nadu

(and often when it is too late) perpetuates this destructive cycle. Communities that depend on marine resources face the long-term challenge of sustainability yet are often confronted with immediate economic hardship. For developing country like India, action is hardly ever preventive, and is usually undertaken only after irreversible damage has occurred.

In the face of this increasing uncertainty, the adoption of a precautionary approach is a *sine qua non* to the conservation of marine and coastal biodiversity. The precautionary principle which is now widely recognised as a emerging part of customary international environmental law, requires that no harmful action be undertaken until all the effects on marine and coastal biodiversity have been clearly identified and weighed against the expected benefits. Moreover, this precautionary approach should cover all the activities of past, present and future, bearing in mind the cumulative impact that these activities combined will have on marine biodiversity.

Keeping the above facts and figures in mind several international instruments have been with Parties to achieve the Convention's objectives with respect to marine biodiversity. The following are the important instruments with greatest potential for synergy with the Convention on Biological Diversity.

- United Nations Convention on the Law of the Sea, Montego Bay, (UNICLOS).
- Agenda 21, Rio de Janeiro, 1992.
- UN Agreement on Straddling and Highly Migratory Fish Stocks, New York, 1995, and FAO Code of Conduct for Responsible Fishers, Rome 1995.
- The UN General Assembly Drift-Net Resolution 46/15, 1991.
- UNEP Conference on Protection of the Marine Environment from Land Based activities, Washington, 1995.
- Protocol on Substances that Deplete the Ozone Layer, 1987 (Montreal Protocol).
- The Framework Convention on Climate Change, Rio de Janerio, (FCCC).
- United Nations Conference on the Sustainable Development of Small Island Developing States, Bridgetown, 1994.
- Convention on International Trade in Endangered species, Washington, 1973 (CITES)
- International Convention for the Prevention of Pollution from Ships (MARPOL). 1973-1978.
- The Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, London, 1972 (London Convention).
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, 1971 (Ramsar Convention).
- International Convention for the Regulation of Whaling, Washington, 1946 (ICRW).

India has signed and ratified several international conventions relating to oceans and related activities. The important ones are the following: MARPOL 1973/1978; London Dumping Convention 1972; Convention on Civil Liability for Oil Pollution Damages (CLC 1969) and its Protocol 1976; Fund 1971 and its Protocol 1979 and Convention on Biodiversity (1992). Many acts and rules related to coastal and marine activities exist in the country. The following are the important ones. Indian Fisheries Act 1897 and its Amendments 1920 and 1980; Indian Ports Act 1902; Merchant Shipping Act 1974; Wildlife Protection Act 1972; Water (Prevention and Control of Pollution) Act 1974; Indian Coast Guard Act 1974; and Marine Zones of India (Regulation of Fishing by Foreign Vessels) Act 1981 and Environment Protection Act 1986. As per the Coastal Regulation Zone Notification, the coastal states must prepare a Coastal Zone Management Plan identifying and classifying the CRZ areas within 1 year from the date of CRZ notification (Ministry of Environment and Forests Notification, August, 1994). The CRZ notification also stated that during the interim period till the coastal zone management plans are prepared and approved, all developments and activities within CRZ should not violate the provisions of this notification. As per the Environmental Protection Act, 1986, Coastal Regulation Zone Notification 1991, the following activities are banned in the land part of the country. 1. Setting up and expansion of new industries, fish processing units except those, which require waterfront. 2. Manufacture or handling or storage or disposal of hazardous substances and discharge of untreated waste and effluents from industries, cities or towns and other human settlements. 3. Dumping of fly ash from thermal power stations and other solid waste dumping. 4. Land reclamation, bunding or disturbing the natural course of seawater. 5. Mining of sand, rocks and other substrate materials other than raw minerals. 6. Drawal of ground water within 200 m of high tide level. 7. Any construction activity between the low and high tide line. 8. Altering of sand dunes and other natural features including landscape changes.

In the ecologically sensitive areas, construction of civil and other man made structures like break waters for harbour, floating industries, laying of pipelines, reclamation of sea and its bed, sea bed mining and ship breaking activities are prohibited. However, they can be permitted at a no-impact distance from the outer limit of environmentally sensitive areas. Discharge of untreated and treated domestic, industrial and aquaculture wastes, nuclear and thermal power plants, dredged materials and operational discharges are prohibited in environmentally sensitive areas. Although marine ecosystems have a larger coverage than the other ecosystems these are poorly represented among world's protected areas. Only 100 of the 1162 National Parks of United Nation List include or adjoin reef ecosystem. In India four out of the 583 protected areas (National Parks 89, Sanctuaries 482 and Biosphere Reserves 12) are with reference to marine ecosystems. These are Gulf of Mannar, Gulf of Kutchch, Marine National Park of Andaman Island (Mahatma Gandhi Marine National Park) and Rani Jhansi Marine National Park in Andaman Island. The protected areas (a total of 102) of the Andaman and Nicobar Islands cover substantial areas of marine waters also. The Gujarat State Government in 1980 constituted the first Marine Sanctuary in India in the Gulf of Kutchch to cover an area of 456 sq km. From Okha to Jodiya having a core area of 162.9 sq km. The second Mahatma Gandhi Marine National Park was notified on May 24, 1989 in Andaman and it covers an area of 281.5 sq km.

Consequently, effective research and extension programmes which are critical to the conservation and management of marine ecosystem, have been given priority. The following institutions under the Government of India are engaged in the research and extension as well as conservation and management of the Marine and Coastal Ecosystems of India: Ministry of Agriculture, Department of Agriculture and Cooperation; Fishery Survey of India, Central Institute of Fisheries, Nautical and Training, Integrated Fisheries Project, Central Institute of Coastal Engineering for Fishery, Development of Coastal Marine Fisheries, Development of Fisheries Harbours, Assistance for Strengthening Fish Marketing Infrastructure, Fish Farmers Development Agency, Brackishwater Fish Farmers Development Agency, Deep-sea Fishing, Fisherman Welfare Schemes. Department of Agriculture Research and Education, Central Marie Fisheries Research Institute, Central Inland Capture Fisheries Research Institute, Central Institute of Freshwater Aquaculture, Central Institute of Brackish water Aquaculture, Central Institute of Fisheries Technology, Central Institute of Fisheries Education, National Bureau of Fish Genetic Resources, National Research Centre on Coldwater Fisheries, Ministry of Commerce, Ministry of Food Processing Industries, Ministry of Environment and Forests, Zoological Survey of India, universities such as Annamalai University, Centre of Advanced Studies on Marine Biology, Madurai Kamaraj University, Andra University, *etc.*

7.1 Actions and relevant international agreements for conservation of marine ecosystem

The need to devise methods to manage and protect marine ecosystems and resources became widely recognized internationally during 1950s and early 1960s. Thus, the World Conference on National Parks (1962) considered the need for protection of coastal and marine areas but the development of practical responses to this need required a legal framework for addressing the sovereignty and jurisdictional rights of nationals to the seabed, beyond the customary three-mile territorial sea. In 1958 three conventions known collectively as the Geneva Conventions on the Law of the Sea were adopted, *viz.*, the Convention on the Continental Shelf, the Convention on the High Seas and the Convention on Conservation of the Living Resources of the High Seas.

Increasing technical capability to exploit mineral resources on or beneath the seabed and to exploit fishery resources in deep waters led to the long-running Third United Nations Conference of the Law of the Sea, held between 1973 and 1982. During the 1970s there was increasing recognition and mounting concern regarding the regional nature of the environmental problems of the marine living resources of the world. In 1971, the Convention of Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) was developed, defining wetlands to conclude many coastal marine habitats. In 1972, the Convention for the Protection of the World Cultural and Natural Heritage (known as the World Heritage Convention) was developed to give international recognition to areas 'of outstanding universal value'; these could include marine areas.

Also in 1972, the Governing Council of the United Nations Environmental Program (UNEP) was set up and given the task of ensuring the emerging environmental problems and adequate consideration by Governments. In 1975, IUCN conducted a conference on Marine Protected Areas in Tokyo. The report of that conference noted increasing pressures upon marine environments and called for the establishment of a well-monitored system of Marine Protected Areas representative of the world's ecosystems. In 1981, a workshop was organized as a part of the UNESCO Division of Marine Science COMAR (Coastal and Marine) Program to consider research and training priorities for coral reef management. An outcome of this workshop, which was held in conjunction with the IV International Coral Reef Symposium, was the publication of the UNESCO Coral Reef Management Handbook. In 1982, the IUCN Commission on National Parks and Protected Areas (CNPPA) organized a series of workshops on the creation and management of marine and coastal protected areas as part of the III Worlds Congress on National Parks held in Bali, Indonesia.

UNESCO organized the First World Biosphere Reserve Congress in Minsk, USSR in 1983. In that meeting it was recognized that the Biosphere Reserve concept is potentially applicable to the marine environment and that an integrated, multiple use Marine Protected Area can confirm to all of the scientific, administrative and social principles that define a Biosphere Reserve under the UNESCO Man and Biosphere (MAB) Program.

In 1987, the World Commission on Environment and Development (WCED) published its report "Our Common Future", which highlighted the importance of marine conservation. In November of the same year, the General Assembly of the United Nations welcomed the WCED report. At the same time, it adopted the "Environmental Perspective to the year 2000 and Beyond" which was developed by UNEP in tandem with the WCED report. In 1988 UNEP and IUCN published the three volume "Coral Reefs of the world", a global directory of coral reefs prepared by then IUCN Conservation Monitoring Centre. These and other publications have highlighted the series of threats, which confront marine areas around the world.

All these above-mentioned experiences helped to formulate the marine conservation at a global level at a larger scale.

7.2 Convention on Biological Diversity

Under the Convention, each Party is required to protect components of coastal and marine biodiversity within its national jurisdiction. As defined by the law of the sea, embodied in the United Nations Convention on the Law of the Sea (UNCLOS), coastal States can exercise jurisdictional rights over vast areas of the marine relam, including inland waters, the terrestrial sea, the contiguous zone, the Exclusive Economic Zone (EEZ), and parts of the continental shelf.

Action in the following eight general categories will be critically important in the application of the Biodiversity Convention to the marine and coastal realm. The first five areas are those identified in the Jakarta Mandate (see below). The last three actions aim to support implementation of the Mandate. While these eight areas of action are priorities in most marine and coastal ecosystems, each Party will select or develop its own means of implementation and priorities within these eight areas. The action items are the following: 1. Institute integrated coastal area management (ICAM), including community-based coastal resource management, and prevention and reduction of pollution from land-based sources; 2. Establish and maintain marine protected areas for conservation and sustainable use; 3. Use fisheries and other marine living resources sustainably; 4. Ensure that mariculture operations are sustainable; 5. Prevent introduction of and control or eradicate harmful alien species; 6. Identify priority components of biodiversity and monitor their status and threats to them; 7. Build capacity to study and share the benefits from marine genetic resources; 8. Take responsibility for transboundry harm and global threats to marine biodiversity.

Action Items 1 to 5 correspond to priorities identified in the Jakarta Mandate adopted by the second Conference of Parties (COP) in 1995. Action Items 6 through 8 are recommended, as actions needed to support the first five items.

This ambitious set of actions reflects the Biodiversity Convention's comprehensive approach that seeks conservation and development in every sector that affects biodiversity. Implemention of these actions will require major changes in policies and programs in all Parties to the Convention, both developed and developing. Many countries, however, have very limited resources to devote to reshaping policies and institutions for sustainable use and conservation. This is especially true for developing countries.

8. FUTURE DIRECTION

Thirst for understanding changes in marine biodiversity resulting from human activities, calls for ecological and oceanographic research spanning a broad range of spatial scales, from local to regional, and over approximately long time scales for capturing the dynamics of the system under study. This paper proposes a fundamental change in the approach by which biodiversity is measured and studied in the ocean by emphasizing integrated regional-scale research strategies within an environmentally relevant and socially responsible framework. This is now possible because of recent technological and conceptual advances within the ecological, molecular, and oceanographic sciences. A major goal of this paper is to improve the diversity of life in the sea, in order to improve conservation and management plans.

A well-defined set of biodiversity lessons learnt in other regions of the world is proposed for implementation in several different types of regional-scale marine ecosystems. These ideas will permit meaningful comparisons across different habitats of the causes and consequences of changes in biodiversity due to human activities. This lesson requires significant improvement in taxonomic expertise for identifying marine organisms and documenting their distributions, in knowledge of local and regional natural patterns of biodiversity, and in understanding of the processes that create and maintain these patterns in space and time.

Biodiversity Conservation in India can be best managed by the following guidelines :

- Clear understanding of what is valuable.
- Application of anthropogenic objectives of maintaining biodiversity so that it is of actual or possible value to humankind.
- Local people's priority recognized.
- Biodiversity Conservation practiced with a precise definition and with clear targets.
- Need for rapid expansion in taxonomy in order to interpret, manage, conserve and use biodiversity sustainably and need to pull together existing data from all sources by forming an information network of all agencies in the country.
- Knowledge about the extent and state of biodiversity is necessary to understand the measures of Biodiversity.
- Priorities for Biodiversity conservation identified to understand what values are important, which genes/species/habitat, how much biodiversity should be conserved and how should biodiversity be conserved.
- To achieve best biodiversity conservation objectives improved methodologies practiced for different projects, more effective policy and targeted projects with highest priority.

The pressure on natural habitats associated with increasing population and economic growth will continue to lend to the loss of biological diversity. Recognition of the scale of problem, the nature of the underlying causes and the limited resources available to counteract powerful destructive trends will definitely lead to the best way of conserving the Biological Diversity of the Marine Ecosystems of India.

9. REFERENCES

Baskar, S. 1993. *The status and ecology of Sea Turtles in the Andaman and Nicobar Islands.* Center for Herpectology Publication, Madras, 41pp.

De Fontaubert, A. C. Dowenes, D.R. and Agardy, T.S. 1996. *Biodiversity in the seas: Implementing the Convention on Biological Diversity in Marine and Coastal Habitats.* IUCN Gland and Cambridge. (vii+82pp).

Food and Agricultural Organization of the United Nations (FAO). 1993. *Maritime Fisheries and the law of the sea: A decade of Change.* Fisheries Circular No. 853.

Food and Agricultural Organization of the United Nations (FAO). 1995. *The State of World Fishery and Aquaculture.* Rome: FAO.

Norse, E. ed. 1993. *Global Marine Biological Diversity: A Strategy for Building Conservation into Decision Making.* Washington, D.C. : Island Press.

Pillai, C.S.G. 1971. Composition of the coral fauna of the southern coast of India and Laccadives. *Symp. Zool. Soc. London.* **28** : 301-327.

Pillai, C.S.G. 1986. Recent corals from southeast coast of India. In: *Recent advances in Marine Biology.* Today and Tomorrow. New Delhi. 107-201.

Qasim, S.Z. 1977. Biological productivity of the Indian Ocean, India. *J. Mar. Sci.* **6**: 122-137.

Qasim, S.Z., and Sengupta, R. 1982. Marine Environment. In : *State of the Environment, Some Aspects.* 29 pp. (Mimeo).

Ryther, J.H. 1963. International Indian Ocean Expedition: special issue on marine biology. *American Institute of Biological Sciences Bull.* **13** : 48-51.

Scheer, G. 1984. The distribution of reef-corals in the Indian Ocean with a historical review of its investigation. *Deep-Sea Research* **31** : 885-900.

Whitaker, R. 1985. *Endangered Andamans: Managing Tropical Moist Forests.* Environmental, serving group, WWF India, MAB, Department of Environment New Delhi 54 pp.

World Resource Institute (WRI). 1996. *World Resources,* 1996-97. New York: Oxford University Press.

Islands

A. K. Das

ENVIS–*Zool. Surv. India*
Ecosystems of India : 317-347, 2001.

Islands

A. K. Das

Zoological Survey of India
'M' Block, New Alipore, Kolkata-700 053

1. INTRODUCTION

Islands represent fragile, ecologically sensitive and biogeographically significant ecosystems. These are the living laboratories on earth for demonstrating the process of organic evolution, speciation and adaptive radiation. It is well known that Charles Darwin developed the primary concept of organic evolution by natural selection largely based on data derived from the biota of Galapagos islands, located about 1000 km west of South America. He brought out his epoch-making book "On the Origin of Species by means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life" in 1859. Coincidentally, another eminent naturalist, Alfred Russel Wallace simultaneously but independently put forth identical views on organic evolution as conceived by Darwin, stressing natural selection as the prime factor. Wallace also developed his concept after studying the biota of another island groups, the Malayan archipelago which lie on the eastern side of the globe. Afterwards he wrote a classic book "Island Life" which is still considered very useful and first of its kind. Since then, island biota with its simplicity and diversity has drawn the attention of naturalists, biologists, ecologists and biogeographers throughout the globe. As a result, considerable information and data are now available on different aspects of island life revealing clearly the need and significance of conservation of this fragile and precious ecosystem.

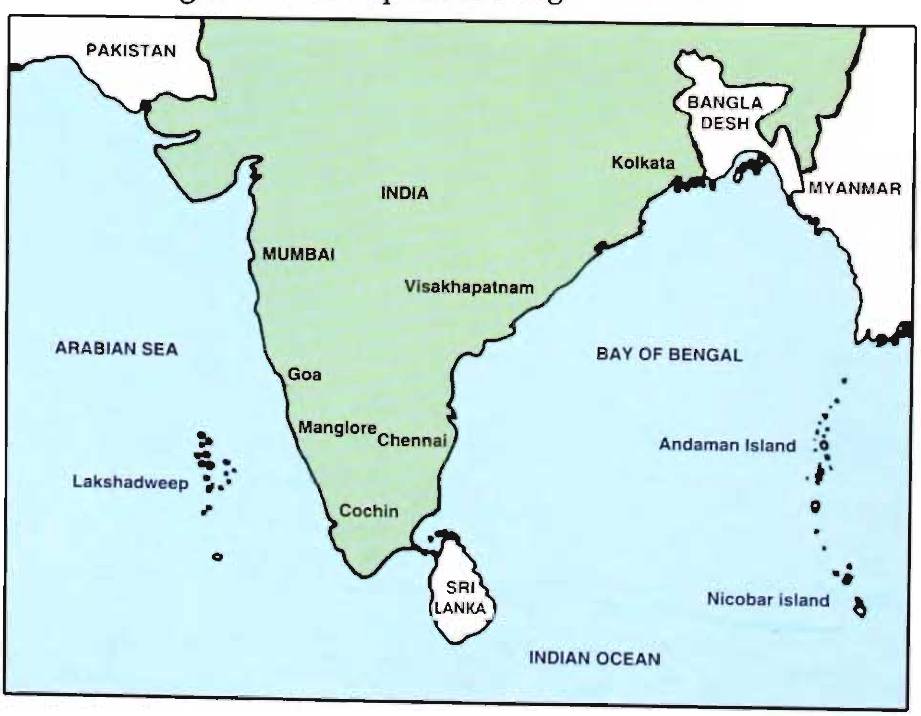


Fig. 1 : Showing the location of Lakshadweep and Andaman & Nicobar islands

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

2.1 Classification of islands

From geographical point of view, islands are land masses surrounded by water barriers. Biogeographical definition of islands is simply an extention of above and states that islands are water surrounded land masses where fauna is simplified when compared to that of a continent (Udvardy,1969). Wallace (1880) categorised islands into two distinct types– continental and oceanic. According to him, continental islands are detached fragments of continents consisting of complex continental rocks and always inhabited by terrestrial mammals and amphibians. On the other hand, oceanic islands are originated in the ocean, comprising of volcanic rocks and corals and not inhabited by terrestrial mammals and amphibians. Present information on island fauna reveals that such distinction of island types may hold good geologically but not faunistically as mentioned above.

Darlington (1966) made some arbitrary classification of islands for analysing distribution pattern of island life, more specially vertebrate animals. He grouped islands under three broad categories, such as, (i) Recent continental islands (either tropical or non-tropical), (ii)Fringing archipelago (all tropical) and (iii) Other islands and archipelago (not arranged by climate). Carlquist (1965) contended that an island may be continental in origin if its biota contains phylogenetically primitive forms with poor dispersal ability. Since biota of continental islands is the remnant of a formerly continuous mainland biota, its phylogenetically primitive nature is expected. At the same time, continental islands may possess some subsequent immigrants and introduced species by human agency. Thus continental islands may harbour both harmonic and disharmonic flora and fauna. On the other hand, oceanic islands would possess waif biota since this type of islands is usually inhabited by immigrants which reached the islands by long distance dispersal.

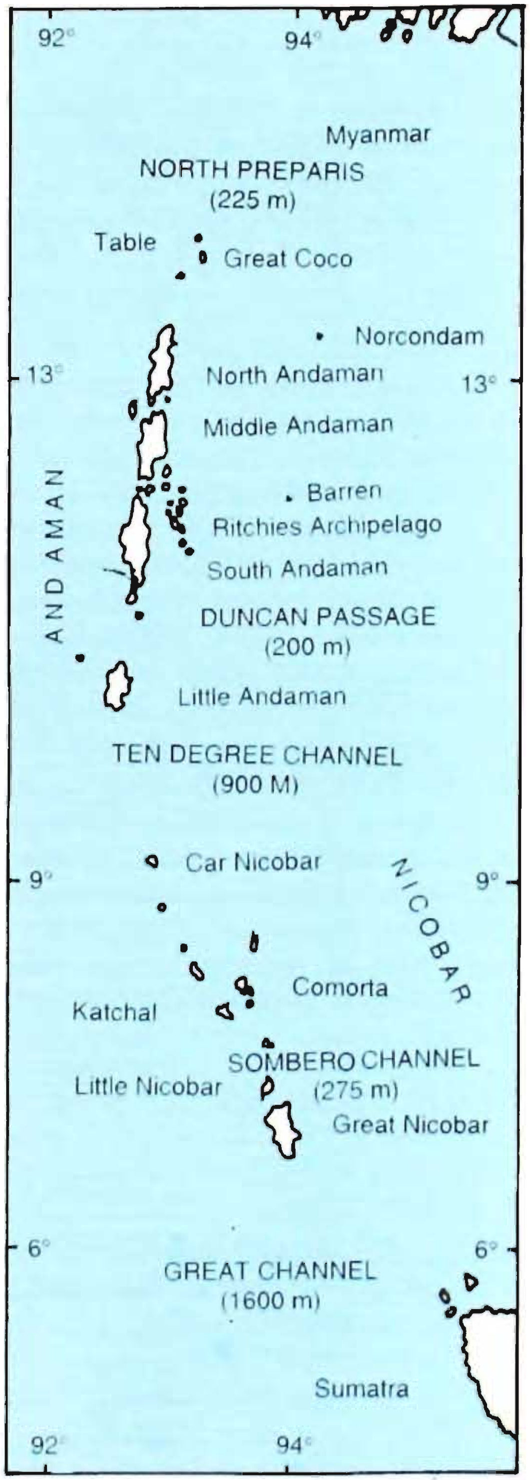


Fig. 2 : Andaman and Nicobar archipelago

2.2 Indian Islands

India includes two different island groups, namely, the Andaman and Nicobar islands lying in the Bay of Bengal and the Lakshadweep in the Arabian Sea.

2.2.1 Andaman & Nicobar Islands : These Bay islands consist of an arcuate chain of more than 500 islands, islets and rocky outcrops running north to south in the Bay of Bengal between 6^0 45′ N and 13^0 30′ N latitudes and 90^0 20′ E and 93^0 56′ E longitudes, extending over 800 km. These islands are the summits of a submarine mountain range, lying on the great tectonic suture zone that extends from the Eastern Himalaya along the Arakan Yoma of lower Myanmar in the north to Summatra and Lesser Sundas in the south. They comprise main island chains of Andaman and Nicobar, Ritchie's archipelago and the two outlying volcanic islands–Barren and Narcondam. These islands occupy a total land area of 8293 sq km, of which 6340 sq km belong to the Andaman group and the remaining 1953 sq km belong to the Nicobars

The Andaman group consists of 324 islands, out of which only 25 are inhabited. The main part of this island group is collectively known as the Great Andaman, comprising five closely adjoining islands, namely, North Andaman, Middle Andaman, South Andaman, Baratang and Rutland islands. All of these are separated from adjacent islands by narrow channels. To the contrary, the southernmost island of this group, known as Little Andaman, is separated from the Great Andaman by a deep channel, called Duncan Passage.

The Nicobar group comprises 28 islands, 13 of which are inhabited. These are found in three distinct clusters, namely, Car Nicobar, Middle Nicobar and Great Nicobar.

From geological point of view the Bay islands are oceanic. But, these island chains start considerably nearer from the mainland. The nothernmost part of these islands (North Andaman) is only 285 km apart from Cape Negaris of Southern Myanmar and isolated by a deep channel known as the North Preparis having about 225 m depth. The southernmost island (Great Nicobar) of this island chain is about 189 km away from the Acheen Head of Western Sumatra and isolated by the Great Channel having 1600 m depth. There are also other deep channels, namely, the Ten Degree Channel (140 km width and 900 m depth), the Duncan Passage (46 km width and more than 200 m depth), and the Sombero Channel (58 km width and 275 m depth). The first one isolates the Andaman group of islands from the Nicobars, the second one separates the Great Andaman group from the Little Andaman and the third isolates the Middle Nicobar cluster from the Great Nicobar. In addition to these, there is another water barrier having 88 km width and 250 m depth between Car Nicobar and the Middle Nicobars. Since Pleistocene sea level lowering never exceeded 160 m (Gascoyne *et al.*, 1979) it is quite evident that permanent water barriers not only isolated these island chains from the adjacent mainlands but also one of its segments from the other some 100 million years ago during the Upper Mesozoic.

These islands usually have undulating terrain with spur hills and intervening valleys. The highest peak in the Andaman is the Saddle Peak (726 m), located in North Andaman and that of the Nicobar group is the Mount Thullier (670 m) lying in Great Nicobar. There are, however, some more or less flat islands like Car Nicobar and Trinket.

The climate of these islands is tropical, that is, warm, moist and equable. Variation of temperature is 23^0-32^0C and relative humidity is high (over 80 percent). The islands receive heavy rainfall usually from May to December, averaging about 3000 mm per anum under the influence of both south-west and north-east monsoons.

2.2.2 Lakshadweep : This archipelago is the smallest territory in India which is irregularly scattered in the South Arabian sea

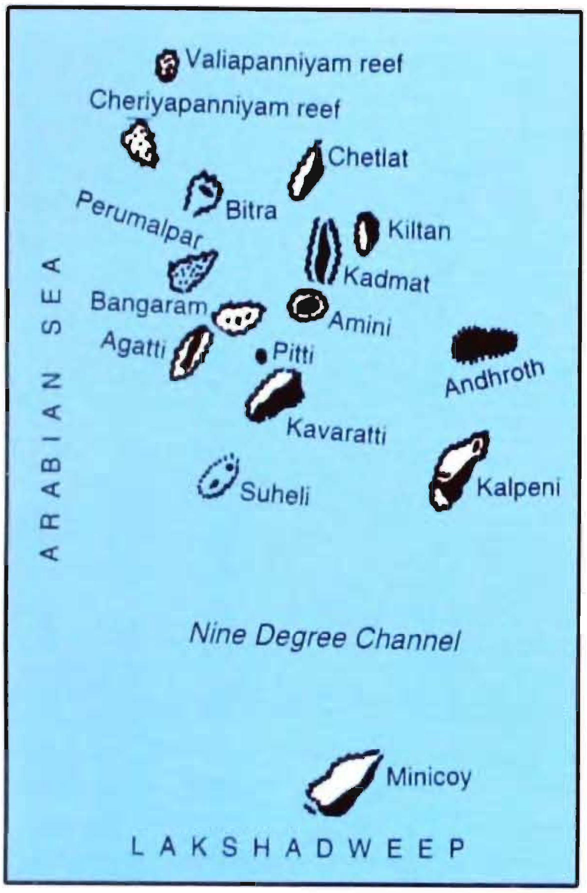


Fig. 3 : Lakhadweep archipelago

between 8^0N-$12^0$30'N latitudes and 71^0E-74^0E longitudes. It is located about 220-440 km away from Indian mainland, Kochi in Kerala and stretched about 2500 km in the ocean along north-south direction.

This archipelago comprises 36 islands including 12 atolls, 3 reefs and 5 submerged banks, occupying a total land area of only 32 sq km. However, with lagoons it occupies a vast area of about 4200 sq km. Only 11 islands are inhabited in this archipelago. These are : Agatti, Amini, Andrott, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy. The last one is the southernmost island of this archipelago and separated from the rest of the islands by 9^0 Channel of about 180 km widh and from the neighbouring Maldives in the south by 8^0 Channel of about 120 km width.

The Lakshadweep, Maldive and Chagos archipelagos form a contingUous mountain ridge in the ocean. This ridge is considered to be in continuation of the Aravalli mountain range of Gujarat and Rajasthan of the Indian mainland since late Tertiary times (Mukundan, 1979). The atoll rises steeply from 1500-3000 m depth. A gradual accretion of marine sediments for a long period has possibly led to the formation of these islands. Fringing reefs were rapidly built and strengthened by the growth of stony corals. Sand banks developed along the reef margins and their growth is quite poor in the vicinity of the reef opening.

The islands are flat, rising only 3-5 m above sea level. These are enclosed within coral reefs and situated generally on the windward reef flat at eastern sides. There are no natural forests, hillocks, bay, creeks, estuary, river, lake or freshwater tank. The atolls and submerged reefs are roughly crescent shaped. The lagoons are saucer-shaped shallow water depressions varying from 1 sq km to 150 sq km in area and 2-15 fathoms in depth. Coral reefs in the western side and the island proper in the eastern side protect the lagoons from severe wave action. Reefs are open in their disposition, with surge channels constantly exchanging water between the surrounding sea and the lagoon. These channels are of navigable depth, enabling the local people to use the lagoons as natural harbours.

The islands slope abruptly in the eastern side resulting in steep shelf close to the shore. The beaches in this side are subjected to severe wave action. In the western side, these are sheltered and protected from the wave action.

Top soil layer of these islands is thin and quite porous. It retains very little moisture. It is formed mostly of fragmented coral lime, stones and sedimentary rocks. The climate is tropical, warm and humid. Temperature varies from 17°C to 37°C with slight increase from south to north. Average annual rainfall in the islands is 1600 mm under the influence of both south-west and north-east monsoosn.

3. BIOLOGICAL DIVERSITY

3.1 Habitat divesity

3.1.1 Andaman and Nicobar islands : These islands are adorned with three natural ecosystems, namely, forests, mangroves and coral reefs. But their terrestrical part, *i.e.*, islands as per geographical definition harbours mainly the forests and partly the mangroves. The latter harbours a rich diversity of terrestrial fauna like birds, mammals, insects, mites, *etc.*, besides marine fauna mainly polycaetes, molluscs and crabs in the mangrove fringed littoral area.

Being influenced by tropical climates and both south-west and north-east monsoons with abundant rainfall, all the major islands support a luxuriant growth of evergreen, semi-evergreen, moist deciduous and littoral forests spreading from mountain tops to the sea coast. Champion and Seth (1968) recognised 7 major natural forest types, namely, Giant evergreen, Andaman tropical evergreen, Southern hill-top evergreen, Andaman semi-evergreen, Andaman moist deciduous, littoral and tidal swamp/ mangroves. There are also few more forest types, such as, crane brakes, bamboo brakes, *etc.* In addition to these, grasslands are also present in Car Nicobar and Nancowary islands. Andaman forests have a profuse growth of epiphytic vegetation comprising mostly orchids and ferns. Excepting grasslands and magroves all other forest types can not be distinctly demarcated. Rather, they imperceptibly merge into each other forming an intimate mixture.

The coast line of these islands covers about 1962 km. It is quite wavy with large number of bays, lagoons and serpentine creeks and, rocky, coralline and muddy beaches. At several places tidal creeks penetrate far inside the land and form outlets for freshwater streams. The continental slope is narrow with a steep slope.

Except in Great Nicobar there is no perennial freshwater river in these islands. But, a few rain fed streams which dry up in summer are present in Andaman islands. There is no typical estuary in these islands since there is no tidal freshwater river as mentioned above. Even then, these islands support rich mangroves which are estimated to be about 1190 sq km, covering about 18 per cent of the total Indian mangroves. Here mangroves occur either in luxuriant formations or in patches along the tidal creeks, sea inlets and sheltered bays. They are found to encroach coralline substrata in some areas of these islands (Das and Dev Roy, 1989 ; Das, 1996).

There are also luxurious coral formations around these islands. Corals have grown in the form of fringing reefs on the estern side whereas they constitute barrier reef on the western side. In these islands corals grow in the direction of the prevailing wind and in the channels which are usually protected from winds due to presence of islands on both the sides (*e.g.*, Camorta-Nancowry complex and channels of South Andaman). Moreover, in several places mangroves provide a sheltered environment for corals from severe wave action and abrupt deposition of land drawn sediment.

3.1.2 Lakshadweep : All the islands of this archipelago are flat and fully enclosed within coral reefs. Due to such identical topography and uniform climatic condition vegetation of these islands is very similar in character. Natural vegetation mostly comprises herbaceous and shruby bushes. All the islands are almost covered with coconut groves excepting the rocky Pitti islet.

These islands possess a typical reef lagoon system. Here reefs offer excellent examples of typical in-shore marine ecosystem.

3.2. Species Diversity

3.2.1 Flora

Andaman and Nicobar islands : The flora of these islands are very rich with 2395 plant species. In addition to these, 118 species of

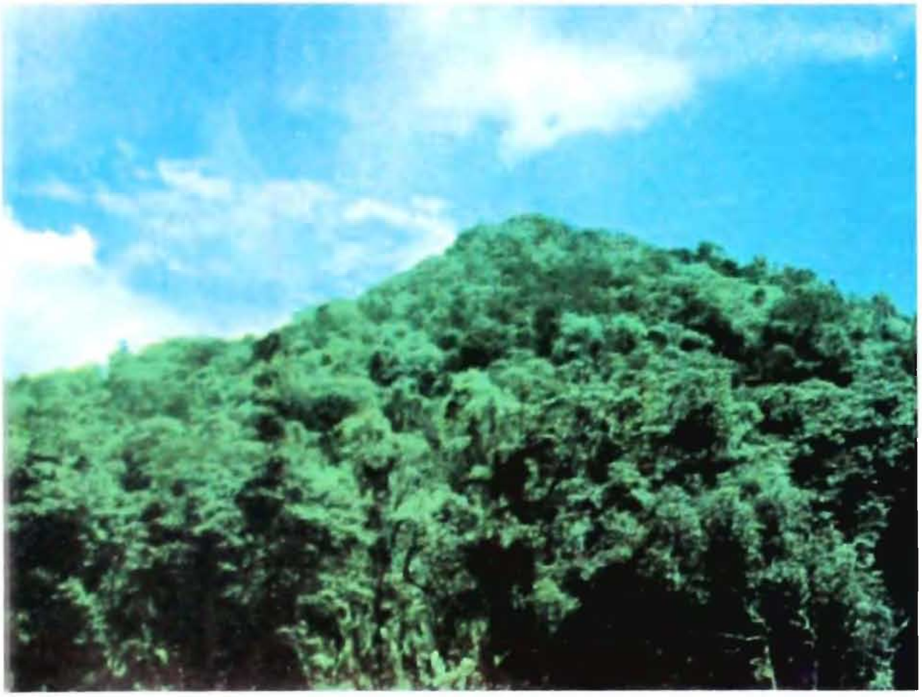


Fig. 4 : Southern hilltop tropical evergreen forests

marine algae have also been reported from here (Table 1). Terrestrial flora comprise 2200 species of angiosperms, 130 species pterydophytes, 50 species of lichens and 15 species of mosses and hepatics.

The Giant evergren forests are the most luxuriant type of multistoreyed forests on these islands and form the climatic climax vegeation. They occur near banks of larger streams where soils are deep and alluvial. The dominant speces found in this forest type are *Dipterocarpus* spp., *Calophyllum soulattri,, Artocarpus chaplasa, Sideroxylon longepetiolatum, Amoora wallichii, Sterculia campanulata, etc.*

Fig. 5 : Mangroves, *Nypa fruticans* on the Bank of Galathea river, Great Nicobar

Andaman tropical evergreen forests occur throughout the islands as caps to hills, with the slopes having moist deciduous forests. This forest type is not as luxuriant as the Giant evergreen forests, particlarly in the size of the top storey. Moreover, deciduous species are more frequent in this type. *Artocarpus* spp, *Planchonia andamanica, Hopea odorata, Endospermum chinense, Xanthophyllum andamanicum, Myristica andamanica, Baccarea sapida, etc.,* are dominant species occurring in this forest type.

The Southern hill-top evergreen forests occur on hill tops and sometimes on steep slopes lower down on poor soils and are usually exposed to high winds. The vegetation is comparatively stunted in growth. The significant species occurring in this forest type are : *Diptercarpus costatus, Mesua ferrea, Canarium manni, Hopea helferi, Cratoxylon formosum, Euphorbia trigona, etc.*

The Andaman semi-evergreen forests are also luxuriant type of forests where climbers are usually plenty. This type of forests includes both deciduous and evergreen species. It is mostly confined to the main valleys on well drained immature alluvial soil. *Terminalia bialata, T. procera, Pterygota alata, Albizzia chinensis, A. lebbeck, Artocarpus lakoocha, A. chaplasa, Pterocarpus dalbargiodes, Legerstroemia hypoleuca* are the common species in this forest type.

The Andaman moist deciduous forests are confined to hilly ground, usually not extending beyond 100 metre. These forests are multi-storeyed, top canopy of which is formed by the giant trees of about 40 m in height, 3 m in girth and heavily buttressed. These forests are the most important source of a number of valuable commercial timbers like Paduak *(Pterocarpus dalbargiodes)*, Marble wood *(Diospyros marmorata)*, White Bombway *(Terminalia procera)*, Chooi *(Sageraea elliptica)*, Koko *(Albizzia lebbek)*, White Dhup *(Canarium euphyllum), etc.*

The Littoral forests are found on alluvial high level soil beyond the reach of the sea.

Fig. 6 : Littoral forests in South Andaman

The most common species found in this forest type are *Mimusops littoralis, Tetrameles nudiflora, Terminalia catappa, Pongamia glabra, etc.*

As mentioned earlier, mangrove forests usually occur along the tidal creeks, sheltered bays and sea inlets. Among mangrove species, *Rhizophora mucronata* and *R. apiculata* occupy the most outer sea-ward fringe forming thick clusters. *Bruguiera gymnorrhiza* and *B. parviflora* are abundant in tidal creeks. On open mudflats and sometimes on rocky and coral reef flats *Sonneratia alba, S. apetala* and *Avicennia marina* are found to grow. Tidal swamps are occupied by *Avicennia officinalis, Ceriops tagal, Kandelia candel, Xylocarpus granatum, X. moluccensis, Lamnitzera littorea, L. racemosa,* *Excoecaria agallocha* and *Aegiceras corniculatum*. *Acanthus ilicifolius* forms a dense prickly undergrowth generally near the creek. *Heritiera littoralis*, *Cynometra iripa*, *Scyphiphora hydrophylacea* and *Brownlowia tersa* grow towards the landside of mangrove swamp. In the degraded and disturbed mangrove forests *Acrosticum aureum* and *A. speciosum* are sometimes very frequent in South Andaman.

Lakshadweep : In this archipelago deciduous herbs, shrubs and climbers grow with the onset of monsoons and dry up with the start of summer. Thickets of screw pine jungles and thorny bushes are found on the shore of some islands. Littoral communities comprise mainly *Casurina*, *Pandanus* and *Terminalia* spp. About 350 species of vascular plants comprising around 300 species of angiosperms and 50 species of ferns, lichens and mosses have been reported from these islands (Raghaban, 1977, Mukundan, 1979). Besides these, more than 100 species of marine algae and sea-weeds have also been recorded from atolls (Krishnamurthy and Joshi, 1970 ; Anon, 1979) (Table 2).

3.2.2 Fauna

Andaman and Nicobar islands : These islands possess undulating topography with mountains of variable heights and rich tropical forests as stated earlier. Moreover, mountainous parts of the southern islands get around 3000 mm rainfall annually. In island environment such vegetation, topography and abundant rainfall offer a wide gamut of ecological habitats from the sea coast to mountain top, ideal for supporting rich and diversified terrestrial fauna which may migrate from mainland source or from other adjacent islands. Again, such habitats in the island are very much favourable for subsequent establishment and evolution of island fauna.

Fig. 7 : Lakshadweep : a view from the coast

Table 1. Species diversity and endemism in Andaman and Nicobar islands

Taxonomic group	No of species/ subspecies	No of endemics sp/ssp	Endemic %
A. **INLAND BIOTA**			
Flora			
Lichens	50	—	—
Mosses and hepatics	15	—	—
Pteridophyta	130	14	10.8
Angiosperms	2200	232	10.5
Inland Flora Total	**2395**	**246**	**10.2**
Fauna			
Mollusca	110	77	70.0
Annelida	30	9	30.0
Insecta	**2256**	**485**	**21.5**
Collembola	8	—	—
Odonata	50	7	14.0
Orthoptera	67	12	17.9
Phasmida	4	—	—
Dermaptera	8	2	25.0
Embioptera	2	—	—
Mantodea	5	2	40.0
Blattaria	12	—	—
Isoptera	38	21	55.2
Phthiraptera	4	—	—
Hemiptera	250	36	14.4
Thysanoptera	30	2	6.6
Neuroptera	13	2	15.3
Coleoptera	541	154	28.5
Siphonoptera	2	—	—
Diptera	231	23	9.9
Lepidoptera	795	200	25.1
Trichoptera	20	—	—
Hymenoptera	176	24	13.6
Arachnida	94	38	40.4
Crustacea (Freshwater)	2	2	—
Myriapoda	22	—	—
Pisces (Freshwater)	13	—	—
Amphibia	18	5	27.7
Reptilia	76	24	31.6
Aves	246	99	40.2
Mammalia	52	33	63.5
Inland Fanua Total	**2919**	**769**	**26.3**

Table 1. (contd.)

Taxonomic group	No of species/ subspecies	No of endemics	Endemic %
B. MARINE BIOTA			
Flora			
Algae	118	1	0.8
Fauna			
Porifera	91	—	—
Anthozoa	326	2	0.6
Polychaeta	184	4	2.2
Crustacea	586	6	1.0
Sipuncula	2	—	—
Mollusca	932	18	1.9
Echinodermata	336	4	1.2
Pisces	820	2	0.2
Reptilia	12	—	—
Mammalia	3	—	—
Meiofauna	486	102	21.0
Marine Fauna Total	3778	138	3.6

As already mentioned, these islands support richest coral formations in their surrounding marine zone and luxurious mangroves in some sheltered coasts at the interphase between the terrestrial and marine ecosystems. It is well known that coral ecosystem sustains innumerable varieties of life forms like, molluscs, crabs, echinoderms, fishes, *etc*. Mangrove ecosystem is also an important reservoir and feeding, breeding and nursery grounds of a large number of animal species, both terrestiral and marine. It is, therefore, quite inevitable that these islands would harbour a very rich faunal biodiversity in both terrestrial and marine habitats.

Animals of these islands can broadly be divided into two categories—the inland animals inhabiting land and fresh water and the marine ones, occupying marine zones covering these islands. A total of 6697 species have so far been reported from the Bay islands (Tikader and Das, 1985 ; Tikader, *et al.*, 1986 ; Das and Dev Roy, 1989 ; Pattanayak, 1999; Chandra, K., 2000 and Das, A. K., 2000). Out of these, 2919 species are from inland (terresterial and freshwater) and 3778 species are marine (Table 1). It is needed to mention here that large number of islands (mostly uninhabited ones) are still unexplored or underexplored for faunal components. In view of this and considering the habitat diversity coupled with long period of geographical isolation, we could expect the addition of large number of species to the present faunal list, more particularly terrestrial invertebrates if extensive and planned faunistic surveys of these islands are organised

Mammals : These islands are poor in mammalian species with the exception of bats and rats. Out of 52 species of terrestrial mammals known from the islands, bats and rodents constitute 26 species and 14 species respectively (Tikader and Das, 1985). This may be explained by the fact that bats can reach the islands by means of their own power of flight whereas rats can migrate easily through ships and country boats. Other mammals of the islands include the Crab-eating Macaque of Nicobars, the Wild Pigs of both Andamans and Nicobars and the Palm Civet of the Andamans. Four species of Spiny Shrew belonging to the genus *Crocidura* and

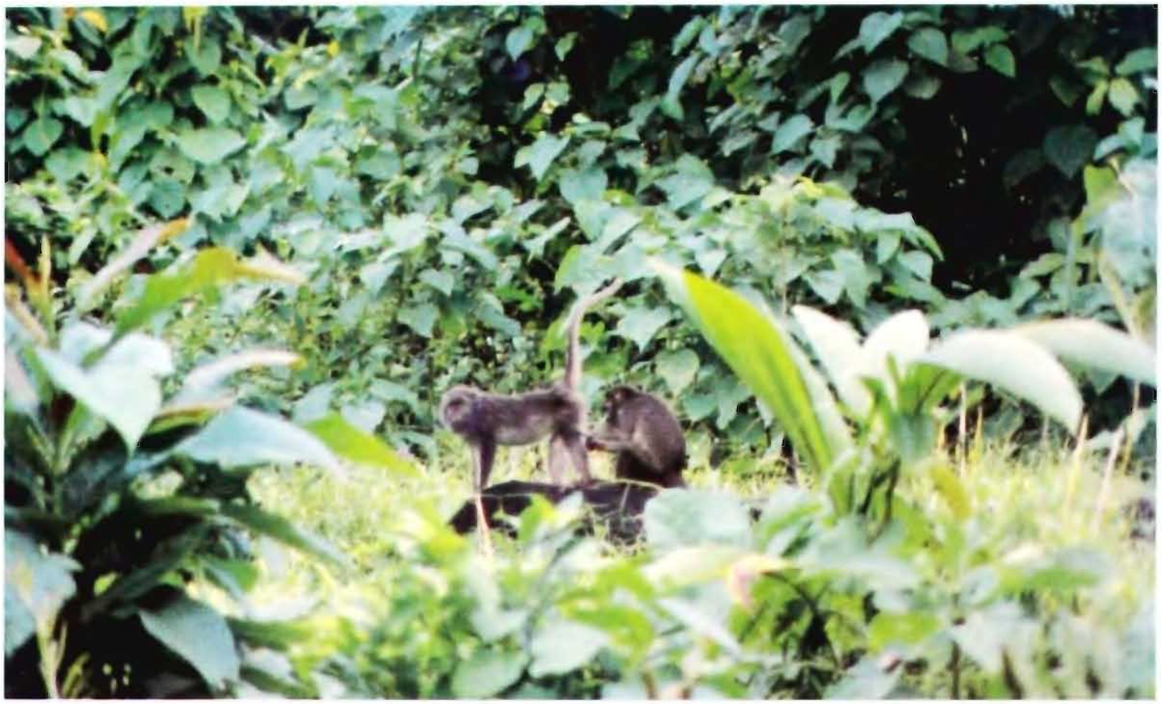


Fig. 8 : Nicobar Crab-eating Macaque

Birds : A total of 246 species and subspecies of birds are known from these islands. Out of these, several species of birds (*e.g.*, the Grey Pelican, the Eastern Sand Plover, the Eastern Knot, the Javan Gullbilled Tern, the Little Bunting, *etc.*) were collected by single example or seen only once, that too, during the Nineteenth Century. The avifauna of the Bay islands include 99 resident and endemic (Table 5), 43 residents, 100 migrants and 4 introduced species. The introduced

one species (2 subspecies) of the Tree Shrew, *Tupaia nicobarica* also occur in these islands. In addition to these, there are some introduced mammals like Indian Elephant, Spotted Deer, Northern Palm Squirrel, *etc.*, which will be discused elsewhere. Interestingly, there is no ungulate and large carnivores in these islands.

The Dolphins (*Delphinus delphis*) and the Dugongs (*Dugong dugon*) are the marine mammals abound in Andaman and Nicobar waters. In addition to these, False Killer Whale, *Pseudorca crassidens* is occasionally stranded around these islands.

Fig. 9 : Megapode on mound

species of birds are the South Indian Grey Patridge, the Peafowl, the Common Myna and the House Sparrow, all of which are thriving well. Breeding birds that are best represened in these islands are herons (11 spp.) hawks (9 spp), pigeons (8 spp) and kingfishers (8 spp.). Of these, herons and kingfishers are generally associated with water and the remaining two are strong fliers. Passerines are, in general, poorly represented in this archipelago excepting Cuckoo-shrikes (Campephagidae) with five species, which appear to be good dispersers.

Reptilies : Out of 76 species of reptiles recorded so far from these islands snakes represent 40 species. Among land snakes Cobra, King Cobra, Banded Krait and Pit Vipers are venomous. Of these, the first two are very rare and found only in Andaman islands. Pit Vipers are common and inhabit both the island groups. The largest and the heaviest Indian land snake, Reticulated Python (*Python reticulatus)* also occurs in these islands, only in the Nicobars. This snake inhabits wet evergreen forests and lives on small mammals, birds and reptiles.

Lizards of these islands include geckos, agamids, skinks, Andaman Water Monitor and the Burrowing lizards *(Dibamus novaeguineae* and *Dibamus nicobaricum).* The last ones are worm-like limbless lizards with reduced eyes and occur in Nicobars only. Distribution of *D. novaegineae* is extended from the Nicobars to New Guinea and it lives in the humus of the tropical forests. *D. nicobaricum* is endemic to the Nicobars (Chandra, K., 2001).

Four species of marine turtles, more particularly the Green Turtle and the Hawksbill frequent coastal waters and come to sandy shore for laying eggs. Two species of sea-snakes belonging to the genus *Laticauda* also come to the shore for the same purpose.

Amphibians : Amphibians are not properly explored in these islands. In all, 18 species of this faunal group are known from these islands. Out of these, only one species, *viz., Bufo melanostictus* is toad (Family Bufonidae) and the remaining are frogs belonging to the families Ranidae, Microhylidae and Rhacophoridae. Five species of amphibia, namely, *Limnonectes andamanensis, L. shompenorum, Microhyla chakrapani, Rana charlesdarwini* and *Polypedates insularis* are endomic to these islands.

Fishes : These islands are very rich in fish fauna which are mostly marine. Only 13 species of freshwater fishes are found in ponds and tanks of these islands. All the species are introduced from Indian mainland and include carps, murrels, catfishes, Anabas, freshwater eel and Tilapia.

Out of 820 species of marine fishes recorded so far from these islands, only a few categories of fishes are abundant and commercially important like sardines, anchovies, perches, silver bellies, carangids, mackerel, seer fishes, mullets, elasmobranchs, tunas and pomfrets. Also 11 species of stream fishes are known from these islands (Tikader and Das, 1985). According to Annandale and Hora (1925), the fluviatile fish fauna of these islands are derived from the surrounding sea rather than from any other territory.

There are five perennial rivers in Great Nicobar. So far 24 species of fishes have been reported from these rivers (Menon and Talwar, 1972). These fishes are predominantly estuarine.

Invertebrates : In all, 2514 species of invertebrates have been reported so far from terrestrial and freshwater habitats of these islands, representing 86.1 per cent of the total inland animal species. The terrestrial invertebrates comprise annelids (earthworms and leeches), insects, molluscs, arachnids (spiders and scorpions) and myriapods (centepedes and millipedes) revealing that many invertebrate groups including soil fauna are yet to be recorded from the islands. Among invertebrates, insects are represented by 2256 species bellonging to 1446 genera

Fig. 10 : Coconut Crab, *Birgus latro*

under 242 families and 19 orders (Chandra, 2000), constituting 77.2 percent of the total inland fauna.

Freshwater invertebrates include 51 species of molluscs belonging to gastropods and bivalves (Subba Rao *et al.* 1980) and one species each of ostracod and copepod (Crustacea), *viz.*, *Centrocypris horrida* and *Neodiaptomus meggitti* respectively. Both the crustaceans have been reported from a freshwater tank of Port Blair, South Andaman in recent years. Occurrence of *N. meggitti* in Andaman islands is noteworthy since this species has so far been recorded only from freshwater pools of Rangoon in Myanmar and Malacca in Malaysia (Reddy, 2000).

Marine invertebrates comprise 2943 species constituting 77.8 per cent of the total marine fauna of these islands. These invertebrates include sponges, corals, polychaetes, crustaceans, sipuncula, molluscs and echinoderms. Occurrence of one species of Hermit crab, namely, the Robber Crab or the Coconut Crab *(Birgus latro)* in these islands is noteworthy. It is the world's largest land crab and found in South Sentinel island (North

Fig. 11 : A light house at Pygmalion point, the southernmost point of Indian territory

Andaman) in large numbers. Marine invertebrates of these islands are inadequately explored.

Lakshadweep : So far, 1680 animal species have been reported from this archipelago (Anon, 1991), out of which only 172 species are terrestrial and the remaining 1508 species are marine. Table 2 clearly reveals that this archipelago is poor in faunal species probably due to small area of land mass, uniform topography and climatic conditions and lack of forests or diversified habitats. Terrestrial vertebrates are represented by 86 species, of which birds alone comprise 73 species. No freshwater fishes are reported from these islands. Only two species of amphibia, *viz.*,

Table 2. Biota of Lakshadweep archipelago

Taxonomic group	No of species/ subspecies	No of endemics sp/ssp	Endemic %
A. **INLAND BIOTA**			
Flora			
Lichens, mosses and ferns	50	—	—
Angiosperms	300	—	—
Total	**350**	—	—
Fauna			
Oligochaeta (earthhworms)	3	2	66.6
Insecta	**83**	—	—
Orthoptera	10	—	—
Dermaptera	2	—	—
Mantodea	1	—	—
Dictyoptera	4	—	—
Coleoptera	9	—	—
Diptera	5*	—	—
Lipidoptera	52	—	—
Amphibia	2	—	—
Reptilia	8	—	—
Aves	73	—	—
Mammalia	3	—	—
Inland Fauna Total	**172**	**2**	**1.1**
B. **MARINE BIOTA**			
Flora			
Algae and sea weeds	100+	—	—
Fauna			
Polychaeta	69	—	—
Sipuncula	17	1	6.0
Mollusca	424	—	—
Echiura	7	—	—
Crustacea (Stomatopoda)	13	2	15.4
Echinodermata	72	—	—
Pisces	741	—	—
Reptilia	10	—	—
Mammalia	3	—	—
Meiofauna	152	6	0.6
Marine Fauna Total	**1508**	**9**	**0.6**

* In Diptera 1 species each under the families Tethinidae and Cloropidae not identified even up to generic level (Anon, 1991, p. 266)

Bufo melanostictus and *Rana tigrina* have been recorded from this archipelago, that too, only in Kavaratii island and Minicoy respectively. These amphibians are probably introduced by the local authorities for the use in educational institutions. The unused ones released on the islands survived and multiplied.

Eight species of terestrial reptiles reported from these islands comprise 6 species of lizards, *viz.*, *Calotes calotes*, *C. liocephalus*, *C. versicolor*, *Hemidactylus frenatus*, *Mabuia carinata* and *Gekko smithi* and, two species of Snakes, *viz.*, Blind snake, *Typhlops braminus* and Wolf Snake, *Lycodon travancoricus*.

Only three species of terestrial mammals are known from Lakshadweep. These include two species of house rats, *viz.*, *Rattus rattus alexandrinus* and *R. rattus rufescens* and one species of Mask Shrew, *Suncus murinus*.

Terrestrial invertebrates comprise 3 species of earthworms and 83 species of insects belonging to 7 orders (Table 2). It is, therefore, quite evident that these islands need to be thoroughly surveyed for different group of invertebrates including insects.

Marine invertebrates are dominated by molluscs in species diversity with 424 species followed by echinoderms (72 spp) and polychaetes (69 spp). Moreover, sipuncula, echiura and stomatopods are fairly known. Meiofauna of these islands with 152 species comprise 12 faunal groups, *viz.*, Hydrozoa (1 sp.), Turbellaria (3 spp), Nematoda (38 spp), Gastrotricha (16 spp), Kinorhyncha (3 spp), Archiannelida (12 spp), Polychaeta (19 spp), Copepoda (51 spp), Isopoda (3 spp), Tardigrada (2 spp), Halacarida (1 sp), Mollusca (3 spp).

Among marine vertebrates fishes are represented by 741 species. Ten species of marine reptiles (turtles 4 spp and sea-snakes 6 spp) and 3 species of mammls, *viz.*, Common Dolphin *(Delphinus delphis)*, Porpoise *(Orcha* sp.) and Blue whale *(Belenoptera musculus)* are found around Lakshadweep archipelago.

4. SPECIAL FEATURES

4.1 Andaman & Nicobar Islands

These islands harbour considerably small number of mammalian species excepting bats and rodents. In fact, bats and rats constitute 40 species and the remaining terrestrial mammals comprise only 12 species. This is expected since, as stated earlier, bats are well capable of crossing water barrier by means of flight and rats could conveniently reach these islands through raft.

Absence of all the characteristic Malayan species of mammals, such as, ungulates, carnivores and flying lemurs are noteworthy. Since ecological set up of both the Andamans and Nicobars is very much favourable to support rich and varied fauna the paucity of mammalian species may be explained on presumption that these islands were isolated at such time when mammals which are now characteristic of Malaya region did not exist there. Great depth of water barrier surrounding these islands since Upper Mesozoic prevented subsequent migration of these mammals to this region. According to Miller (1902), presence of mammals other than bats and rats can not be explained otherwise than through introduction by man. In fact, introduction of deer and Indian elephant in Andamans and goat in Barren island (Andaman) is well known. Northern Palm Squirrel which was not noticed during Boden Kloss's visit to these islands (in 1902) appears to be recently introduced. Remaining terrestrial mammals like Crabeating Macaque, Wild pigs, shrews and Palm civets might have also been introduced as was probably done on the Moluccas and Lesser Sundas (Darlington, 1966). These mammals have survived well in the islands and subsequently evolved as endemic subspecies due to long isolation. Interestingly, 12 species and subspecies of bats out of 26 and 11 species of rodents out of 14, which possess high degree of dispersal ability have also become endemic.

In fact, endemism is significantly high in almost all groups of island fauna as shown in Table 1 as expected in island environment. Amongst vertebrates, mammals exhibit highest percentage of endemism (63.5%) followed by birds (40.2%), reptiles (31.6%) and amphibia (27.7%) in descending order. Among invertebrates, land molluscs show considerably high degree of endemism (70%) followed by spiders (40.4%), annelids (30%) and insects (21.5%).

Birds of these islands are significant not only due to their higher percentage of endemism but also for their restricted distribution within these island chains. For example, Narcondam Hornbill is found only in Narcondam island. Some endemic subspecies of birds either occur on one particular island or on few adjacent islands. For example, 3 endemic subspecies of White-headed Myna, *viz*, *Sturnus erythropygius andamanensis*, *S. erythropygius erythropygius* and *S. erythropygius katchalensis* are distributed in these islands. Among these, the first one occurs in several adjacent islands of Andamans while the second and the last ones are restricted to Car Nicobar and Katchal islands respectively. There are several such examples out of which distribution of Magapodes *Megapodius freycinet* may be cited. Two subspecies of this unique bird inhabit these islands. One subspecies, the North Nicobar Megapode, *Megapodius freycinet nicobariensis* is restricted to the Nicobar group islands which are lying north to Sombero Channel (except Chowra and Car Nicobar). The second one, the South Nicobar Megapode, *M. freycinet abbotti* is distributed only in Little Nicobar and Great Nicobar lying south of Sombero Channel.

Racial endemism is very significant among higher vertebrates, more particularly among the flying ones like bats and birds as shown in Table 3. From this table it is quite evident that among birds 13 are endemic at species level while as many as 86 are endemic as subspecies. In case of bats there are 3 endemic species against 9 endemic subspecies. In non-flying vertebrates endemic races are far less, specially in reptiles. Exception is one species of rodent (mammal), *Rattus rattus* which exhibits 4 endemic races on these islands. Such high racial endemism among flying vertebrates and rodents may be presumably due to their vigorous dispersal ability, enabling them to colonise on different islands of this archipelago as isolated populations for long and evolve as endemic races as expected in island environment (Das and Maiti, 1992).

Other evolutionary changes, such as, dwarfism, gigantism, *etc.*, are also evidenced

Table 3. Racial endemism in the vertebrates of the Bay islands

Group	No of species	No of subspecies/races
Mammals	**15**	**19**
Bat	3	9
Spiny Shrew	4	—
Tree Shrew	1	2
Macaque	—	1
Palm Civet	—	1
Wild Pig	—	2
Rodent	7	4
Birds	**13**	**86**
Reptiles	**21**	**3**
Lizards	9	1
Snakes	12	2
Amphibia	**5**	—

in these islands. For example, two endemic species of Serpent Eagles, *viz.*, *Spilornis elgini* and *S. klossi* occur in the Andamans and the Nicobars respectively. Both the species are smaller in body size and wing size than their sister species *S. cheela* which is wide-spread in the inlands. Again, the Nicobar Serpent Eagle, *S. klossi* is smaller than the Andaman Serpent Eagle, *S. elgini*. Endemic wild pigs of the islands are described as dimunitive wild pigs of the mainland (Mouat in Blyth, 1863). The reverse trend, that is, gigantism is shown by the Green Imperial Pegion, *Ducula aenea* and the Red-cheeked Parakeet, *Psittacula longicauda*. In both the cases the Nicobar races are larger than the Andamann races. Further to mention that these islands are the only place on earth where two species of Serpent Eagle of the genus *Spilornis* exist sympatrically. They, however, occupy different habitats. In the Andamans *S. cheela davisoni* occupies mangrove fringed creeks while *S. elgini* is found more inland. In Great Nicobar *S. klossi* inhabits closed type of tropical forests while *S. cheela malayensis* are found in forest clearings near the coast.

4.2 Lakshadweep

Terrestrial flora and fauna of this archipelago are quite similar in composition due to uniform topography and climatic condiations. There are no endemic plants in Lakshadweep (Prain, 1983) and majority of them are found in adjacent Maldives and other atolls of the Indo-Pacific region. The land fauna here are mostly exotic with very little endemism (Table 2). Only 2 species of earthworms, *viz.*, *Lampito mauritsi* and *Megascolex kankanensis* are endemic in this archipelago (Stephenson, 1921).

5. INTRODUCED BIODIVERSITY

5.1 Andaman & Nicobar islands

Introduced biodiversity in these islands comprises mainly the plants of agricultural and horticultural importance and, several domestic animals. Moreover, some wild plant and animal species are also introduced in the islands time to time. Paddy, large varieties of vegetables, fruits, pulses, oil seeds, spices, plantation crops and ornamental plants of mainland are grown in the islands. Some exotic timber species like teak, mehogony, eucalyptus, pine, *etc.*, have also been introduced. Unique grass heaths in Car Nicobar and Nancowry islands were created over a century ago by forest clearing as a part of Danish effort to develop diary firm in the region. Several species of mammals, birds, freshwater fishes and invertebrates were also introduced in the islands as presented in Table 4. Impact of these introduced biodiversity in the Bay islands is not yet assessed.

5.2 Lakshadweep

Large number of plant species, producing rice, vegetables, fruits, tubers, spices, sugar arecanut, *etc.*, are introduced from Indian mainland. Introduced animals of this archipelago include domestic cattle, specially goats, domestic cat, poultry birds and two species of amphibia, *Rana tigrina* and *Bufo melanostictus* as mentioned earlier.

6. BIOGEOGRAPHIC AFFINITIES

6.1 Andaman & Nicobar islands

Due to geographical proximity and past geological connections of Andaman islands with Myanmar (Indo-Chinese Subregion) and Nicobar islands with Sumatra it is expected that Indo-Chinese faunal elements will be prevalent in the Andamans while Malayan elements will be more in the Nicobars. According to Smith (1930), Andaman contains an impoverished "Burmese fauna" and fauna of Nicobars approximates to Sumatran type. Again, some workers (Blanford, 1901; Mani, 1974) stated that biotas of the Andamans and Nicobars differ substantially from one another. But, while analysing the reptilian fauna of Nicobar islands Stoliczka (1870) stated that "Andaman and Nicobar will show a great similarity with each other; several species of

Table 4. List of introduced animals of Andaman and Nicobar islands		
Name	Place and year of introduction	Ramarks
1. Spotted Deer, *Axix axis* 2. Barking Deer, *Muntiacus muntjack* 3. Sambar, *Cervus unicolor*	Andamans around 1915	Spotted Deer thriving well in Andamans, Barking Deer reported to be occasionally found in Middle Andaman, Sambar probably extinct.
4. Panther species	Middle Andaman in 1952	Two males released to check deer population, but not traceable afterwards.
5. Domestic goat	Barren Is. in 1891	Adapted well in the island
6. Indian Elephant, *Elephas maximus*	Andamans in 1960s	Some breeding herds (around 30) in Interview island and North Andaman
7. Northern Palm Squirrel, *Funambulus pennanti*	Port Blair in 1940s	Thriving well
8. Common Myna, *Acridotheres tristis tristis*	Ross Is., South Andaman in 1867	Abundant throughtout South Andaman
9. Common Peafowl, *Pavo cristatus*	Ross Is., South Andaman in 1868 & 1960s	Few individuals available in the island
10. Common House Sparrow, *Passer domesticus indicus*	Ross Is. in 1882 and 1895	Abundant throughout South Andaman
11. South Indian Grey Partrige, *Francolinus pondicerianus pondicerianus*	Port Blair in about 1890	Found in fair number around Port Blair, South Andaman
12. Freshwater fishes	Andamans, 1950 onwards	About a dozen of species introduced in freshwater ponds and tanks by the Bengalee settlers
13. Giant African Snail, *Achatina fulica fulica*	Andaman & Nicobars during World War II	Introduced by Japanese during 2nd World War ; now causing considerable damange to crops
14. Exotic snails : *Goanaxis quadrilateris, Euglandia rosea*	South Andaman in 1970s	Imported from Hawaii and introduced in South Andaman for biological control of Giant African Snail. They could not survive
15. Indian snail, *Gulella bicolor* 16. Millipede, *Orthomorpha* sp.	South Andaman in 1970s	Introduced for biological control as above and could not survive

lizards and snakes are common to both and the whole fauna greatly resembles the Malayan passing into Burmese fauna" Dispersal of snakes and lizards probably took place both from north and south of this archipelago. Indo-Chinese elements entered the Andamans through Myanmar and the Malayan elements reached the Nicobars *via* Sumatra. However, data presently available on taxic diversity of terrestrial vertebrates, more particularly birds do not support such generalised statement on biogeographic affinities.

Ripley and Beehler (1989) analysed the distributional list of breeding birds of these islands in sufficient details. Based on this analysis they suggested that the major path of colonisation of these island birds was extended along a single route from South-Western Myanmar *via* a series of water barriers which acted as filters. They also stated that Nicobarese avifauna has higher affinity to that of Myanmar than to that of Sumatra, inspite of physical proximity of the latter. They suggested further that Andamanese and Nicobarese avifaunas are subsets of a single avifaunal unit and Nicobarese avifauna appears nothing more than an impoverished subset of Andaman avifauna although probable source of a few bird species like *Ottus balii*, *Columba palumboides* and *Macropygia rufipennis* is Sumatra. Ripley and Beehler *(op.cit.)* justified this affinity by introspection of the historical effects of sea level changes. These islands were never connected with any mainland by a Pleistocenne land bridge as stated earlier. During the sea level minima, width of the Great Channel separating Sumatra from Great Nicobar remained unchanged. On the other hand, Great Andamans which became single island during that period was separated from Myanmar by a reduced channel, narrower than the Great Channel.

6.2 Lakhadweep

The terrestrial fauna of this archipelago show similarity with those of adjacent parts of South India, Sri Lanka and Maldives due to geographical proximity. Majority of these island biota excepting birds and rats have been introduced by man for various prupose like agriculture, horticulture, *etc.*

7. VALUE

Direct values of biological resources in these islands are considerable since tribals and settlers use large number of plant and animal species as food, fodder, construction material, medicines, *etc.* Forests with timber potential play a great role in the economy of these islands. *Dipterocarpus* spp., *Artocarpus* spp., *Terminalia* spp. and several others have a great demand. A rich diversity of marine fishes abound in coastal waters of these islands, many of which have considerable commercial value. Commonly available commerical fishes of the islands include sardines, shark and rays, anchovies, perches, silver bellies, carangids, mackerels, seer fishes, mullets, tunas, cat fishes and pomfrets.

Coral reef of these islands are quite productive, supporting a fascinating array of diverse assemblage of animals and micro-organisms. These reefs are the potential sources of numerous varieties of ornamental aquarium fishes of considerable commercial value. The corals and their associated fauna are the major store houses of many bioactive chemicals which possess antibiotic, anticoagulent and antileukemic properties.

Indirect values of biological resources of these islands are immense. It is now well established that islands and archipelagoes are the living laboratories on earth where evolution *vis-a-vis* speciation and adaptive radiation are likely to take place rapidly in small isolated populations. Moreover, islands harbour large percentage of endemic biota as is evident from the floral and faunal data presented in Tables 1 and 5. Coastal areas of these islands harbour coral reefs and mangroves. These are very much significant not only commercially but also ecologically since they act as buffer against the impact of heavy wave action on the shore, protect the beaches from soil erosion and there by check loss of littoral vegetation. In the past coral reefs played a great role in the formation of many islands in this archipelago. Now also they might be playing the same role slowly and steadily.

8. THREATS

Biodiversity of these islands is threatened mainly due to habitat destruction and alteration, population influx and indiscriminate exploitation of biological resources. Pollution although much less in these islands compared to mainland may cause considerable threat to island biota. Oil spills which were observed on Nicobar waters a few years ago may pose severe threat to biological resources, if such incidents are not checked for future particularly during the movement of oil tankers in this region.

Habitat alteration is caused mainly by agriculture and its associated activities, logging operations and platation of some exotic plants like rubber plantation and red oil palm plantation. The impact of these activities is mainly on forest ecosystems. The forest coverage was about 86 per cent of total land area of these islands. It has now been reduced considerably due to clearing of forests for human settlement, development activities, road construction and agriculture.

Wide spread cutting of mangroves in recent years for fuel, fodder and other domestic and industrial needs is also of great concern. It is well known that wood of these islands has been lavishly exploited for local consumption as well as export to mainland India in sufficient quantity since the beginning of the twentieth century.

Fig. 12 : Barren island, Andamans showing a dormant volcano

Fig. 13 : Active volcano in Barren Island, Andamans

Sand quarring on nesting beaches, poaching of eggs and pollution have greatly endangered sea turtles like Green Sea Turtle, *Chelonia mydas* and Hawksbill, *Eretmochelys imbricata*. Since some endemic species and subspecies of birds like Narcodum Hornbill, Megapode and White-headed Myna have a very restricted distribution in these islands any severe threat to their habitats in those particular island may exterminate those species and subspecies of birds for good.

Population influx and increasing tourism in the islands have a adverse impact on marine biological resources, more particularly stony corals. Corals are extensively collected for presentation, decoration, fancy sale and educational purpose. A considerable quantity of molluscs and echinoderms are also collected for trading purpose. Collections are indiscriminate and no close season is observed.

9. CONSERVATION

Number of forest management plans were formulated since 1906. But, these were never put into operation. In 1952 Chengappa prepared a working plan, the "Andaman Canopy Lifting Sheltered Wood System" for replenishing depleted forest resources. Although this system yielded good regeneration still it was not sucessful for number of reasons. It leads to changing of the character of the forests, *i.e.*, from evergreen to deciduous because it emphasised on increasing the density of commercially useful trees compared to other plant species.

Andaman and Nicober administration has been taking some steps in recent years to check deforestation and conserve the island ecosystem. Forest clearing operations are considerably restricted and afforestation programmes have been launched. Large number of conservation areas including 96 sanctuaries, 9 National Parks and one Biosphere Reserve covering 1354 sq km were created for the conservation of both inland and marine biological resources of these islands (Table 6). However, majority of these conservation areas are small islands and are quite vulnerable to environmental disturbances. It is also questionable whether such small areas could sustain viable population for longer period and support rich biodiversity. Even then, this effort may pay good dividents, if these areas could be properly managed.

10. FUTURE DIRECTIONS

Indian islands, more particularly the Bay islands harbour large number of unique and endemic biota and rich marine biodiversity in their surrounding waters as discussed earlier. Moreover, island ecosystem being fragile and ecologically sensitive is to be given top priority for conservation.

In view of above, a strategy for conservation and sustainable utilisation of

Table 5. List of endemic taxa of mammals and birds of Andaman and Nicobar islands

Name of taxa	Distribution
MAMMALS	
Order : INSECTIVORA	
Spiny Shrew	
1. *Crocidura hispida* Thomas	Andaman
2. *Crocidura andamanensis* Miller	Andaman
3. *Crocidura nicobarica* Miller	Nicobar
4. *Crocidura jenkinsi* Chakraborty	Andaman
Order : SCANDENTIA	
Tree Shrew	
5. *Tupaia nicobarica nicobarica* (Zelebor)	Nicobar
6. *Tupaia nicobarica surda* Miller	Nicobar
Order : CHIROPTERA	
Flying Fox	
7. *Pteropus melanotus satyrus* Anderson	Andaman
8. *Pteropus faunulus* Miller	Nicobar
9. *Pteropus melanotus melanotus* Blyth	Nicobar
Fruit Bat	
10. *Cynopterus brachyotis scherzeri* Zelebor	Nicobar
11. *Cynopterus brachyotis brachysoma* Dobson	Andaman
Horseshoe Bat	
12. *Rhinolophus affinis andamanesis* Dobson	Andaman
13. *Rhinolophus cognatus cognatus* Anderson	Andaman
14. *Rhinolophus cognatus famulus* Anderson	Andaman
Leafnosed Bat	
15. *Hipposideros ater nicobarulae* Miller	Nicobar
16. *Hipposideros diadema nicobarensis* Dobson	Nicobar
Mouse-eared Bat	
17. *Myotis dryas* Anderson	Andaman
Pipistrelle	
18. *Pipistrellus camortae* Miller	Nicobar
Order : PRIMATE	
Crabeating Macaque	
19. *Macaca fascicularis umbrosa* Miller	Nicobar
Order : CARNIVORA	
Masked Palm Civet	
20. *Paguma larvata tytleri* (Tytler)	Andaman
Order : ARTIODACTYLA	
Wild Pig	
21. *Sus scrofa andamanensis* Blyth	Andaman
22. *Sus scrofa nicobarica* Miller	Nicobar

Table 5 (contd.)

Name of taxa	Distribution
Order : RODENTIA	
House Rat	
23. *Rattus rattus andamanensis* (Blyth)	Andaman
24. *Rattus rattus atridorsum* (Miller)	Andaman
25. *Rattus rattus flebilis* (Miller)	Andaman
26. *Rattus rattus holchu* Chaturvedi	Andaman & Nicobar
27. *Rattus palmarum* (Zelebor)	Andaman & Nicobar
28. *Rattus stoicus* (Miller)	Andaman
29. *Rattus taciturnus* (Miller)	Andaman
30. *Rattus pulliventer* (Miller)	Nicobar
31. *Rattus burrus* (Miller)	Nicobar
32. *Rattus burrulus* (Miller)	Nicobar
33. *Rattus burrescens* (Miller)	Nicobar
BIRDS	
Order : CICONIIFORMES	
Little Green Heron	
1. *Aradeola striata spodiogaster* (Sharpe)	Andaman & Nicobar
Tiger Bittern	
2. *Gorsachius melanolophus minor* Hachisuka	Nicobar
Order : ANSERIFORMES	
Grey Teal	
3. *Anas gibberifrons albogularis* (Hume)	Andaman
Order : FALCONIFORMES	
Black-crested Baza	
4. *Aviceda leuphotes andamanica* Abdulali & Grubh	Andaman
Shikra	
5. *Accipiter badius butleri* (Gurney)	Nicobar
6. *Accipiter badius obsoletus* (Richmond)	Nicobar
Crested Hawk-Eagle	
7. *Spizaetus cirrhatus andamanensis* Tytler	Andaman
Serpent Eagle	
8. *Spilornis cheela davisoni* Hume	Andaman & Nicobar
9. *Spilornis cheela minimus* Hume	Nicobar
10. *Spilornis elgini* Blyth	Andaman
11. *Spilornis klossi* Richmond	Nicobar
Order : GALLIFORMES	
Megapode	
12. *Megapodius freycinet nicobariensis* Blyth	Nicobar
13. *Megapodius freycinet abbotti* Oberholser	Nicobar
Blue-breasted Quail	
14. *Coturnix chinensis trinkutensis* Richmond	Nicobar
Order : GRUIFORMES	
Bluebreasted Banded Rail	
15. *Rallus striatus obscurior* (Hume)	Andaman & Nicobar

Table 5 (contd.)

Name of taxa	Distribution
Andaman Banded Crake	
16. *Rallina canningi* (Blyth)	Andaman
White breasted Waterhen	
17. *Amaurornis phoenicurus insularis* Sharpe	Andaman & Nicobar
18. *Amaurornis phoenicurus midnicobariensis* Abdulali	Nicobar
Order : COLUMBIFORMES	
Greyfronted Green Pigeon	
19. *Treron pompadora chloroptera* Blyth	Andaman & Nicobar
Green Imperial Pigeon	
20. *Ducula aenea nicobarica* (Pelzeln)	Nicobar
21. *Ducula aenea andamanica* Abdulali	Andaman
Wood Pigeon	
22. *Columba palumboides palumboides* (Hume)	Andaman
23. *Columba palumboides nicobariensis* Abdulali	Nicobar
Cuckoo-Dove	
24. *Macropygia rufipennis rufipennis* Blyth	Nicobar
25. *Macropygia rufipennis andamanica* Abdulali	Andaman
26. *Macropygia rufipennis tiwarii* Abdulali	Nicobar
Emerald Dove	
27. *Chalcophaps indica maxima* Hartert	Andaman
28. *Chalcophaps indica augusta* Bonaparte	Nicobar
Order : PSITTACIFORMES	
Red-breasted Parakeet	
29. *Psittacula alexandri abbotti* (Oberholser)	Andaman
Nicobar Parakeet	
30. *Psittacula caniceps* (Blyth)	Nicobar
Large Parakeet	
31. *Psittacula eupatria magnirostris* (Ball)	Andaman
Red-cheeked Parakeet	
32. *Psittacula longicauda tytleri* (Hume)	Andaman
33. *Psittacula longicauda nicobarica* (Gould)	Nicobar
Order : CUCULIFORMES	
Andaman Koel	
34. *Eudynamys scolopacea dolosa* Ripley	Andaman & Nicobar
Andaman Crow-Phaesant	
35. *Centropus andamanensis* Beavan	Andaman
Order : STRIGIFORMES	
Barn Owl	
36. *Tyto alba deroepstorffi* (Hume)	Andaman
Scops Owl	
37. *Otus balli* (Hume)	Andaman
38. *Otus magicus* ssp	Nicobar

Table 5 (contd.)

Name of taxa	Distribution
Lesser Scops Owl	
39. *Otus (Scops) modesta* (Walden)	Andaman
40. *Otus (Scops) nicobaricus* (Hume)	Nicobar
Hawk-Owl	
41. *Ninox affinis affinis* Beavan	Andaman
42. *Ninox affinis isolata* Baker	Nicobar
43. *Nonox affinis rexpimenti* Abdulali	Nicobar
44. *Ninox scutulata obscura* Hume	Andaman & Nicobar
Order : CAPRIMULGIFORMES	
Longtailed Nightjar	
45. *Caprimulgus macrurus andamanicus* Hume	Andaman
Order : APODIFORMES	
White-bellied Swiftlet	
46. *Collocalia esculenta affinis* Beavan	Andaman & Nicobar
Order : CORACIIFORMES	
Blue-eared Kingfisher	
47. *Alcedo meninting rufigaster* Walden	Andaman
Three-toed Forest Kingfisher	
48. *Ceyx erithacus macrocarus* Oberholser	Andaman & Nicobar
Stork-billed Kingfisher	
49. *Pelargopsis capensis osmastoni* (Baker)	Andaman
50. *Pelargopsis capensis intermedia* Hume	Nicobar
White-collared Kingfisher	
51. *Halcyon chloris davisoni* Sharpe	Andaman
52. *Halcyon chloris occipitalis* (Blyth)	Nicobar
Ruddy Kingfisher	
53. *Halcyon coromanda mizorhina* (Oberholser)	Andaman
White-breasted Kingfisher	
54. *Halcyon smyrnensis saturatior* Hume	Andaman & Nicobar
Chestnut-headed Bee-eater	
55. *Merops leschenaultii andamanensis* Marien	Andaman
Broad-billed Roller	
56. *Eurystomus orientalis gigas* Stresemann	Andaman
Narcondam Hornbill	
57. *Rhyticeros plicatus norcondami* Hume	Andaman
Order : PICIFORMES	
Black Woodpecker	
58. *Dryocopus javensis hodgei* (Blyth)	Andaman
Fulvous-breasted Pied Woodpecker	
59. *Picoides macei andamanensis* (Blyth)	Andaman

Table 5 (contd.)

Name of taxa	Distribution
Order : PASSERIFORMES	
Hooded or Green-breasted Pitta	
60. *Pitta sordida abbotti* Richmond	Nicobar
Blacknaped Oriole	
61. *Oriolus chinensis andamanensis* Tytler	Andaman
62. *Oriolus chinensis macrourus* Blyth	Nicobar
Blackheaded Oriole	
63. *Oriolus xanthornus reubeni* Abdulali	Andaman
Andaman Drongo	
64. *Dicrurus andamanensis dicruriformis* (Hume)	Andaman
65. *Dicrurus andamanensis andamanensis* Tytler	Andaman
Racket-tailed Drongo	
66. *Dicrurus paradiseus otiosus* (Richmond)	Andaman
67. *Dicrurus paradiseus nicobariensis* (Baker)	Nicobar
Swallo-Shrike	
68. *Artamus leucorhynchus humei* Stresemann	Andaman
Glossy Stare	
69. *Aplonis panayensis tytleri* (Hume)	Andaman & Nicobar
70. *Aplonis panayensis albiris* Abdulali	Nicobar
While-headed Myna	
71. *Sturnus erythropygius erythropygius* (Bylth)	Nicobar
72. *Sturnus erythropygius andamanensis* (Tytler)	Andaman
73. *Sturnus erythropygius katchalensis* (Richmond)	Nicobar
Hill Myna	
74. *Gracula religiosa halibrecta* Oberholser	Andaman & Nicobar
Andaman Tree Pie	
75. *Dendrocitta bayleyi* Tytler	Andaman
Large Cuckoo-Shrike	
76. *Coracina novaehollandiae andamana* (Neumann)	Andaman
Barred Cuckoo-Shrike	
77. *Coracina striata dobsoni* (Ball)	Andaman
Pied Cuckoo-Shrike	
78. *Coracina nigra davisoni* (Kloss)	Andaman & Nicobar
Scarlet Minivet	
79. *Pericrocotus flammeus andamanensis* Beavan	Andaman
Black-headed Bulbul	
80. *Pycnonotus articeps fuscoflavescans* (Hume)	Andaman
Red-whiskered Bulbul	
81. *Pycnonotus jocosus whistleri* Deignan	Andaman
Nicobar Bulbul	
82. *Hypsipetes nicobariensis* Moore	Nicobar

Table 5 (contd.)

Name of taxa	Distribution
Paradise Flycatcher	
83. *Terpsiphone paradisi nicobarica* Oates	Nicobar
Blacknaped Flycatcher	
84. *Hypothymis azurea tytleri* (Beavan)	Andaman
85. *Hypothymis azurea idiochroa* Oberholser	Nicobar
86. *Hypothymis azurea nicobarica* Bianchi	Nicobar
Palefooted Bush Warbler	
87. *Cettia pallidipes osmastoni* (Hartert)	Andaman
Andaman Shama	
88. *Copsychus malabaricus albiventris* (Blyth)	Andaman
Andaman Magpie-Robin	
89. *Copsychus saularis andamanensis* Hume	Andaman
Ground Thrus	
90. *Zoothera citrina andamanensis* (Walden)	Andaman
91. *Zoothera citrina albogularis* (Blyth)	Nicobar
Plaincoloured Flowerpecker	
92. *Dicaeum concolor virescens* Hume	Andaman
Olivebacked Sunbird	
93. *Nectarinia jugularis andamanica* (Hume)	Andaman
94. *Nectarinia jugularis klossi* (Richmond)	Nicobar
95. *Nectarinia jugularis proselia* (Oberholser)	Nicobar
Yellow-backed Sunbird	
96. *Aethopyga siparaja nicobarica* Hume	Nicobar
Nicobar White-eye	
97. *Zosterops palpebrosa nicobarica* Blyth	Andaman & Nicobar
White-backed Munia	
98. *Lonchura striata fumigata* (Walden)	Andaman
99. *Lonchura striata semistriata* (Hume)	Nicobar

biotic resources of the Indian islands, specially those of coastal and marine biodiversity is suggested below :

- To prepare an inventory of inland and marine flora and fauna and their distribution pattern based on recent surveys and past records.
- To identify targetted taxa having ecological and economical significance and study their population dynamics.
- To identify culturable species other than already known and develop ecofriendly culture.
- To improve infrastructural facilities and surveillance safe guards to strengthen existing protected areas and to identify new areas for establishment of bioreserves.
- To carry out soico-economic survey of the user groups and the local people, to assess the extent of their dependence on the ecosystem and consequence there of.
- To develop an integrated data base involving above mentioned ecological, economical and social paramenters for formulating an Integrated Management Plan and its subsequent implementation for sustainable use of biotic resources of the islands.

Table 6. Conservation areas of Andaman and Nicobar islands*

Great Nicobar BIOSPHERE RESERVE

National Parks

1. Mahatma Gandhi Marine National Park (Wandoor)
2. Middle Button Island National Park
3. Mount Harriett National Park
4. North Button Island National Park
5. Saddle Peak National Park
6. South Button Island National Park
7. Campbell Bay National Park
8. Galathea River National Park
9. Rani Jhansi Marine National Park

Wild life Sanctuaries

1. Arial Island Sanctuary
2. Bambo Island Sanctuary
3. Barren Island Sanctuary
4. Battimalv Island Sanctuary
5. Belle Island Sanctuary
6. Bennett Island Sanctuary
7. Binghan Island Sanctuary
8. Blister Island Sanctuary
9. Bluff Island Sactuary
10. Bondoville Island Sanctuary
11. Brush Island Sanctuary
12. Buchanan Island Sanctuary
13. Chanel Island Sanctuary
14. Cinque Island Sanctuary
15. Clyde Island Sanctuary
16. Cone Island Sanctuary
17. Curlew Island Sanctuary
18. Curlew (B.P.) Island Sanctuary
19. Cuthbert Bay Sanctuary
20. Defence Island Sanctuary
21. Dot Island Sanctuary
22. Dottrell Island Sanctuary
23. Duncan Island Sanctuary
24. East Island Samctuary
25. East or Inglis Island Sanctuary
26. Egg Island Sanctuary
27. Elat Island Sanctuary
28. Entrance Island Sanctuary
29. Gander Island Sanctuary
30. Girjan Island Sanctuary
31. Galathea Bay Sanctuary
32. Goose Island Sanctuary
33. Hump Island Sanctuary
34. Interview Island Sanctuary
35. James Island Sanctuary
36. Jungle Island Sanctuary
37. Kwangtung Island Sanctuary
38. Kyd Island Sanctuary
39. Landfall Island Sanctuary
40. Latouche Island Sanctuary
41. Lohabarrack (Saltwater Crocodile) Sanctuary
42. Mangrove Island Sanctuary
43. Mask Island Sanctuary
44. Mayo Island Sanctuary
45. Megapode Island Sanctuary
46. Montogemery Island Sanctuary
47. Narcondum Island Sanctuary
48. North Brother Island Sanctuary
49. North Island Sanctuary
50. North Reef Island Sanctuary
51. Oliver Island Sanctuary
52. Orchid Island Sanctuary
53. Ox Island Sanctuary
54. Oyster Island 1 Sanctuary
55. Oyster Island 2 Sanctuary
56. Paget Island Sanctuary
57. Parkinson Island Sanctuary
58. Passage Island Sanctuary
59. Patric Island Sanctuary
60. Peacock Island Sanctuary
61. Pitman Island Sanctuary
62. Point Island Sanctuary
63. Potanma Island Sanctuary
64. Ranger Island Sanctuary
65. Reef Island Sanctuary
66. Roper Island Sanctuary
67. Ross Island Sanctuary
68. Rowe Island Sanctuary
69. Sandy Island Sanctuary
70. Sea Serpent Island Sanctuary
71. Shark Island Sanctuary
72. Shearma Island Sanctuary
73. Sir Hugh Rose Island Sanctuary
74. Sisters Island Sanctuary
75. Sanke Island 1 Sanctuary
76. Sanake Island 2 Sanctuary
77. South Brother Island Sanctuary
78. South Reef Island Sanctuary
79. South Sentinel Island Sanctuary
80. Spike Island 1 Sanctuary
81. Spke Island 2 Sanctuary
82. Stoat Island Sanctuary
83. Surat Island Sanctuary
84. Swamp Island Sanctuary
85. Table (Delgarno) Island Sanctuary
86. Table (Excelsior) Island Sanctuary
87. Talabaicha Island Sanctuary
88. Temple Island Sanctuary
89. Tillongchan Island Sanctuary
90. Tree Island Sanctuary
91. Trilby Island Sanctuary
92. Tuft Island Sanctuary
93. Turtle Island Sanctuary
94. West Island Sanctuary
95. Wharf Island Sanctuary
96. White Clife Island Sanctuary

* *Source* : ENVIS Bulletin, Vol. 3, No. 1, 2000, Wildlife Institute of India

11. SELECTED REFERENCES

Anandale, N. and Hora, S. L. 1925. The freshwater fish from the Andaman islands. *Rec. Indian Mus.*, **27** : 33-42.

Anon, 1979. A report of the survey of marine algal resources of Lakshadweep. *Cent. Salt & Mar. Ch. Res. Inst.*, 48 pp.

Anon, 1991. Fauna of Lakshadweep. *State Fauna Series* **2**, *Zool. Surv. India ;* 1-413.

Blanford, W. T. 1901. The distribution of vertebrate animals in India, Ceylone and Burma. *Phil. Trans. Roy. Soc.* **B, 194** : 201-436.

Blyth, E. 1846. Notes on the fauna of Nicobar islands. *J. Asiat. Soc. Bengal,* **15** : 367-369.

Blyth, E. 1863. The Zoology of Andaman islands. Appexdix to Moutat's *'Adventure and Reserarches among the Andaman Islands'* : 345-367

Carlquist, S. 1965. *Island life : A natural History of the Islands of the World.* Natural History Press, New York.

Champion, H. G. and Seth, S. K. 1968. *A revised survey of forest types of India.* pp. xxvii + 1-404. Manager of Publication, Govt. of India, New Delhi.

Chandra, K. 2000. Insect biodiversity in Andaman and Nicobar islands. *ENVIS Newsletter, Zool. Surv. India,* **6** : 7-8.

Chandra, K. 2001. Fauna of Great Nicobar Biosphere Reserve. *ENVIS Newsletter, Zool. Surv. India,* **7** : 5-8.

Das, A. K., 1996. Faunal diversity, distribution pattern and zonations in the managrove ecosystem of Andaman and Nicobar islands. *Proc. Zool. Soc., Calcutta,* **49** : 57-65.

Das, A. K. 2000. Biodiversity in island environment with special reference to Andaman and Nicobar islands. In : *Biodiversity and Environment* (eds : A. K. Aditya and P. Halder), Daya Publishing House, Delhi, India, pp. 191-196.

Das, A. K. and Dev Roy, M. K. 1989. A general account of the mangrove fauna of Andaman and Nicobar islands. *Fauna of Conservation Areas :* **4**, *Zool. Surv. India* : 1-173.

Das, A. K. and Maiti, P. K. 1992. Island fauna : its dispersal, mode of colonisation and evolutionary pattern. *Proc. Zool. Soc., Calcutta,* **45** (Suppl. **B)** : 41-55.

Darwin, C. 1859. *On the Origin of Species by means of Natural Selection or the Preservation of Favoured Races in the Sturggle for Life,* London.

Gascoyne, M., Benjamin, G. J. and Schwartz, H. P., 1979. Sea level lowering during the Illinoian glaciation : evidence from the Bahama 'blue hole' *Science,* **205** : 806-808.

Krishnamurty, V. and Joshi, H. V. 1970. A checklist of Indian marine algae. *Cent. Salt & Mar. Ch. Res. Inst.,* 36 pp.

Mani, M. S. (ed.), 1974. *Ecology and biogeography of India.* W. Junk. Hague, Netherland.

Menon, A. G. K. and Talwar, P. K. 1972. Fishes of the Great Nicobar Expedition, 1966 with description of a new gobid fish of the family Kraemeriidae. *Rec. zool. Surv. India,* **66** : 35-62.

Miller G. S. 1902. The mammals of the Andaman and Nicobar islands. *Proc. V. S. natn. Mus.,* **24** : 751-795.

Mukundan, T. K. 1979. *Lakshadweep—a hundred thousand islands.* Academy Press, New Delhi, 225 pp.

Pattanayak, J. G. 1999. Annotated checklist of marine sponges of Indian Region. *Memoirs Queensland Mus.* **44** : 439-455.

Prain, D. 1983. Botany of the Laccadives. *J. Bombay nat. Hist. Soc.,* **8** : 57-86.

Raghaban, R. S. 1977. Floristic studies in India—the Western Circle. *Bull. Bot. Surv. India,* **19** : 95-108.

Reddy, Y. R. 2000. *Neodiaptomus meggitti* Kiefer, 1932 : A rare south-east Asian species from the Andaman islands, India (Copepoda, Calanoidea, Diaptomidae). *Crustaceane,* **73**(3) : 257-272.

Ripley, D. S. and Beehler, B. M., 1989. Ornithographic affinities of the Andaman and Nicobar islands. *J. Biogeography,* **16** : 223-232.

Stephenson, J. 1921. Oligochaeta from Manipur, the Laccadive islands, Mysore and Other parts of India. *Rec. Indian Mus.,* **22** : 746-768

Stoliczka, F. 1870. Observation on some Indian and Malayan amphibia and reptilia. *J. Asiat. Soc. Bengal,* **39** : 136-138.

Subba Rao, N. V., Das, A. K. and Mitra, S.C. 1980. On freswater molluscs of Andaman and Nicobar islands. *Rec. zool. Surv. India,* **77** : 215-246.

Tikader, B. K. and Das, A. K., 1985. *Glimpses of Animal Life of Andaman and Nicobar Islands.* Zool. Surv. India, Calcutta, 1-xi + 1-170.

Tikader, B. K., Daniel, A. and Subba Rao, N. V., 1986. *Seashore Animals of Andaman and Nicobar Islands.* Zool. Surv. India, Calcutta, 1-188.

Udvardy, M. D. F. 1969. *Dynamic Zoogeography with Special Reference to Land Animals.* Van Nostrand Reenhold Company, New York.

Wallace, A. R. 1880. *Island Life.* Macmilan, London.

Western Ghats

K.V. Lakshminarayana, G.M. Yazdani and C. Radhakrishnan

ENVIS–*Zool. Surv. India*
Ecosystems of India : 349-369, 2001.

Western Ghats

K.V. Lakshminarayana*, G.M. Yazdani** and C. Radhakrishnan

Western Ghats Field Research Station
Zoological Survey of India, Calicut 673 002.

1. INTRODUCTION

The Western Ghats have attracted the attention of naturalists for nearly 100 years in course of the studies on the biological material of their interests or in their discussions on the biogeography of the Indian biota. The Western Ghats, one of the major tropical evergreen regions in India possess exceptionally rich biological diversity owing to its climatic and geographic factors as well as its evolutionary continuity for more than 50 million years. The complex topography of the ghats with a wide range of microclimatic

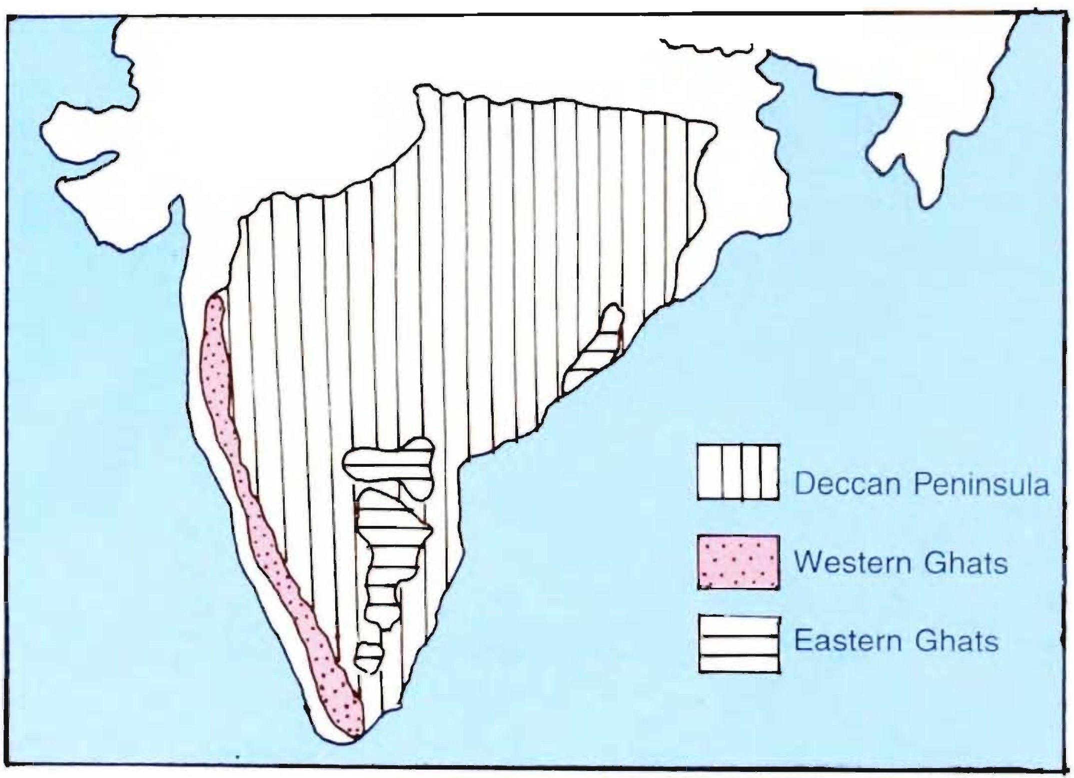


Fig. 1 : Showing location of Western Ghats, Eastern Ghats and Deccan Peninsula (only coloured area dealt with in the article)

* Scientist 'SE' (Retired), Southern Regional Station, Zoological Survey of India, Chennai 600 028.
** Scientist 'SF' (Retired), Western Regional Station, Zoological Survey of India, Pune 411 044.

and soil conditions have resulted in a mosaic of plant communities and animal associations unique to itself.

Besides being biologically rich in genera and species, the Western Ghats is rich in endemics too. For instance, two thirds of India's endemic plants are found here. All the major Peninsular rivers have their origin in the Western Ghats. Thus, Western Ghats form the major watershed in Peninsular India.

The forests of the Western Ghats are presumed to be the relict forests of probably a larger belt of forests that existed at one time in the Peninsular India. From the geological point of view, the Peninsular India once formed a part of the Gondwana continent. Therefore, some of its flora and fauna indeed show a relationship with the flora and fauna of the present day disjoined continents and islands such as South America, Africa, Madagascar, Sri Lanka and even Australia. Amphibia of the whole of India are almost completely derived from the Gondwana fauna and a number of fishes along with a few invertebrates also belong to this ancient fauna. The biotas were essentially of a tropical humid type and were also very widely distributed not only throughout the Peninsula, but also up to the foot of the newly rising Himalaya until perhaps relatively recent times. The continental drift, the rise of the Himalaya and the glacial period brought about a lot of changes in the then prevailing habitat conditions and transmigration of the temperate and Eurasian forms to Peninsular mountain ranges and forests took place. The large scale climatic changes and the resultant dessication in the Peninsular plains influenced by the rising Himalaya, coupled with large scale deforestation brought about by man within historical times forced some of the originally widespread species to confinement in the last vistages of forests in the mountain ranges especially in the Western Ghats. Thus, we find today in the Western Ghats an admixture of the relict fauna of the Gondwana, the autochthonous fauna and the later migrants. Therefore, the biocommunes in the Western Ghats form a major genetic resource of the country.

In summary, the Western Ghats being an area having one of the richest biological resources form a distinct ecological and biogeographical region of India and is considered an extremely important life supporting system in the Peninsular India. The biotic richness in terms of genera, species and endemicity as well as the threats it faces due to man's interference in recent times have made the Western Ghats figure today as one of the 25 'Hot-spots' in the world.

2. DESCRIPTION GEOGRAPHICAL DISTRIBUTION AND PHYSIOGRAPHY

The Western Ghats or the Sahyadris (Map) stretch from 22° N to 8°N latitude (from the River Tapti in the north to Kanyakumari in the south) for nearly 1400 km, covering an area of nearly 1,40,000 sq km, parallel to the west coast of peninsular part of India through the states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala. Most of the high peaks of the ghats rise above 1400 m. The highest peak in the northern part or north Sahyadri is Kalusubai (1646 m) lying close to Igatpuri (Maharashtra). The Sahyadri running a little below 16°N latitude and up to the Nilgiris is referred to as Central Sahyadri. Vavulmala (2339 m) is the highest peak in this region. The southern hills (ghats) referred to as southern Sahyadri are separated from the main Sahyadri by the Palghat gap. The latter is believed to have been formed by a rift valley in the past. The southern Sahyadri radiates into three ranges from the Anaimudi Peak (2695 m), *i.e.*, the Anaimalai to the north, Palni to the northeast and the Elamalai or Cardamom Hills to the south. The most picturesque mountain range is the Nilgiri (2600 sq km area with a summit level of 1800-

2500 m) with temperate climate. The highest peak here is Doda Betta (2636 m). It connects three mountain systems of the Peninsular India, *viz.*, the main Sahyadri in the north opposite Mukurti peak, the Eastern Hills (ghats) in the northeast and the southern Sahyadri in the south across the Palghat gap. Therefore, it plays a significant role in the biogeographic evolution of the flora and fauna.

The major rivers of the southern Peninsular India and their tributaries have originated in the Sahyadri Ranges. The river Godavari (1500 km) rises near Nasik, and all the tributaries like Wardha, Penganga, Wainganga, Sabari, etc., also owe their origin to Sahyadris. The Krishna (1400 km) is another major river and its largest tributary Bhima has its source near Mahabaleswar. Its other tributaries like Venna, Thungabhadra, etc., have also their origin in Sahyadris. Another major river, the Cauvery (805 km) originates near Talai Cauvery in Coorg district (Karnataka) at an elevation of 1340 m. All these rivers flow eastwards while some rivers like Gayatri, Kalinadi, Nethravathi, Sharavathi, Bharathapuzha, Periyar etc., flow westwards. There are picturesque waterfalls like Gersoppa and smaller streams or lakes on the ghats which harbour a number of aquatic species often endemic and limited in distribution, and also peculiar hill stream or torrential stream adapted fauna.

Unlike the extra-peninsular rivers, the Peninsular rivers are dependent exclusively on monsoons. The climate in the Western Ghats is chiefly monsoonic and main rainy season lies between June-September. Depending on the elevation and topography, the rainfall varies from 100-500 cm and sometimes even more as in some parts of Kerala with average

Fig. 2 : A view of Anamudi

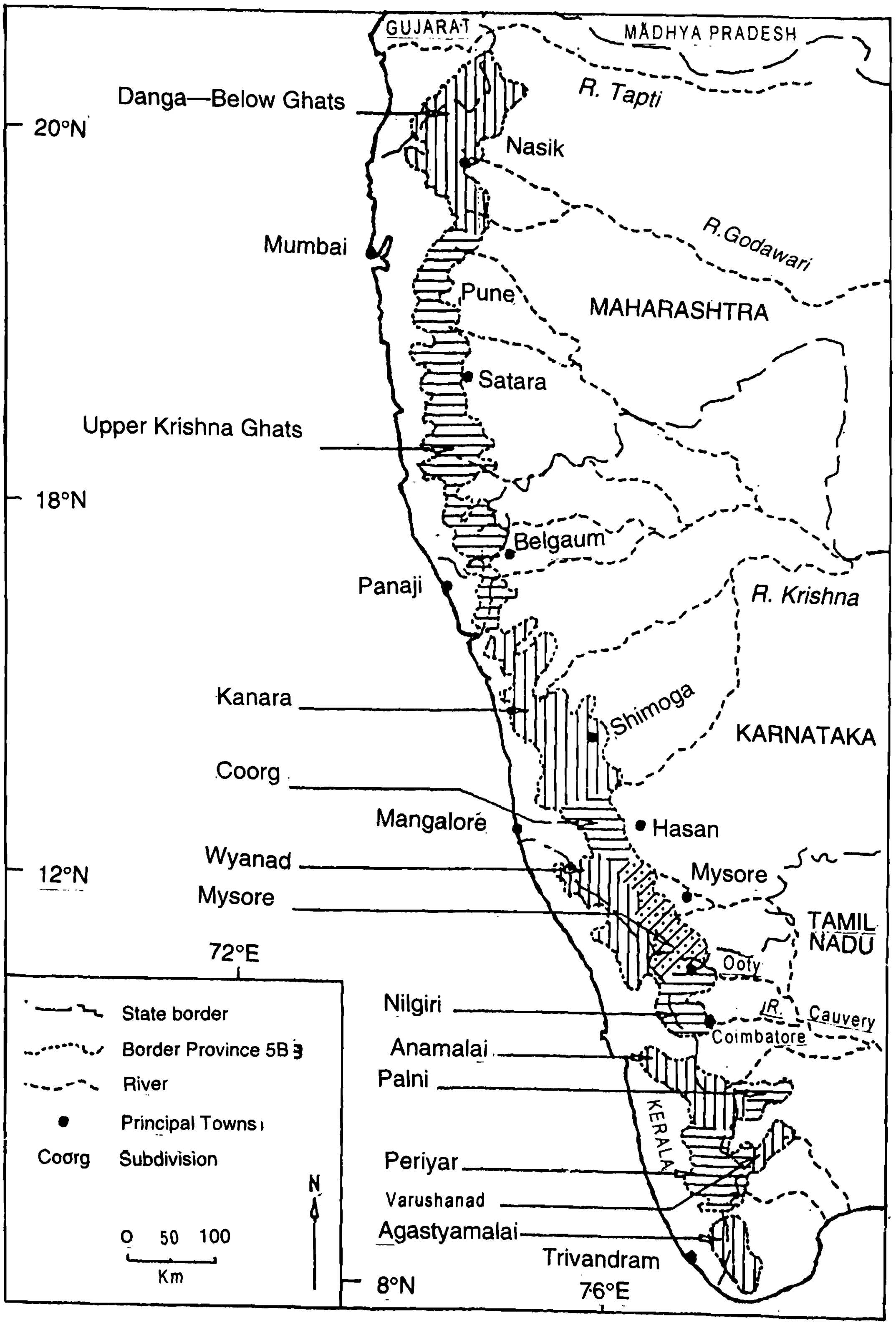


Fig. 3 : Biodiversity areas in Western Ghats

rainfall well over 700-850 cm. The temperature fluctuates between 10-38° C (mean annual temperature) in the wet evergreen zone. The atmosphere is highly humid even upto 80% in early hours of the day in forested zones.

The Western Ghats soils can be broadly grouped in to three types. The red soils derived from the granites and gneisses which are porous varying from sandy to clayey loams. The red soils bear dense wet-evergreen and semi evergreen forests. Another group of soils is the black soils derived also from the granites and gneisses or basaltic lava and are alluvial in origin. These soils are rich in nutrients and bear dense moist deciduous vegetation. The third type of soil is lateritic, poor in nutrients and supports plants of scrub type.

Fig. 4 : A high elevation grassland habitat in the Eravikulam National Park, Kerala

3. BIOLOGICAL DIVERSITY

3.1 Ecosystem/habitat diversity

Western Ghats fall under the Palaeotropical (Indo-Malayan) biogeographical zone. It is a relatively homogenous and biologically distinctive zone divided into the biotic provinces of the Malabar coasts/plains and the Western Ghats mountains. The typical biome in the Malabar coasts/plains comprises of evergreen forests, moist deciduous forests and wetlands. This area spreads over the coastal plains south of the Tapti River through Gujarat, Maharashtra, Goa, Karnataka, Kerala and up to Kanyakumari in Tamil Nadu ending at 250 m. Contour of the Western Ghats mountains in the hinterland, once did have a distinctive forest cover of swamp, evergreen and deciduous components though at present is largely deforested. The biotic province of Western Ghats mountains harbours the most important evergreen, moist deciduous and montane forests besides grasslands and wetlands. All the mountain ranges from the Tapti River to Kanyakumari, the eastern boundary of which is the divide between potential moist and dry forest zones fall under the Western Ghats mountains province.

Though ecosystems are shaped and influenced by the topography and climate, interlinkages between these in Western Ghats present a picture of confusing complexity comprising of a whole range of gradients, both altitudinal as well as latitudinal in many climatic factors. The complex topography, variation in edaphic factors between sites and variation in plant and animal communities are too large here to identify the features typical of a particular ecosystem though Western Ghats is generally considered a typical forest eco-zone.

3.2 Species diversity

The flora and fauna of Western Ghats in addition to being derivatives of the ancient Gondwanan elements show prominent affinity to the Malayan and Indo-Chinese biota. There are a large number of tropical American and Australian elements besides Pleistocene relicts which are temperate and boreal species of the Himalaya, that once had a continuous range but later became isolated in the post-glacial climatic and consequent ecological changes. Many hill-tops and plateaus reaching 2000 m or more in elevation harbour such relict biotas. Delimited by the sea to the west, the Vindhya and Satpura ranges to the north and the arid Deccan plateau to the east, the western ghats are both insulated and isolated, and have provided conditions for the development of a large number of endemic flora and fauna. The very humid climate with relatively short spells of dry season has resulted in rich species diversity of plants and animals.

3.2.1. Flora : Floristically, the Western Ghats is one of the richest areas in India, harbouring no less than 3500 species of flowering plants which constitute about 27% of the flowering plants in the country. There is an equal proportion of lower plants as well. The Western Ghats is the most important distribution range for many plants at family and generic level. Many plants found in the Western Ghats are extremely restricted in distribution. For instance, the Chemmunji peak area in the Agasthyamalai Range is the type locality for half a dozen endemic plant species and the Agasthyar Peak itself is exceptionally rich in plants with a number of species of restricted distribution (Nair, S.C. 1991).

The ten dominant families of plants in the Western Ghats belong to Poaceae, Leguminosae, Acanthaceae, Orchidaceae, Asteraceae, Euphorbiaceae, Rubiaceae, Asclepiadaceae, Geraniaceae and Labiatae. Genera, such as, *Crotaleria, Impatiens, Diospyros, Ipomoea, Eugenia, Strobilanthus, Ficus,*

Fig. 5 : Tropical wet evergreen forest in Western Ghats, India

Fig. 6 : Shola-grassland ecosystem in high range, Kerala

Desmodium, Habenaria, Grewia and *Osbechia* are represented by more than 15 species each in the Western Ghats.

There are 1500 endemic plant species in the Western Ghats, of which 101 occur in fragemented populations. The plant family Poaceae has the highest number of endemic genera and the genus *Nilgirianthus* has species-wise the maximum number comprising of 20 endemic species. Bambusae in the Western Ghats includes 17 species under 6 genera. The genus *Ochalandra* of Bambusae has 6 species endemic in Western Ghats, out of the 17 reported from India. Among the 200 species of the herbaceous plant genus *Impatiens* known from India, 86 species occur in the Western Ghats. Of the 21 palms reported from the Western Ghats, *Bentenckia coddapanna, Pinanga dicksonii* and nine species of *Calamus* are endemic to the stretch of the ghats, south of Coorg. This area is considered floristically the richest section in the Western Ghats. Four species of *Myristica* including *M. fragrans*, the cultivated nutmeg tree, are reported from this section. Families, such as, Podostemaceae, Umbelliferae, Loranthaceae, Acanthaceae, etc., are well represented in the southern Western Ghats. The wild relatives of many economically important plants like *Dioscorea, Elletaria, Musa, Oryza, Piper, Zingiber* and *Curcuma* are also abundant there. The economically important leguminous genus *Dalbergia* to which the much valued rosewood belong has 22 species in Western Ghats, out of 25 species known from India. *Dalbergia beddomei* and *D. travancorica* are endemic to the ghats of Kerala and occur only in the Silent Valley and Agasthyamalai Range respectively. The Western Ghats harbour 84 species of Orchids belonging to 30 genera, of which 3 genera are endemic. 37% of the known orchids of the Peninsular India are endemic to the Western Ghats region.

Phytogeographically four regions can be recognised within Western Ghats (Abraham, 1986). They are: (1) region from River Tapti to Goa, (2) region from River Kalinadi to Coorg, (3) the Nilgiris and (4) the Anamalai, Palani and Cardamom Hills. The main types of vegetation found in the region from the River Tapti to Goa are the scrub, dry semideciduous, dry deciduous, moist deciduous and the montane sub-tropical evergreen hill forests. The entire area from the River Kalinadi to Coorg is hot and humid and scrub, moist deciduous and wet evergreen forest types are found there. The flora of the Nilgiris shows relationship with that of the Eastern Himalaya and the forest in this region is evergreen composed of tropical and subtropical vegetation. The evergreen 'Sholas' occur at elevations of 1600 m and above. Insectivorous plants like *Drosera* and *Utricularia* are common above an elevation of 2000 m. The flora of the Anamalai, Cardamom and Palani Hills region shows marked affinity with that of Sri Lanka in having a large number of species in common. Interestingly, the monotypic genus *Kendrickia* of the family Melastomataceae is restricted to Anamudi, the highest peak in Western Ghats and Adam's Peak, the highest peak in Sri Lanka. The indigenous conifer, *Decussocarpus wallichianus* is found in the wet evergreen forests of this region of Western Ghats.

3.2.2. Fauna : Faunal wealth of certain groups especially the vertebrates is known in details while information on invertebrates is widely scattered. Therefore, vertebrate groups are discussed first followed by the lesser known invertebrate groups. Diversity of animal species/subspecies reported so far from Western Ghats is presented in Table 1.

Fishes : 209 species of freshwater fishes occur in the Western Ghats, of which 120 are endemic to the area. The genera *Lepidopygopsis, Bhavania, Travancoria, Horabagrus,* and *Horaglanis* are truly autochthonous, differentiated from the phylogenetically older and widely distributed ancestral forms and also restricted to the Western Ghats. Many of the genera of fishes in Western Ghats show affinities to the fishes of Malayan Peninsula. Jayaram (1974) opines that the autochthonous elements of the Indian subregion are curiously restricted to the southern part of the Peninsula and none of them occur in Sri Lanka, probably indicating their recent origin (post-Pleistocene).

Six species are endemic to Nilgiris alone. They are *Danio neilgherriensis, Osteobrama neilli, Kantaka brevidorsalis, Puntius mudumalaiensis, Schistura nilgiriensis* and *Mesonemacheilus pulchellus. Puntius bimaculatus,* formerly known only from Sri Lanka has been subsequently discovered in the Southern Western Ghats. Among the fishes endemic to the Western Ghats, about 16 species have been identified as economically important cultivable/sport fishes and 51 species as potential ornamental fishes by the National Bureau of Fish Genetic Resources (NBFGR), Lucknow. Biogeography of the fishes of Indian Peninsula (and Western Ghats) has been discussed by Hora (1949) and Mani (1974).

Amphibians : Western Ghats is the richest region in India in terms of amphibian endemicity. About 48% of the 219 species of amphibians known from India are endemic in the Western Ghats. The majority of the species inhabit the evergreen moist forests of the ghats. 133 species occur in Western Ghats, of which 106 are endemic in this biogeographic zone (Table 1). Majority of the Gymnophiona (limbless amphibians) known from India are endemic in the Western Ghats. Among Anura, *Bufo hololius, Ramanella triangularis, Nyctibatrachus deccanensis, Rana brevipalmata, Rana rufescens, Philautus flaviventris, P. temporalis, P. travancorensis, Rhacophorus calcadensis* and *R. lateralis* are rare and represented in the ghats. The Malabar Tree toad, *Pedostibes tuberculosus* and the black microhylid, *Melanobatrachus indicus* of Western Ghats are listed in the Red Data Book. The Anuran genera *Micrixalus* and *Nyctibatrachus* are mostly restricted to Western

Table 1. Diversity of animal species in the Western Ghats (based on published reports)

Taxa		No. of Species/ Subspecies	No. of endemic Species/Subspecies
Vertebrates		**921**	**400**
Class	MAMMALIA	**106**	**12**
Order	Insectivora	6	1
	Scandentia	1	—
	Chiroptera	30	2
	Primate	6	2
	Pholidota	1	—
	Carnivora	23	3
	Proboscidea	1	—
	Artiodactyla	10	1
	Lagomorpha	1	—
	Rodentia	27	3
Class	AVES	**310**	**73**
Order	Ciconiiformes	6	—
	Falconiformes	18	—
	Galliformes	12	5
	Gruiformes	5	—
	Charadriformes	6	1
	Columbiformes	9	1
	Psittaciformes	4	2
	Cuculiformes	12	3
	Strigiformes	8	2
	Caprimulgiformes	4	1
	Apodiformes	6	—
	Trogoniformes	1	1
	Coraciiformes	19	5
	Piciformes	17	4
	Passeriformes	183	48
Class	REPTILIA	**163**	**89**
Order	Testudines (Turtles & tortoises)	8	2
	Lacertilia (Lizards)	64	36
	Serpentes (Snakes)	91	51
Class	AMPHIBIA	**133**	**106**
Order	Gymnophiona	13	13
	Anura	120	93

Table 1 contd.

Taxa		No. of Species/ Subspecies	No. of endemic Species/Subspecies
Class	PISCES	209	120
	Invertebrates	4623*	39*
	PROTOZOA	111	—
Phylum	PORIFERA	18	4
Phylum	CNIDARIA	1	—
Phylum	ANNELIDA	26+	
Phylum	ARTHROPODA		
Class	CRUSTACEA	18	
Class	INSECTA	4056	
	Arachnida	193	9
	Chilopoda	40	9
	Diplopoda	4	
	Symphyla	2	
Phylum	MOLLUSCA	236**	17
	Total	5626+	439*

* Data of invertebrate species in general and endemic invertebrates in particular considerably incomplete
** include 5 fossilised species of freshwater bivalves

Ghats. In general, the amphibian genera in India including Western Ghats are considered to be derived from the Gondwana fauna hence, ancient and relict.

Reptiles : The Western Ghats harbour 163 species of reptiles out of which 89 species are endemic (Table 1). Presence of at least one group of rough-tailed primitive burrowing snakes belonging to the family Uropeltidae in the ghats makes it an important centre for reptile conservation.

Among the chelonians, two threatened species, *viz.*, *Geoemyda silvatica* (Cochin Forest cane turtle) and *Indotestudo forstenii* (Travancore tortoise) occur in Western Ghats. Many of the chelonians have existed unchanged since Triassic and, therefore, they are to be treated as rare and relict species.

36 species of lizards are known to be endemic in Western Ghats. The species of the gekkonid genus *Cnemaspis (indica, wynadensis, sisparensis, ornata, beddomei, mysoriensis, littoralis, goaensis, nairi)* are all dwarf geckos confined to the Western Ghats. The family Gekkonidae is the most ancient family, compared to Agamidae and Scincidae, the other member of the living lizard group. *Hemidactylus prashadi* is a gekkonid designated as threatened and endemic to the Western Ghats. *Cyrtodactylus* has the species *dekkanensis* and *albofasciatus* endemic in the Western Ghats. *Dravidogecko anamallensis* is known only from southern Western Ghats.

The Agamid *Draco dussumieri*, the only south Indian flying lizard is found in Western Ghats. *Otocryptis beddomei* related to those found in Sri Lanka is also endemic here. Other endemic species of Agamids include *Salea horsfieldi*, *S. anamallayana* and three species of *Calotes (grandisquamis, rouxi, elliotti)*. The only member of Lacertidae, *viz.*, *Ophisops beddomei* is an endemic one. The skinks *Scincella* with five species *(travancoricum, beddomei, laterimaculatum,* *bilineatum, pulnicum), Riopa* with three species *(guentheri, lineata, goaensis), Ristella* with four species *(rurki, travancorica, beddomei, guentheri)* and *Mabuya clivicola* and *Eumeces poonaensis* are endemic in the ghats.

The snakes include five families and several of their members are endemic in Western Ghats. *Lycodon flavomaculatus, Dendrelaphis grandoculis, Rhabdops olivaceus, Boiga dightoni, Calliophis beddomei, Dryocalamus nympha, Ambhiesma monticola*, etc., are only a few of a large number of species that can be cited occurring as endemic in Western Ghats. The rough-tailed snakes or Uropelts comprising of 30 species, endemic in Western Ghats are specially noteworthy.

Snakes of India are dominantly Indo-Chinese in origin. The Palaearctic and Ethiopian elements are small and are represented by degenerate forms. The Malayan element is considerable both in Indo-Chinese and Indian subregions including the Sahyadris. The snakes that are largely concentrated in the Western Ghats and Sri Lanka appear to be relicts of a once widespread fauna which radiated in more than one phase.

Birds : India harbours 2123 species/subspecies under 405 genra and 78 families (Saha, 1998). The avifauna of Western Ghats comprises 15 orders, 137 genera and 310 species/subspecies of which 73 species/subspecies are endemics (Ripley. 1961) as detailed in Table 1.

Mammals : Mammals in the Western Ghats are represented by 106 species under 73 genera and 10 orders (Table 1). Swengel (1990) places *Suncus dayi* (Insectivora), *Latadens salimalii* and *Otomops wroughtoni* (Chiroptera), *Macaca silenus* and *Trachypithecus johnii* (Primates), *Funambulus tristriatus, Platacenthomys lassilurus* and *Mus famulus* (Rodentia), *Martes*

Fig. 7 : Great Pied Hornbil, *Buceros bicornis*, exhibiting discontinuous distribution

Fig. 8 : Nilgiri Tahr—*Hemitragus hylocrius* a Palaearctic element, endemic to Western Ghats

gwatkinsi, Viverra civettina and *Paradoxums jerdoni* (Carnivora) and *Hemitragus hylocrius* (Artiodactyla) as endemic to Western Ghats. In addition, the Western Ghats also harbour the Slender Loris *(Loris tardigradus)* and the Grizzled Giant Squirrel *(Ratufa macroura)* which are vulnerable and the Indian Pangolin *(Manis crassicaudata)* the status of which is indeterminate.

Invertebrates

Our knowledge of the invertebrate fauna in general in the country and more so from Western Ghats is very insufficient. Further, the literature is widely scattered and not always available in comprehensive forms like catalogues or monographs. In this context, an attempt has been made here, to evaluate the information on the invertebrate fauna of the Western Ghats based on published records.

Protozoa : No specific or exhaustive work on the Protozoa occurring in Western Ghats has been carried out. However, Nair, K. N (in press) has reported 111 species of Protozoa under 44 genera and 29 families from the Nilgiri Biosphere Reserve. The ciliates of the order Entodiniomorpha, namely, *Elephantophilus zeta* and *Polydiniella mysoreum* (Polydiniellieae) have been reported from caecum and colon of the elephants from Nilgiri mountains.

Porifera : 18 species of freshwater sponges are known from the Western Ghats. Annandale (1911) considers the poriferan fauna of Malabar zone of the ghats very distinctive. Three species of *Stratospongilla* and one species of *Pectispongilla* are considered endemic. Occurrence of *S. bombayensis* in Western Ghats and again in Natal (South Africa) explains the past Gondwanan connection between Africa and India.

Cnidaria : The fresh water medusa *Limnocnida indica* is reported from the smaller streams of the upper Krishna river system on the eastern slopes of the Western Ghats. This species has also been reported from the Chota-Nagpur area of the Indian Peninsula. According to Mani (1974) this is an African form and is considered a Gondwanan relict.

Annelida : The Moniligastrid genus *Drawida* contains many species endemic to India and also contains the longest worms sometimes reaching a length of over one meter like *D. nilamburensis* and *D. grandis* found in the Western Ghats. The subfamily Malabarinae of Ocnererodrilidae is believed to have evolved in the Western Ghats of the Malabar area. Stephenson (1932) remarks that the southern region has considerably more indigenous species than any other area in India. The indigenous species according to him belong to the genera *Drawida, Plutellus, Woodwardia, Spenceriella, Comarodrilus, Megascolides, Notoscolex, Perionyx, Pheretima, Dichogaster, Curgia, Wahoscolex* etc. Many of the species show relationship with Madagascan species and a number of genera occur in Australia and New Zealand.

Chandra (1983) provided a checklist of leeches (Class:Hirudinea) pertaining to 60 species and subspecies under 25 genera available in the country. Of this, 13 species under 12 genera are known to occur in the Western Ghats.

Mollusca : Streams in the hills and at higher elevations have a different molluscan fauna from those in the plains and in this respect the streams in the Western Ghats and Nilgiris are remarkable for their characteristic malacofauna. For instance, the fresh water mollusc, *Cremnoconchus (C.) syhadrensis* occurs only at the edge of waterfalls at Khandala in Western Ghats. This is to mention here that the fresh water species *Physa (Bullinus) principepii, Corbicula ingens, Cerithium stoddardi, Paludina normalis* and *Lymnaea subulata* have been found fossilised in the Cretaceous Intertrappean beds of the Deccan lava. Of these, the genus *Physa* became extinct in India, although it still exists in Africa. Western Ghats has a representation of 231 species comprising of 204 species of land gastropods, 20 species of freshwater gastropods and 7 species of freshwater bivalves. Out of these, 17 species (13 land gastropods, 2 freshwater gastropods and 2 freshwater bivalves) are endemic in Western Ghats (Subba Rao, 1989).

Arthropoda : Arthropoda include diverse classes and the information is scattered in scientific literature. However, the State of Art Report (ZSI, 1991, 1998) gives fairly well a resume on various classes.

Crustacea : 18 species under 10 genera are found in the Western Ghats. Michael and Sharma (1988) reported 9 species of ostracod viz., *Ceriodaphnia quadrupula, Scapholeberis kingi, Sinocephalus acutirostratus, Moina micrura, M. macrocopa, Macrothrix laticornis, Chydorus hermanni, C. ventricosus* and *Alona guttata* from Western Ghats. Among the Conchostraca there is a data deficiency in Western Ghats though the group is exclusively found in fresh waters. Among the Decapoda, fresh water crabs, such as, *Paratelphusa (Barytelphusa) jacquemonti, P. (Liotelphusa) levia* have been reported from Silent valley. The prawn, *Macrobrachium latimanus* of Macrura has been reported from the kerala part.

Chilopoda : About 40 species of Chilopoda are known from Western Ghats, of which *Arthororheldus jonesii, Cormocephalus denticaudus, C. nigrifasciatus, Asanda agarkhari, Digitipes gravelyi, D. indicus, Ethmostigmus platycephalus platyecphalus, E. platicephalus cribifer* and *Rhysida crassispina* are endemic in the Ghats.

Diplopoda : Of the 162 species known from India, 93 are reported from S. India. *Chodromorpha kelaarti, C. severini, Streptogonopus phipsoni* and *S. nitens* have been recorded from Silent Valley.

Symphyla : Very little is known about this group in India. The genera, *Hanseniella* and *Symphyella* are known from Silent Valley.

Arachnida : 32 species of Scorpionida (scorpions) occur in Western Ghats, of which 9 are endemic in the ghats. The orders belonging to Pedipalpida, Solpugida, Opiliones (Phalangida), Pseudoscorpionida, Acari and Araneae are rather poorly worked out in our country except to some extent the orders Pseudoscorpionida, Acari and the Araneae. Tikader (1973) recorded 2 species of Uropygi (Thelyphonidae), 1 species of Amblypygi, 4 species of Solpugida and 154 species Araneae from Western Ghats.

Insecta : Species diversity of the Insecta recorded so far in the Ghats is presented in Tables 1 and 2. Among the Apterygote (wingless) insects, 5 species of Protura and about 43 species of Collembola including the monotypic genus *Indoscopus* and the species *I. spinosus* are known from the Sahyadris (Hazra, 1991; Prabhoo, 1971).

The pterygote (winged) insects are better known in Western Ghats than the Apterygotes. Among the Odonata (damsel and dragonflies), the genera, *Chloroneura, Indoneura, Melanonaura, Esme, Phylloneura, Idiophya*, etc., are endemic in the Western Ghats. Plecoptera (Stoneflies) are known in the Ghats by the genera *Neoperla* and *Perla*. Some of the Orthoptera (Grasshoppers and Crickets) genera like *Bababuddinia, Chitaura, Coptacra* and *Palniacris* are endemic in the Western Ghats. About 146 species of Phasmida (stick and leaf insects) are known from India (Shishodia, 1998). The Malayan element of Peninsular Phasmida has been summariesed by Mani (1974). *Pharnacia serratipus* occurring in Malabar, Borneo and Malaya is one of the largest phasmids and measures about 330 mm. *P. ingens* occurring in Malabar and Myanar measures 260 mm. Dictyoptera include cockroaches (Blattaria) and the mantids (Mantodea). About 156 species of Blattaria are known from India. The Blattid genera reported from Silent Valley are *Neostylopyga, Stictolampra, Anaplecta, Ellipsidion, Blatella, Ischnoptera, Trichoblatta, Panesthia, Salganea, Nauphoeta, Thorex, Epilampra* and *Calolampra*. 45 species of mantids occur in southern India (Hazra and Mukherjee, 1998). 21 species of Dermaptera (Earwigs) are endemic in the Ghats. Maiti and Saha (1998) reported the occurrence of 73 species of Isoptera (termites) from Western Ghats. Ananthakrishnan (1978) stated that as result of conversion of Forests to plantation crops, the two best known gall thrips (Thysanoptera) *Kochumania excelsa* and *Leeuwenia vorax* of Western Ghats have recently become scarce. Species of *Bactriodothrips* and *Dinothrips* have become rare besides the total disappearance of *Erotidothrips mirabilis*, a relict species of thrips recorded earlier from the Thenmalai Hills of the Ghats.

Heteroptera and Homoptera, together treated as Hemiptera by some authors constitute one of the largest component of the exopterygote insect orders. Rao (1986) reported 14 species of Cicadellidae (Homoptera) from Silent Valley. Of the 18 species of rare leaf hoppers (Cicadellidae) found in the Western Ghats, 13 are considered endemic. Ananthasubramanian (1996) has dealt with the Indian Membracidae (Homoptera) commonly known as cow bugs, horn bugs and tree hoppers. David and Subramanian (1976) studied the Aleurodoidea (Homoptera) or white flies occurring in the Western Ghats. Silent Valley got its name in the belief that no Cicadas (Cicadidae : Homoptera) are present there, which however is not true; rather *Platylomia larus* and *Gaena atkinsoni* have been reported from the Silent Valley. About 430 species of Fulgoridae (Homoptera) or lantern flies are known from India of which, species belonging to the genera *Hemispherius*, *Phromnia*, *Stacta* and *Tambira* are known from the Ghats in Kerala. Mathew (1986) described the Pentatomid bug *Gellia kuntiae* from Silent Valley. Among the aquatic and semiaquatic Heteroptera known from the Ghats, 7 genera and 13 species are recorded so far only in the Ghats. Among the Coleopteran species known from the Ghats, *Copelatus biswasi* (Dytiscidae); *Onthophagus keralicus*, *O. taruni*, *O. sahai* (Scarabaeidae); *Icthyurus silentvalleyensis* (Chauliognathidae) are so far known to occur only in Silent Valley.

The butterfly fauna of the Western Ghats, the Nilgiris in particular (Larsen, 1987, 1988) is considerably rich in terms of species and genetic diversity. Mathew (1999) has dealt with the butterflies and moths of Silent Valley.

Dutta and Parui (1991) provided a review of the Indian Diptera (true-flies). Of the 6093 species of Diptera known from India, about 30% are likely to occur in the Western Ghats. Information on the Hymenoptera of the Ghats can be found in Bingham (1897, 1903), Narendran (1989, 1994) and Sureshan (1999).

4. SPECIAL FEATURES

The number of endemic species *vis-a-vis* total number of animal species known from the Western Ghats is already outlined in Tables 1 and 2. Suffice to state that the Western Ghats ecosystems is the only undisturbed evergreen forest ecosystem at least in part. Therefore, many of the original Gondwana relicts, the autochthouous fauna of Peninsular India, the transmigrants from the Palaearctic and later Indo-chinese and Malayan species and some Himalayan relicts which reached Peninsular India during glacial periods have found a refugium in the Western Ghats forests. They also evolved here in their own way. In the Western Ghats, there are a series of forest Gaps which are actually valleys that break the continuity of the mountain ranges. Some of the major Gaps are the Palghat Gap, Moyar Gap or gorge and the Chenkotta Gap. These Gaps have resulted in preventing the spread of certain species and have hence facilitated local speciation and endemism.

The Western Ghats harbour a healthy population of most of the animal species of the Peninsular India, *viz*., tiger, elephant, gaur, dhole, sloth bear, panther and several species of deer. It also exhibits a fairly good degree of endemism amongst mammals, such as, primates, ungulates, carnivores, rodents, squirrels and among birds. Amongst amphibians, most of the species and nearly half the genera are endemic, while a good degree of endemism is visible amongst reptilies, fishes and insects. However, the

Table 2. Species diversity of Insects in Western Ghats

Order	No. of Species	
	India	Western Ghats
Protura	20	5
Collembola	210	43
Odonata	499	122
Plecoptera	113	6
Orthoptera	1750	33 (Silent Valley)
Phasmida	146	38
Dermaptera	320	73
Blattariae	186	13 (genera)
Mantodea	162	45
Isoptera	253	73
Phthiraptera	400	35
Hemiptera	6500	255
Homoptera : Membracidae	233	100
Cicadellidae	680	14 (Silent Valley)
Aleurodoidea	117	20
Psyllidae	48	15
Heteroptera : Aquatic & semi-aquatic families	183	92
Pentatomidae	700	14 (Silent Valley)
Thysanoptera	693	162
Neuroptera	335	24
Coleoptera	15500	13
Gyrinidae	35	7 (Silent Valley)
Chauliognathidae	30	1 (Silent Valley)
Dytiscidae	223	5 (Silent Valley)
Strepsiptera	18	1
Diptera	6093	1800
Lepidoptera	15000	710
Trichoptera	812	126
Hymenoptera	10000	492
	Total :	4056

faunal endemism is mostly restricted to the central and southern parts of the ghats.

Some of the faunal components of the ghats are of great zoogeographical significance. Fresh water fishes belonging to genera like *Horabagrus*, *Bhavania* and *Travancoria* are restricted to the Western Ghats. Amphibian genera such as *Micrixalus*, *Nyctibatrachus* and most of the Indian species of limb-less amphibians (Gymnophiona) are restricted to the ghats. Among snakes, the entire family Uropeltidae is essentially restricted to the Western Ghats and Sri Lanka. Among birds, the Grass warbler genus *Schoenicola* and among mammals the muscardinine genus *Platycanthomys* are endemic to the Western Ghats. The tahr of the genus *Hemitragus* exemplifies a most intriguing pattern of geographical distribution in which the species Nilgiri Thar, *H. hylocrius* is confined to the Western Ghats while Himalayan Thar, *H. jemlahicus* the only other species of Indian tahr is found in the far off Himalaya. The similar pattern is exhibited by other mammalian genus *Martes*, two subspecies of the bird Laughing thrush *Gerrulux delesserti*, reptilian genus *Draco* and the freshwater fish genera *Thynnichthys*, *Silurus* and *Batasio*.

Thus, Western Ghats ecosystem is one of the prime gene pool resources of the country both in terms of flora and fauna, primarily because a number of taxa found in the country exclusively occur here.

5. INTRODUCED BIODIVERSITY

The introduction of exotic species to the country took place long ago so that many of them have assumed to become pseudonatives (naturalised exotics). The glaring examples from the Western Ghats are exotic flora Eucalyptus, Coffee, tea, rubber, etc., and exotic fauna, such as, Rainbow trout (game fish) and tilapia (food fish). Monoculture practices in the Western Ghats with introduced flora and even with indigenous plant species, have resulted in the degradation and disruption of natural communities upsetting their stability and biodiversity equilibrium. It has also been responsible for severe pest outbreaks and emergence of secondary pests.

Some of the Coleoptera and Heteroptera that have established as pests of the introduced plants have also secondarily established as pests of a number of indigenous plants and are spreading even to our cultivars. *Antestia cruciata* of the insect order Heteroptera is a typical case. More examples can be seen in the outbreak of teak skeletoniser *(Eutectona machaeralis)* and teak defoliator *(Hyblaea puera)* in almost all the teak growing areas of Western Ghats and the outbreak of *Pteroma plagiophleps* (Lepidoptera) on *Albizia falcataria.* These lepidopteran species are generally inaucuous pests in the natural forests. Introduction of the exotic fodder plant *Lucaena leucocephala* (su-babul) has also brought along its pests, *Heteropsylla cubana* (Homoptera) and *Ithome lassula* (Lepidoptera), to the ghats.

Cultivation of rice in areas cleared of forest in the ghats has favoured the population build up of the Heteropteran paddy pest, *Leptocorisa varicornis* which originally was surviving mostly on wild grasses. The present day distribution of the Agromyzide (Diptera) *Ophiomya lantanae* and *Tropicomyia coffeae* in the ghats are limited to cultivated areas and the abundance of these leaf miners coincide with maximum deforestation and introduction of their host plants to hill agriculture and plantations. Introduction of certain Malayasian creepers as cover crops in rubber plantations is responsible for the occurrence of its leaf miner *Japanagromyza indica* in the ghats.

Procecidochares utilis, a Neotropical species of Tephritidae (Diptera) was introduced in India including the Western Ghats for eradication of the obnoxious weed *Eupatorium trapezoideum* after its grand success in Hawaii. However, the fly inspite of establishing itself sufficiently well has not been effective in India. *Teleonemia scrupulosa*, an exotic Hemipteran bug was introduced in India for the control of *Lantana* weed. However, the insect was found to be a threat to teak plants as well.

The exotic Rainbow Trout, *Salmo gairdnerii gairdnerii* has established itself in the cold-water systems of the High Range and the Nilgiris in the ghats. The African Cichlid, *Oreochromis mossambica*, popularly known as tilapia, has become naturalised in the inland waters, significantly in many lakes and reservoirs associated with the river systems in the country including the ghats. Their success has been doubted to be at the expense of our native fish fauna.

6. VALUE

The wealth of the Western Ghats is mainly due to its natural resources, especially those wherein living systems play a vital role. The floral and faunal peculiarities of the ghats have already been discussed. Its functional value serving as the last refugium of Peninsular Indian flora and fauna has also been emphasised.

The ghats provide habitation to many species and genera of plants and animals which are unique to the ghats. Several discoveries new to science pertaining to the flora and fauna, are being brought to light frequently. Obviously, a number of taxa particularly among lower plants and invertebrate animals yet remain to be discovered in the ghats. The spurt in discoveries of new taxa from the Western Ghats in the recent period, in perspective of biodiversity documentation, suggest that the Western Ghats ecosystem is a store house of invaluable biological wealth. The Western Ghats' plant and animal species may be a potential source of dyes and drugs, and also a gene pool for pest resistant varieties of plants. The multi-utility values of its genetic resources may further be revealed in the field of genetic engineering in the years to come. The Western Ghats is also the home of several 'ecosystem people' belinging to tribes like Todas, Irulas and Kanis.

7. THREATS

The most important threat faced in the geological past was the loss of continuity with the rest of the Gondwana land flora and fauna when the continents drifted away. The impact of northern thrust and the uplift of the Himalaya had its impact on the original biota. The Deccan lava has exterminated some of the freshwater molluscs and probably other aquatic and terrestrial fauna by the hot lava flows.

In the recent past, man made factors, such as, encroachment of the forests for habitation, timber and other forest produces, construction of dams, growing plantation crops, shifting cultivation, grazing, etc., have affected the Western Ghats to a large extent. Its implications are the habitat modification in vast tracts leading to shrinking and fragmentation of natural ecosystem communities and the consequent loss of biodiversity.

Home-stead settlement and cattle-grazing in the forest land cause contracting of diseases

Fig. 9 : Clay mining at Madaipara, Kannur district, Kerala

Fig. 10 : A timber trade yard in the forest premises of Kerala

like the rinder pest to wild angulates causing major disasters. Likewise, the Kysanur Forest disease is slowly spreading into other regions, outside the normal zone in the Western Ghats from the Karnataka belt, and probably the Nilgiri langur and Lion tailed Macaque may soon be exposed to its ravages. Already these species are confined to very small areas because of the habitat loss the ghats has suffered.

Construction of large dams have destroyed considerable forest wealth in the ghats by submergence as well as checked the migratory pathways of many aquatic fauna like fishes. For example, *Haplothismia,* a monotypic genus of a saprophytic flowering plant reported from Parabikulam area in the ghats could not be relocated since its limited habitat has been submerged under a reservoir.

Alteration of forest habitats for large scale plantation crops and clearing of forest floor for shifting cultivation in a way have been responsible for flash floods in the lower reaches causing devastation. Mining activities (as in Kudremukh and Goa) also pose considerable threat to the Western Ghats ecosystem.

The loss of litter due to habitat destruction was responsible for the flooding and silting at the lower reaches. The litter cover is essential not only for holding the water, but also for the survival of many litter inhabiting fauna essential for energy conversion about which we know comparatively very little.

8. CONSERVATION

Prevention of game in the forests certainly reduced the threat to wild-life to a considerable extent inspite of illegal poaching. Establishment of National Parks, sanctuaries and Biosphere reserves, and also educating the lay public about the need for conservation have been effective steps taken for the protection of biota. The Western Ghats proper accordingly has 6 National Parks and 35 sanctuaries besides the Nilgiri Biosphere Reserve. Many non-Governmental organisations have come up of late and contributed a lot in our conservation programmes. A typical case is that of Silent Valley in Kerala declared as a National Park, in testimony to the victory of people's movement in conservation efforts.

9. FUTURE DIRECTION

The Western Ghats despite having rich and diverse floral and faunal genetic resources, is a biodiversity threatend 'hot spot' area in the country. In contrast to the known biodiversity of higher groups of flora and fauna, there is a much richer species diversity of lower groups, comprising of species already known as well as yet unknown, to be discovered and described from the Western Ghats. Thus, an assessment about the actual or nearly total biodiversity potential (quantitative assessment) as well as the evaluation of status of taxa, especially those of the endemic and dwindling populations, (qualitative assessment) is an urgent priority. Therefore, it necessitates the augmentation of Western Ghats' biodiversity documentation in the light of rapid and massive natural habitat degradation that has been taking place in the Ghats with the consequent implication of large scale loss of biodiversity.

The modern conservation concept addresses the rationale of placing the conservation programmes and issues, including the biodiversity conservation, in the context of the need for human development. It also underlines that the implementation of such programmes, even the scientific management of ecodevelopment or protected areas, must be based on, or should make use of the wisdom of the local community people and their practices, if such programmes are to succeed and be sustainable.

Considering the factors of ecodevelopment and people, some major objectives to focus on biodiversity conservation are: the need to realize the importance of biological diversity and its conservation, identifying the centres of diversity and endemism, determining the priority areas and selection of adequate number of diversity-rich sites (protected areas), and finally the scientific management of the protected area net-work system.

A scientifically managed protected area net-work system incorporating the modern concept of conservation would obviously reflect the biodiversity characteristics, such as, the maximum species richness and diversity including endemic species, the diverse range of habitats and communities sheltering the maximum genepool resource of flora and fauna that are potentially useful to man, and the maximum number of the threatned taxa available for prompt conservation.

Protected areas if properly managed and conserved, would safeguard the greatest number of taxa or at least the maximum possible number of representative species of flora and fauna, even though the actual number of species may not be accurately known.

10. SELECTED REFERENCES

Abraham, A. 1986. Plant wealth of the Western Ghats and the need for its conservation, pp. 32-35. In : *Ecodevelopment of Western Ghats,* (315 pp); Kerala Forest Research Institute, Peechi, Kerala.

Alfred, J. R. B., Das, A. K. and Sanyal, A. K. (eds.) 1998. *Faunal Diversity in India* i–viii + 1–497. *ENVIS Centre, Zool. Surv. India.*

Jairajpuri, M. S. 1991. An overview, pp. xi-xxvii. In *: Animal Resources of India ; Protozoa to Mammalia-state of the Art,* (694 pp.): *Zoological Survey of India, Calcutta.*

Mani, M. S. 1974. Biogeography of the Peninsula, pp. 614-647. In : *Ecology and Biogeography in India,* (773 pp.) : W. Junk Publishers, The Haque.

Mathew, G. 1999. Butterflies and moths of Silent Valley National Park, pp. 291-296. In *: Silent Valley-Whispers of Reason,* (421 pp.) : Kerala Forest Department, Thiruvananthapuram.

Nair, K. N. (in press). Protozoa. In *: Fauna of Nilgiri Biosphere Reserve : Zoological Survey of India,* Calcutta.

Nair, S. C. 1991. *The Southern Western Ghats : a Biodiversity conservation plan,* (92 pp.); Indian National Trust for Art and Cultural Heritage New Delhi.

Rao, K. R. 1986. On a collection of Leaf hoppers (Cicadellidae : Hemiptera) from the Silent Valley, pp. 49-58. In *: Fauna of Silent Valley, Kerala, India,* (283 pp.): *Rec. zool. surv. India, 84* (1-4).

Varshney, R. K. 1998. Insecta, pp. 146-157 In *: Faunal diversity in India.* i–viii + 1–497, *ENVIS Centre, Zoological Survey of India,* Calcutta.

Eastern Ghats

T. PULLAIAH

ENVIS–*Zool. Surv. India*
Ecosystems of India : 371-386, 2001.

Eastern Ghats

T. PULLAIAH

Department of Botany
Sri Krishnadevarya University, Anantapur 515 003

1. INTRODUCTION

The incessant human assault on forests has left indelible scars on nature and Eastern Ghats in India is an example of this pathetic plight. Conservation of Biodiversity has emerged as a key environmental concern of the modern time. One result of the United Nations Conference on Environment and Development held in Rio de Janerio in June 1992 was a "Convention on Biological Diversity" which has been signed by 156 countries and European community. Eastern Ghats is one of the nine floristic zones of India.

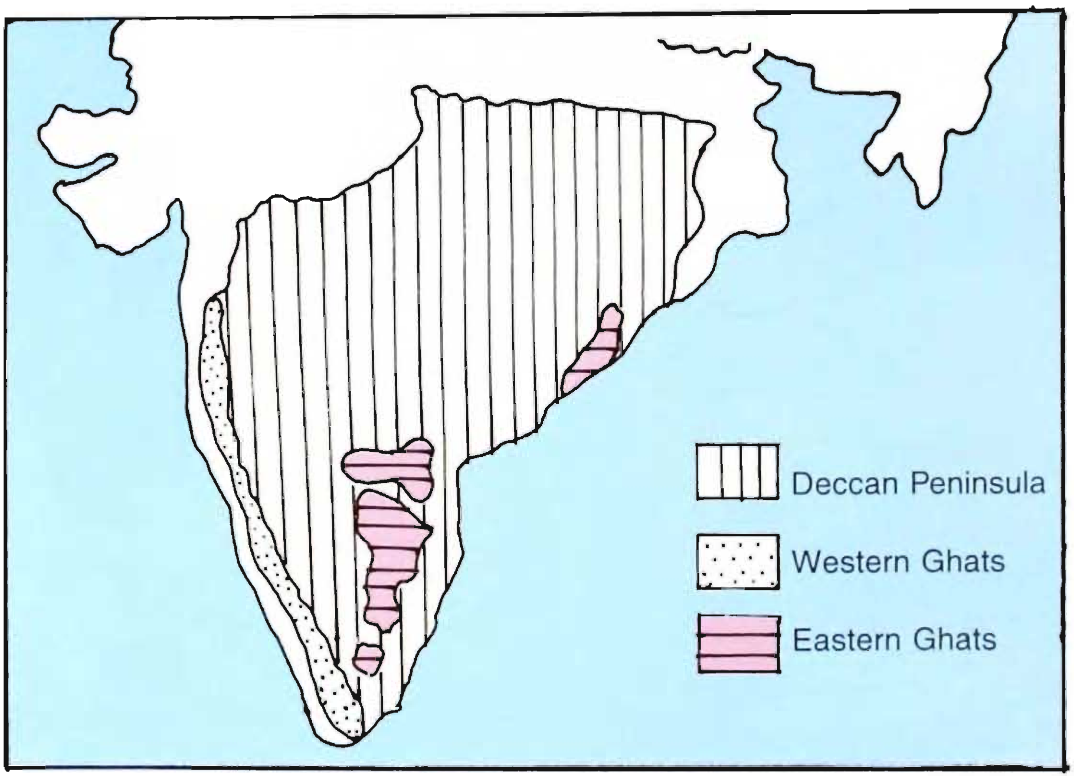


Fig. 1 : Showing location of Western Ghats, Eastern Ghats and Deccan Peninsula (only coloured area dealt with in the article)

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

The Eastern Ghats are located between 77° 22′ and 85° 21′ E longitudes and 11° 31′ and 21° 0′ N latitudes. They extend in a north-east south-west strike in the Indian peninsula covering an area of about 75,000 sq km with an average width of 200 km in the north and 100 km in the south. They extend over a length of 1750 km between the rivers of Mahanadi and Vaigai along east coast. The Mahanadi basin marks the northern boundary of the Eastern Ghats while the southern boundary is the Nilagiri hills. To the west lie the tips of Bastar, Telangana and Karnataka Plateaus and Tamil Nadu uplands. The coastal area in the east limits its eastern part.

Eastern Ghat region mainly spreads through the states of Orissa, Andhra Pradesh and Tamil Nadu. The main portion of the Eastern Ghats in Orissa passes through six districts, *viz.*, Kalahandi, Koraput, Phulbani, Ganjam, Dhenkenal and Sambalpur. The Ghats in Andhra Pradesh pass through the districts of Srikakulam, Vizainagaram, Visakhaptnam, East and West Godavari and parts of Khammam, Krishna, Guntur, Prakasam, Nellore, Kurnool, Anantapur, Chittoor and Cuddapah. In Tamil Nadu Eastern Ghats pass through the districts of Chengalput, North Arcot, South Arcot, Salem, Dharmapuri, Tiruchirapalli and Coimbatore.

The Eastern Ghats do not form a continuous range because the great rivers Mahanandi, Godavari and Krishna cut across them. In 'the northern section of the Eastern Ghats most of the terrain lies about 400 m with a few peaks exceeding 1100 m. The highest point in northern section is Mahendragiri (1501 m) in Ganjam district. The northern section terminates near Guntur, just south of the Krishna river corresponding more or less to the southern limit of Sal (*Shorea robusta*).

After this there is a gap of nearly 130 km. The middle section of the Eastern Ghats extends from the Krishna to near about Madras and includes the Nallamalais, Palakonda, Velikonda, Seshachalam hills whose average elevation is 750 m. In the last section the Eastern Ghats run in a WSW direction meeting the Western Ghats in the Nilagiris. This section includes Javadi hills, the Kollimalai, the Pacchamalai, the Kalrayan, the Shevaroy and the Bilingirangan hills. The highest peak in Eastern Ghats is 1750 m high in the Bilingirangan hills forming southern tip of these Ghats. Other notable peaks are Meghasini (1250 m), Singaraju parbat (1516 m), Devagiri (1382 m), Debmalia parbat (1666 m), Sambari konda (1527 m), Dharakonda (1365 m), Dummakonda (1361 m) and Mahendragiri (1501 m).

The Eastern Ghats are an assemblage of discontinuous ranges, hills, plateaus,

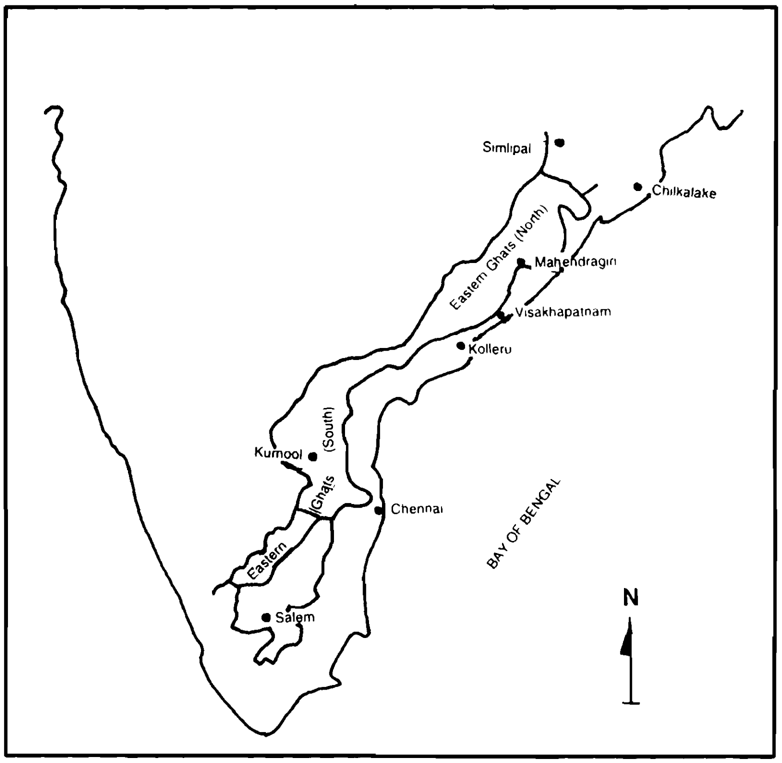


Fig. 2 : Location map of Eastern Ghats in India

escarpments, buttes, tors, narrow basins, gorges, with an elevation ranging from a few meters to 1750 m. Unlike the Western Ghats, the Eastern Ghats are not by any means a range of mountains or escarpment but represent the much broken and weathered relicts of the Penisular plateau, marked by a series of isolated hills. Almost all the major rivers like Mahanadi, Godavari, Krishna, Pennar and Cauvery taking their rise from the Western Ghats have cut extensively through the Eastern Ghats to escape into the Bay of Bengal. Encompassed between these ranges are numerous gorges, waterfalls, wide alluvial valleys structural and erosional basins.

2.1 Climate

The region falls under tropical monsoon climate receiving rainfall from both south-west monsoon and north-east retreating monsoon. In the northern part, the rainfall ranges from 1200 mm to 1600 mm indicating subhumid climate, whereas in the central and southern parts, it is 600 mm to 1000 mm exhibiting semi-arid climate except in the hilly peaks. Heavy winter rains coupled with cyclonic storms are the characteristics of the eastern portion, especially in the coastal plain. The mean temperature in January ranges between 20° C and 25° C indicating a north-south increasing trend. The maximum temperature shoots up to 41° C during hot season and night temperature goes down even up to 2° C during winter. Winter is cold but frost is normally absent or unimportant. During rainy season relative humidity is quite high (70 to 75%). South-west monsoon shares 85.4% of the total rainfall.

2.2 Geology

The Eastern Ghats consist of the outcrops of the older rock formations, such as, the Archaean metamorphics and granities, the Dharwarian mixed sedimentaries with igneous intrusions overlying the Archaeans. The Dharwar system is by far the most important mineralised formation containing ironore, manganese, mica, gold, etc. Overlying the Dharwar and Cuddapah sedimentaries, the sedimentary Vindyans glaciofluvial Gondwana rocks are exposed in the lower Mahanadi and Godavari basins.

3. BIOLOGICAL DIVERSITY

3.1 Habitat Diversity

3.1.1. Forests : The vegetation in the Eastern Ghats can be broadly classified into (i) Evergreen forests, (ii) Tropical semievergreen forests, (iii) Tropical moist deciduous frorests, (iv) Southern tropical dry deciduous forests, (v) Northern mixed dry deciduous forests, (vi) Dry savannah forests, (vii) Tropical dry evergreen forests and (viii) Tropical dry evergreen scrub.

Evergreen forests : This type of vegetation is seen only in very few valleys in Shevaroy hills and Bilingirangan hills. The common trees are *Cinnamomum zeylanicum, Elaeocarpus serratus, Ixora notoniana, Meliosma microcarpa, Callicarpa tomentosa, Symplocos lauriana, Toona ciliata*, etc., with heavily moss laden branches harbouring epiphytic orchids and ferns. The humus laden floor is almost devoid of herbs.

Tropical semi-evergreen forests : These forests are found in moist valleys and on hills of about 800 m. The Simlipal forests of Mayurbhanj district, Atai, Mahendragiri and Banguri forests of Keonjhar district, parts of Puri district, parts of Ganjam and Koraput districts, Sapparla, Dharakonda, Galikonda, Thanjavanam, Minumuluru, some areas near Anantagiri in Visakhapatnam district, Nulakamaddi and Maredumilli in East Godavari district show tropical semi-evergreen forests. *Michelia champaka, Mangifera indica, Artocarpus lakoocha, Dillenia pentagyna, Firmiana colorata, Bridelia tomentosa* and *Xylia xylocarpa* form the top canopy.

Tropical moist deciduous forests : These forests can be subdivided for convenience into several subtypes: (a) Northern tropical moist

Fig. 3 : Semi-evergreen forest—Galikonda hills, Visakhaptnam district, Andhra Pradesh

Fig. 4 : Northern Tropical moist deciduous forest (Sal forest), Salur-Koraput Ghat Road, Northern Eastern Ghats

deciduous forests (Sal forests) are found in parts of the districts of Bastar, Kalahandi, Phulbani, Ganjam, Koraput and Srikakulam. In the Sal forests *Shorea robusta* predominates and is associated with *Syzygium cumini*, *Xylia xylocarpa*, *Adina cordifolia*, *Terminalia tomentosa*, *Pterocarpus marsupium*, *Anogeissus latifolia*, *Albizia procera* and *Madhuca longifolia* to form the top canopy; (b) Southern tropical moist deciduous forests (non Sal forests) are prevalent in parts of Gudem-Rampa agency tracts of Visakhapatnam, East Godavari districts, Gundlabrahmeswaram in Kurnool district, Thalakona forests in Chittoor district, parts of Tamil Nadu and Bilingirangan hills. *Tectona grandis*, *Anogeissus latifolia*, *Xylia xylocarpa, Dillenia pentagyana, Haldinia cordifolia, Mitragyna parviflora, Pterocarpus marsupium, Lagerstroemia parviflora, Schleichera trijuga, Mangifera indica, Dalbergia latifolia* and *Albizia odoratissima* form the top canopy; (c) Southern tropical moist deciduous Riverian forests are found along the banks of river Godavari and other hill streams in a narrow belt. *Terminalia arjuna, Anogeissus acuminata, Barringtonia acutangula, Alangium chinese, Butea monosperma, Strychnos nux-vomica, Bombax ceiba* and *Tamarindus indica* are some of the common trees in these forests.

Southern Tropical Dry deciduous Forests : These forests are widely distributed in Orissa, Andhra Pradesh and Tamil Nadu and Bilingirangan hills in Karnataka. Sal occurs in some forests of Srikakulam and north of it, whereas teak occurs in some of the southern forests. The main components of such forests in association with Sal or Teak are *Terminalia alata, T. chebula, Pterocarpus marsupium, Anogeissus latifolia, Madhuca longifolia, Chloroxylon swietenia, Cassia fistula, Cleistanthus collinus, Bridelia retusa, Sterculia urens etc.*

The Red senders forests (*Pterocarpus santalimus*) are a pride of Eastern Ghats thriving on the hill slopes of Cuddapah district, northern portions of hills of Chittoor district and southern portions of Kurnool district adjoining Cuddapah and Chingleput district in Tamil Nadu.

Northern mixed Dry deciduous Forests : These forests are prevalent in Sukinda-Rebna-Keonjargarh area, Nigirda-Lulung area in

Fig. 5 : Moist deciduous forest—Mahendragiri hills, Gajapathi disrict, Orissa

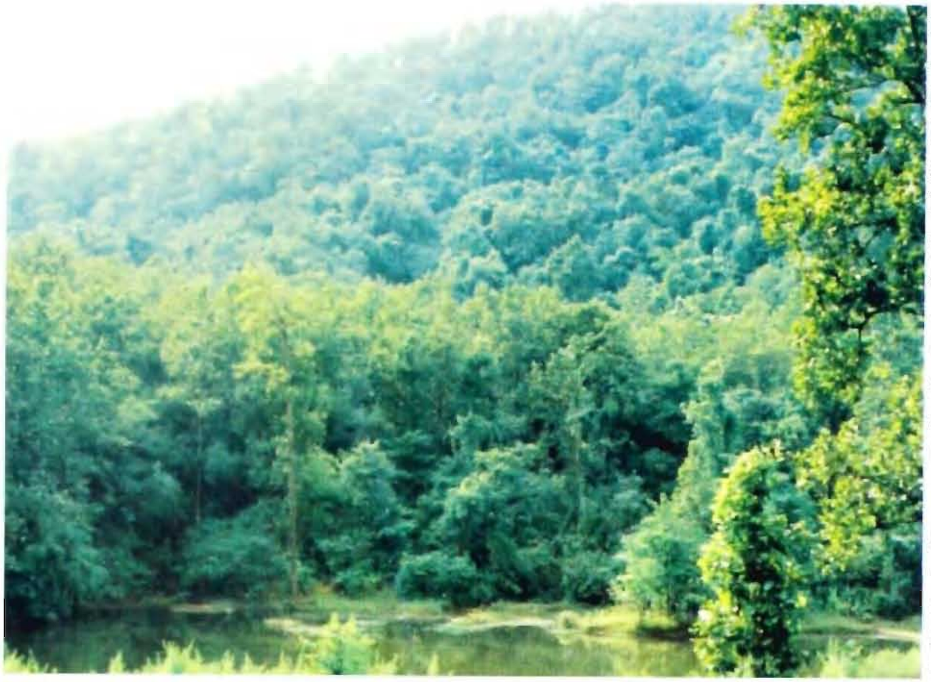


Fig. 6 : Dry deciduous forest—Ushakothi forest, Sambalpur district, Orrisa

Mayurbhanj district, parts of Angul division, parts of Kalahandi, Ganjam and Koraput districts and lower slopes of the hills of Bastar. Sal may or may not be present, but usually *Boswellia serrata* is present. *Terminalia alata, Anogeissus latifolia, Haldinia cordifolia, Pterocarpus marsupium, Hymenodictyon excelsum, Bombax ceiba, Sterculia urens, Bridelia retusa* and *Protium serratum* are some of the dominant trees.

Dry Savannah Forests : These forests, formed mostly as a result of intense biotic interference, are scattered through out the Eastern Ghats. Stunted tree species of *Emblica officinalis, Terminalia chebula, Pterocarpus marsupium*, etc., with *Phoenix humilis* are common.

Fig. 7 : Dry mixed deciduous forest—Peddamantanala Reserve Forest, Prakasam district, Nallamalais

Such forests are seen on the peripheries of all forests. The Erramalais in Rayalaseema region are practically scrub forest only. *Albizia amara, Acacia chundra, Cassia fistula, Anogeissus latifolia, Chloroxylon swietenia, Catunaregum spinosa* and *Euphorbia tirucalli* are some of the common trees. The common shrubs in these forests are *Dodonaea viscosa, Cassia auriculata, Dicrostachys cinerea, Euphorbia antiquorum, Capparis brevispina, Maytenus emarginatus* and *Carissa spinarum.*

Dry Evergreen Forest : This type of forest is seen in South Cuddapah and Mamandur valley in Chittoor district. The tree species are *Manilkara hexandra, Syzygium cumini, Albizia amara, A. lebbeck, Strychnos nux-vomica, Sapindus emarginatus, Drypetes sepiaria, Pterospermum canescens, etc.*

Dry evergreen scrub : This type of vegetation is found in Saidpet division and Madurantakam in Tamil Nadu. *Memecylon edule, Dichrostachys cinerea, Carissa spinarum, Catunaregum spinosa, Diospyros ferrea* with thin grass layer are found here.

3.2 Species Diversity

3.2.1 Flora : Eastern Ghats are rich in floristic diversity. More than 2500 species of Angiosperms occur in this region, which constitutes about 13% of flowering plants of India. Fabaceae is the largest family in Eastern Ghats. Legumes are represented by 74 genera and 328 species in Eastern Ghats (Srirama Murthy *et al.,* 1998). Venkatappa *et al.* (1998) reported 69 species of Convolvulaceae spread over 15 genera in Eastern Ghats. Venkatappa reported that in Eastern Ghats the family Boraginaceae is represented by 14 species under 4 genera, Cordiaceae by 16 species and 4 genera, Cuscutaceae by 5 species and one genus and Solanaceae by 34 species and 12 genera.

Ranjitakaani (1998) who made a floristic survey of Kolli hills in Salem district of Tamil Nadu reported 854 species of Angiosperms, 57 Pteridophytes and 5 Gymnosperms. Senthil Kumar and Krishnamurthy (1993) extensively surveyed the flora of Shevaroy hills and reported 1184 species of flowering plants under 674 genera belonging to 150 families. Ellis (1987-90) made several intensive collections from Nallamalais and enumerated 843 species under 419 genera belonging to 109 families.

3.2.2 Fauna : In sharp contrast to the great strides made on the study of fauna of Western Ghats the study of animals of Eastern Ghats has been grossly neglected. The reason for this is not far to seek. Most of the pioneer writers of the Fauna of India series were foreigners and they paid more

Fig. 8 : Tropical thorn forest or scrub forest, Kambakam hills, Southern Eastern Ghats

attention to collection of Fauna of lush green forests of Western Ghats compared to the more dry forests of the Eastern Ghats whose faunistic wealth is comparatively poor. Subsequent workers also have followed the same trend with the result that the available information on the fauna of the Eastern Ghats is poor and scanty.

Herpetofauna : So far about 115 species of amphibians and reptiles have been reported from the Eastern Ghats (Daniel, 2000). These include 25 species of amphibians and 90 species of reptiles. Some rare/endangered species like the Golden Hill Gecko, the Indian monitor, the python, the solitary species of uropeltid snake and king cobra are available in this area, not to mention the burrowing limbless skink, *Barkudia insularis*.

Rana cyanophlycits, Rana tigerina, R. hexadactyla, R. limnocharis and *R. crassa* are some of the common amphibians. *Bufo hololius* was recently collected from Nagarjunasagar. Golden gecko *Calodactylodes aureus* was recently discovered from Chittoor (Daniel and Bharat Bhushan, 1986). Other reptiles, such as, *Hemidactylus brooki, H. giganteus, Mabuya carinata, Calotes versicolor, Varanus bengalensis* are common. Among the snakes Cobra, King cobra, Russell's viper, Green pit viger, Python, Rat snake, Whip snake, Keel back and Krait are common.

Birds : The Eastern Ghats are very rich in avifauna. However very few systematic surveys have been held compared to the active field work in other parts of the country. The ornithological surveys carried out by several experts helped to list over 297 species of birds belonging to 173 genera under 52 families. Nagula *et al.* (1998). The avifauna of Eastern Ghats includes the great Indian Bustard, Jerdon's Courser, Lesser florican, Grey pelican, several species of water fowl, waders, ducks and teals, raptors, flycatchers, warblers, babblers, game birds, wood peckers, etc. (Whistler and Kinnear, 1930-37). Krishnamraju (1985) listed 300 bird species from Visakhapatnam region.

Jerdon's Courser *(Cursoris bitorquatus)* long considered extinct has been rediscovered in 1986 in the Pennar Valley near Siddavatam in Cuddapah (Bharat Bhushan, 1986). The endangered great Indian Bustard and Lesser Florican occur in plains. The Pink-headed duck, now considered extinct, was earlier recorded from the region (Abdulali, 1945).

The occurrence of some bird species in Eastern Ghats is of zoogeographical interest (Krishnamraju, 1976, 1984). Such species include Tree sparrow, Abbot's babbler (Ripley and Beehler, 1985) and Little Spider hunter, which have been collected recently from Eastern Ghats. Several species found in Eastern Ghats are considered to be relict fauna showing discontinuous distribution.

Some important species known to be having restricted breeding ranges in the Eastern Ghats are *Picumuns innominatus, Dicrurus leucopheus, Dendrocitia formosa, Culicicapa ceylonensis, Trichotstoma abbotti* (Abbot's babbler), *Passar montanus* (Tree sparrow), *Arachnothera longirostris* (Little Spider hunter), *Hemicircus canate, Pericrocrotus rosetis,* and *Stachyris rufifrons.*

The recent field studies indicate a gradual decline in the diversity and abundance of birds in the Ghats, owing to the fast changing forest habitat. The coffee plantations, exotic and monoculture forest plantation might be responsible for the observed alarming trends.

Mammals : Eastern Ghats have a variety of mammals ranging from Madras Tree shrew *(Anathana ellioti)* to tiger *(Panthera tigris).* Among the primates, Bonnet macaque *(Macaca radiata)* and Rhesus macaque *(Macaca mulatta)* are common, the former generally confined to the south, while the latter to the north. Common langur *(Presbytis entellus)* is seen in the northern hilly areas. Slender loris *(Loris tardigradus)* seems to occur in the forests of Sri Venkateswara Sanctuary.

Among the cats, leopard *(Panthera pardus),* tiger *(Panthera tigris)* and Jungle cat *(Felis chaus)* are present in most districts. The common mongoose *(Herpestes edwardsi)* and small Indian civets are seen generally in northern parts of the Eastern Ghats.

The Striped hyena *(Hyaena hyaena)* is still the common scavenger in the country side. This created havoc in Anantapur district between 1980 and 1990 by resorting to lifting of children. Indian wolf *(Canis lupus)* which was recorded earlier from Eastern Ghats is now confined to Deccan plateau. The jackal *(Canis aureus)* is still very common, while the fox *(Vulpes bengalensis)* is relatively rare.

Indian wild dog *(Cuon alipinus)* is seen almost in all the forest districts of the Eastern Ghats. Ratel *(Mellivora capensis)* is found mostly in Visakhapatnam-Vizianagaram forests. The Sloth bear *(Melursus ursinus)* is very common in the Eastern Ghats. Porcupine *(Hystrix indica)* occurs in all districts in suitable habitats. The Indian hare *(Lepus nigricollis)* is equally common, though there has been great reduction in their numbers. Indian gaur *(Bos gaurus)* is distributed in the well forested tracts of Northern circars. Chowsingha *(Tetracerus quadricornis)* is common in the forests of Viskhapatnam and Vizianagaram, while Nilgai *(Boselaphus tragocamelus)* is found in Nallamalais.

Insects : Insect fauna of the Eastern Ghats have a close relationship with the fauna of North-east India and South-eastern parts of Oriental Region (Mani, 1986). Lakshminarayan and Kumar (1998) reported the occurrence of 140 species of insects in and around Ananthagiri. These insects belong to 4 orders, *viz.*, Odonata, Orthoptera, Hemiptera, Thysanoptera, Coleoptera, Hymenoptera and Lepidoptera.

4. SPECIAL FEATURES

4.1 Endemic and endangered species

About 4% of plants of Eastern Ghats are endemic to Eastern Ghats. Nayar *et al.* (1984) gave details of rare and endemic plants of Eastern Ghats.

The endemic and endangered plants include : *Andrographis beddomei* (Nallamalais, Cuddapah hills), *A. nallamalayana* (Nallamalais), *Barleria morrisiana* (Visakhapatnam hills), *Dicliptera beddomei* (Nallamalais), *Justicia gingiana* (Gingee hills), *Neuracanthus neesianus* (Arcot district), *Nilagirianthus circarensis* (hills of Visakhapatnam district), *Phlebophylum jeyporense* (Koraput and hills of Visakhapatnam and East Godavari), *Rostellularia vahlii* var. *rupicola* (Nallamalais), *Santapaua madurensis* (Alagar hills), *Alphonsea madraspatana* (Visakhapatnam, Cuddapah and North Acrot), *Uvaria uncinata* (Mahendragiri hills, Russelkonda), *Bupleurum andhricum* (Koraput, Ganjam, Kalahandi, Araku, Palakonda, Devagiri), *Pimpinella tirupatensis* (Tirumala hills), *Brachystelma glabrum* (Cuddapah), *B. volubile* (hills of Cuddapah), *Caralluma indica* (Circars and Nellore), *C. laciantha* (Chittoor and Anantapur), *Toxocarpus roxburghii* (Northern Eastern Ghats), *Notonia shevaroyensis* (Shevaroy hills), *Vernonia shevaroyensis* (Shevaroy hills), *Cordia domestica* (Kambakkam hills), *C. evolutior* (Mainhalli and Melpat), *Boswellia ovalifoliolata* (Nallamalais, Tirupati hills), *Maytenus bailadillana* (Kalahandi), *Argyrcia arakuensis* (Araku valley), *Kalanchoe cherukondensis* (Visakhapatnam district), *Shorea tumbaggaia* (Cuddapah, Nellore, Chittoor, North Arcot, Chingleput), *Euphorbia linearifolia* var. *nallamalayana* (Nallamalais), *E. senguptae* (Cuddaph and Kurnool), *Croton scabiosus* (Cuddapah and Krunool), *Lasiococcus comberi* (Visakhapatnam hills), *Phyllanthus narayanaswami* (Rampa hills and hills of Visakhapatnam district), *Tragia gagei* (Northern Eastern Ghats), *Cajanus cajanifolia* (Khurda, Ganjam, Visakhapatnam district), *Crotalaria sandoorensis* (Sandoor hills), *C. shevaroyensis* (Shevaroy hills), *Indigofera barberi* (Cuddapah, Kurnool, Chittoor and South Arcot), *Pterocarpus santalinus* (Cuddapah, Chittoor, Chingleput), *Rhynchosia beddomei* (Cuddapah and Chittoor hills), *Sophora interrupta* (Cuddapah, Nellore and Mahaboobnagar), *Tephrosia roxburghiana* (hills of Ganjan, Visakhapatnam and East Godavari), *Leucas* *diffusa* (Godavari and Shevaroy hills), *L. lavandulifolia* var. *nagalapuramiana* (Nagalapuram hills), *L. flaccida* var. *sebastiana* (hills of Visakhapatnam), *L. mukherjiana* (Visakhapatnam), *L. nepetifolia* (Guntur), *Actinodaphne madras patana* (Cuddapah, Nellore, Chittoor), *Urginea nagarjunae* (Nalgonda), *Decaschistia cuddapahensis* (Cuddapah, Chittoor and North Arcot), *D. rufa* (Kambakkam hills and Thiruvallur hills), *Memecylon madgolense* (Madgol hills), *Albizia orissensis* (Panasa), *Habenaria panigrahiana* (Ganjam), *H. ramayyana* (Mahaboobnagar), *Arundinella setosa* var. *lanifera* (Mogilikuppa in Cuddapah district), *Chrysopogon velutinus* (Cuddapah), *Dimeria orissae* (Koraput), *Oryza jeyporensis* (Koraput), *Themeda mooneyi* (Koraput), *Themeda saccicola* (Koraput), *Lasianthus truncatus* (Mahendragiri and hills of Visakhapatnam district), *Pavetta madrassica* (Krishna, Nellore and Visakhapatnam), *Wendlandia gamblei* (Mahendragiri hill, Ventala and Rampa hills), *Triphasia reticulata* var. *parvifolra* (Balapalle and Seshachalam hills), *Eriolanea lushingtonii* (Nallamalai hills) and *Premna hamiltonii* (North Circars, Nallamalai hills, Rampa hills).

The flora of Eastern Ghats include many rare and botanically interesting plants. Tree fern *Cyathea gigantea* grows on the hill slopes in Araku valley. *Psilotum mudum,* a rare Pteriodphyte was reported to occur in Galikonda area. *Gnetum ula,* the Gymnosperm, still grows luxuriantly in Araku valleys. Due to favourable humid surroundings epiphytic orchids like *Eria bambusifolia, Lusia teretifolia,* species of *Dendrobium* and *Oberonia* and several other orchids are found to be common in Eastern Ghats.

Vanilla wightiana, a very interesting and rare orchid has now been located for the first time in the Eastern Ghats growing densely along the thorny scrub jungles near the villages Surampalem Lubarthi Munjaram complex and other surrounding low gravely mounds under the jurisdiction of Rajavommangi forest reserve of East Godavari district. This region needs urgent protection to preserve the valuable endangered orchid species.

Cycas beddomei occurring in Tirumala hills is a highly endangered species and listed in first schedule of Red data book.

4.2 Botanical curiosities

The insectivorous plants *Drosera peltata* and a few species of *Utricularia* are found in this area. The liana *Gnetum ula* is seen in several parts. *Psiltoum nudum* is found in Visakhapatnam district. *Equisetum diffusum* is found in Moul Bhatta near Jeypore in Koraput district of Orissa and the Thungabhadra river bed near Sunkesula in Kurnool district of Andhra Pradesh. Till recently *Equisetum diffusum* was available in the Araku valley but now it has become rare.

5. INTRODUCED BIODIVERSITY

Introduced plants to Eastern Ghats : *Datura metel, Datura stramonium, Eicchornia crassipes, Ipomoea carnea, I. nil, Jatropa curcas, Lantana camara, Opuntia dilleni, Tridax procumbens, Xanthium strumarium, Acanthospermum hispidum, Ageratum conyzoides, Alternanthera pungens, Argemone mexicana, Cassia occidentalis, Cassia tora, Chloris barbata, Croton bonblandianun, Elephantopus scaber, Euphorbia heterophylla, Gomphrena celosioides, Heliotropium indicum, Lagascea mollis, Martynia diandra, Oxalis corniculata, Parthenium hysterophorus* and *Physalis minima.*

6. VALUE

The untapped potentiality of these forests can be gauzed by the presence of such interesting plants as different taxa of *Oryza. Oryza granulata, O. malampuzhaensis* and *O. sativa* grow naturally in Gundlabrahmeswaram in Nallamalais. Similarly *Oryza jeyporensis* grows naturally in Koraput district. The work of Van der Maesen has shown that *Cajanus cajanifolia* growing naturally in northern Eastern Ghats can be utilized for breeding and improvement of Red gram, *Cajanus cajan*. These species can be utilized for plant breeding.

The occurrence of three species of *Piper*, *viz.*, *P. nigrum*, *P. attennuatum* and *P. hymenophyllum* near Gundlabrahmeswaram indicates that the forests once had the evergreeen type of vegetation and can profitably be utilized to cultivate plants like *Piper* spp.

Timber yielding plants : *Tectona grandis*, *Shorea robusta*, *S. roxburghi*, *Mitragyna parvifolia*, *Dalbergia latifolia*, *Anogeissus latifolia*, *Pterocarpus marsupium*, *Terminalia paniculata*, *Xylia xylocarpa*, *Chloroxylon swetenia*, etc.

Gum yielding plants : *Acacia nilotica*, *Sterculia urens*, *Givotia rottleriformis*, *Azadirachta indica*, *Lannea coromandeliana*, *Shorea robusta*, *Pterocarpus marsupium*, *Cochlospermum religiosum*, *Anogeissns latifolia*, etc.

Dye yielding plants : *Mallotus philippensis*, *Butea monosperma*, *Terminalia alata*, *Rubia cordifolia*, *Semecarpus anacardium* etc.

7. THREATS

7.1 Ecological disturbance

Eastern Ghats are under severe environmental stress and many of the natural resources therein are not being managed on sound ecological principles to ensure sustainable yields. The forest cover in the Ghats is diminishing at a much faster rate than its replenishment and the different renewable and non-renewable sources like land, forest and wildlife (animal and plants) are not systematically listed.

Kirandul-Kothavalsa railway line for the transportation of iron ore of Bailadilla across Eastern Ghats offers a small example of how the ecosystem of Eastern Ghats is disturbed recently. The railway line necessitated the stripping of hill flanks and tunnelling of some of the hills resulting in the disturbance to the present erosion pattern of the Eastern Ghats.

7.2 Shifting (Podu) cultivation

Nearly 27 tribal communities with a total population of 11,08,839 inhabit the Eastern Ghats of Andhra Pradesh. The largest among them are Bagatha, Chenchus, Jatapu, Konda dora, Konda Reddy, Savara, Yandi, etc.

Vegetation of a particular area is greatly influenced by past treatment, which is highly manifested in shifting cultivated Podu areas. The most significant feature which has adversely affected the vegetation of Eastern Ghats is the pernicious practice of shifting cultivation, locally known as (Podu) cultivation. Extensive areas of Eastern Ghats are subjected to shifting cultivation by the tribals. Vegetation in the Podu area depends on the cycle of shifting cultivation. Due to increase in population and reduction of available forest area, the cycle of shifting cultivation has inevitably shortened and whatever regrowth develops is clear-felled and burnt. The natural vegetation has been destroyed and the end results scrub forest or bamboo forests or grass with or without a few scattered trees (mostly fruit trees such as Mango, Tamarind, Oranges and *Caryota urens)* and subject to annual fire, a preclimax savannah type. In extreme cases, due to prolonged shifting cultivation, the vegetation has been completely vanished, exposing the parent rock. *Eupatorium* and *Lantana* have also invaded such clearings in hill slopes altering and probably considerbly delaying further succession.

Shifting cultivations was in vogue till very recent times in Keonjhar plateau and in the Khondamal hills. The Ranchi plateau which is at present almost completely deforested was the object of shifting cultivation in the past. In the Saranda hills this pernicious practice has left its mark by way of even-aged forest stands. In the Phulbani region turmeric *(Curcuma longa)* is grown for four years and then the plot is abandoned to become the forest fallow for 10 years. The tops of the hill ranges are totally barren. It is the general

Fig. 9 : Shifting cultivation – Araku Valley, Visakhaptnam district, Andhra Pradesh

opinion of the Forest Officers that the local hill tribes prefer these summit areas for cultivation rathern than the slopes, the climate being healthier and the erosion being less intensive. Since hill tops are the source of water, their denudation leads to the elimination of source of water. In fact, many small streams observed a few decades ago in the region have gone dry. With the absence of the streams, the valleys now present drier conditions. As a result, moisture-loving species are not to be seen in these areas. For example, *Psilotum* and *Equisetum* which were luxuriantly growing here in the 1950's are very rarely seen now.

7.3 Threats to Biodiversity

The precarious position of the existing biodiversity calls for adoption of some drastic steps by the Government. The revenue records reveal that in earlier days even the plains around Nallamalais were full of bamboo. Rapid industrialisation and excessive exploitation of raw materials are some of the reasons for the disappearance of many plants and animals.

Bamboo is supplied to the paper mills in Rajahmundry, Bhadrachalam and Sirpur, and a pulp factory at Devanagaram near Giddalur in Prakasam district. *Givotia rottleriformis* and *Gyrocarpus americanus* are used for the famous Nirmal and Kondapalli toys respectively.

The dams at Srisilam and Nagarjunasagar have submerged considerable part of the forests. In addition to this, the settlements about these projects increase exploitation of forests. Srisailam was surrounded by dense forests not so long ago, but vast stretches of this area are now bare.

According to the latest estimates regarding the digging of Canals and the construction of reservoirs for the Telugu Ganga scheme, about 10371 ha (7265 ha under the reservoir in Kurnool, Cuddapah and Nellore districts and

3113 ha under canals in the forest divisions of Atmakur, Nandyal, Proddatur, Nellore and Chittoor) of reserved forest have been cleared which may further deteriorate the verdant forests of Eastern Ghats to bring about the irreversible ecological disruption. In addition to the above, another area of 1060 ha of forest land is required for the needs of Srisailam Right branch canal Scheme.

Forests fire is an annual problem in Eastern Ghats. Mostly fire is caused by man either willfully or accidentally. Principally wild fire destroys young seedlings and damages the quality of timber either by making hollows in the trunks or by charring the same. The rich humus is burnt and wasted. The permeability of the soil is also affected resulting in loss of fertility, soil erosion and siltation of water reservoirs.

In Eastern Ghats herds of cattle, goats and sheep moving from place to place is a common sight. These animals come from the peripheral villages. The animals destroy a large part of the vegetation by grazing. Because of rampant grazing forests become shrubby vegetation and ultimately grass lands.

Biotic interference has had a marked effect on the vegetation of Eastern Ghats, leading to extinction of rare and valuable plants and animals. Luxurious flora and fauna is on the verge of disappearing. Even some of the evergreen areas once present in the interior areas are being converted into deciduous patches.

The mounting pressure of population has forced the rural population to make incursions into the verdant forests for their habitation

Fig. 10 : Cattle grazing in the open forests of Badrama, Orissa

and to supplement their basic needs. There is hardly any vegetation, which is not affected by human activity. The complete extermination of teak can be seen in large areas of Nallamalai forests. Smuggling of precocious wood and forest produce is regular in Eastern Ghats. Each smuggler gets about Rs. 500-800 for a cart load. Even the teak plantations raised by the forest department have not escaped from these smugglers. Tribals like Chenchus, Konda Reddis, Yanadis extract gum and resin by making incisions on the trees like *Sterculia urens* (Gum Karaya), *Anogeissus latifolia* (Velama), *Givotia rottleriformis* (Poliki) and *Lannea coramandeliana*. Unscientific and reckless tapping weakens the trees and causes their premature death. This has led to the extermination of *Sterculia urens*, a typical gum yielding plant, in several areas in Eastern Ghats. Owing to the mounting biotic pressure many valuable rare plant and animal species are heading towards oblivion.

8. CONSERVATION

The conservation of biodiversity is not only important for preservation by way of a gene bank but also for the protection of existing forests from further degradation and deterioration caused by all factors. The foremost attempt in the conservation strategies should be avoidance of indiscriminate forest felling and forest fire, collection and preservation methods of the seed output and germination of rare and endangered species. It is therefore considered very important to conserve existing biodiversity in terms of increasing population density.

Wildlife is an integral part of forests. Their existence is also necessary for ecological or environmental balance.

There are 12 sancturies in Eastern Ghats, three in Orissa seven in Andhra Pradesh and two in Tamil Nadu (Table 1).

9. FUTURE DIRECTION

To save the Eastern Ghats from further deterioration the following measures are suggested.

Good management of communal grazing on forestland, not by classifying as reserved forest but by devising suitable institution and providing adequate inputs to enable the villagers themselves to protect and manage their land to fulfil fuel and fodder needs. Felling of reserved forest to raise new plantations has to be discontinued. Instead, degraded tracts of reserved forest sought to be used for raising plantations by providing

Table 1. Protected areas in the Eastern Ghats

Name	District
1. Nagarjunasagar Srisailam Project	Guntur, Prakasam, Kurnool, Mahaboobnagar and Nalgonda
2. Papikonda sanctuary	East Godavari, West Godavari and Kahammam
3. Sri Venkateswara Wildlife sanctuary	Chittoor
4. Kinnerasani Wildlife sanctuary	Khammam
5. Kaundinya Wildlife sanctuary	Chittoor
6. Rollapadu (Great Indian Bustard) sanctuary	Kurnool
7. Sri Lankamalleswara (Great Indian Bustard)	Cuddapah
Orissa	
8. Karlapat Wildlife sanctuary	Kalahandi
9. Debrigarh Wildlife sanctuary	Sambalpur
10. Hadagar	Sambalpur and Keonihar
Tamilnadu	
11. Annamalai Wildlife sanctuary	Coimbatore
12. Mudumalai Wildlife sanctuary	Niligiris

incentives. Local people should be involved in apprehending illegal felling and smuggling of timber, commitments to provide industrial raw material from reserved forest areas are to be avoided. Instead of contractors, foresters should be made to handle tree felling for governmental purposes. Special care should be taken to stop further human settlements in forest areas. A public awareness campaign to save the Eastern Ghats has to be launched and the local people educated on the after effects of deforestation.

Any further course and strategy for utilising the resources of Eastern Ghats has to be implemented after providing adequate precautionary measures to ensure that the rich flora and fauna of the area is conserved. Alternative sources of energy to replace firewood in domestic and commercial sectors must be promoted. Wood substitutes for packaging, railway sleepers, and furniture should be encouraged. Liberal fiscal incentives may be given to industries for conserving the biodiversity.

10. SELECTED REFERENCES

Bhirava Murthy, P.V. 1984. *Proceedings of the National Seminar on Resources, Development* and *Environment of the Eastern Ghats*. Andhra University, Visakhapatnam.

Daniel, R., 2000. Rarity of herpetofauna of the Southern Eastern Ghats. India. *The Eastern Ghats Eptri—Envis Newsletter*, **5**(2) : 5-7.

Ellis, J.L. 1987-90. *Flora of Nallamalais.* 2 Vols. Botanical Survey of India, Calcutta.

Krishnam Raju, K.S.R., A.V.R.G. Krishna Murthy, C. Subba Reddy, N.A.V. Prasad Reddy, R. Lokaranjan and K.J.N.G. Shankar. 1987. Status of Wildlife and habitat conservation in Andhra Pradesh *J. Bombay nat. Hist. Soc.* **84** : 605-619.

Lakshminarayana, K.V. and Kumar, K.V.S. 1998. Inventory of the insect fauna recorded at Ananthagiri and envirous. *EPTRI, Proc. Nat. Seminar on conservation of Eastern Ghats, Hyderabad* : 6-35.

Mani, M.S. 1986. *Ecology and biogeography in India.* Dr. W. Junk, B.V. Publishers, The Hague.

Moulali, D.A., P.V. Prasanna and T. Pullaiah. 1989. A case of excessive exploitation. *The Hindu* dated 14.4.1989, p.19.

Nagulu, V., Vasudeva Rao, V. and Srinivasulu, C. 1998. Biodiversity of select habitats in Eastern Ghat regions of Andhra Pradesh. *Proc. Nat. Seminar on Conservation of Eastern Ghats, EPTRI,* Hyderabad : 6-35.

Nayar, M.P., M. Ahmedulla and D.C.S Raju. 1984. Endemic and rare plants of Eastern Ghats. *Indian J. For.,* **7** : 35-42.

Ranjitakaani, P. 1998. Floristic Survey of Kolli hills. *Proc. Nat. Seminar on Conservation of Eastern Ghats, EPTRI,* Hyderabad: 87-91.

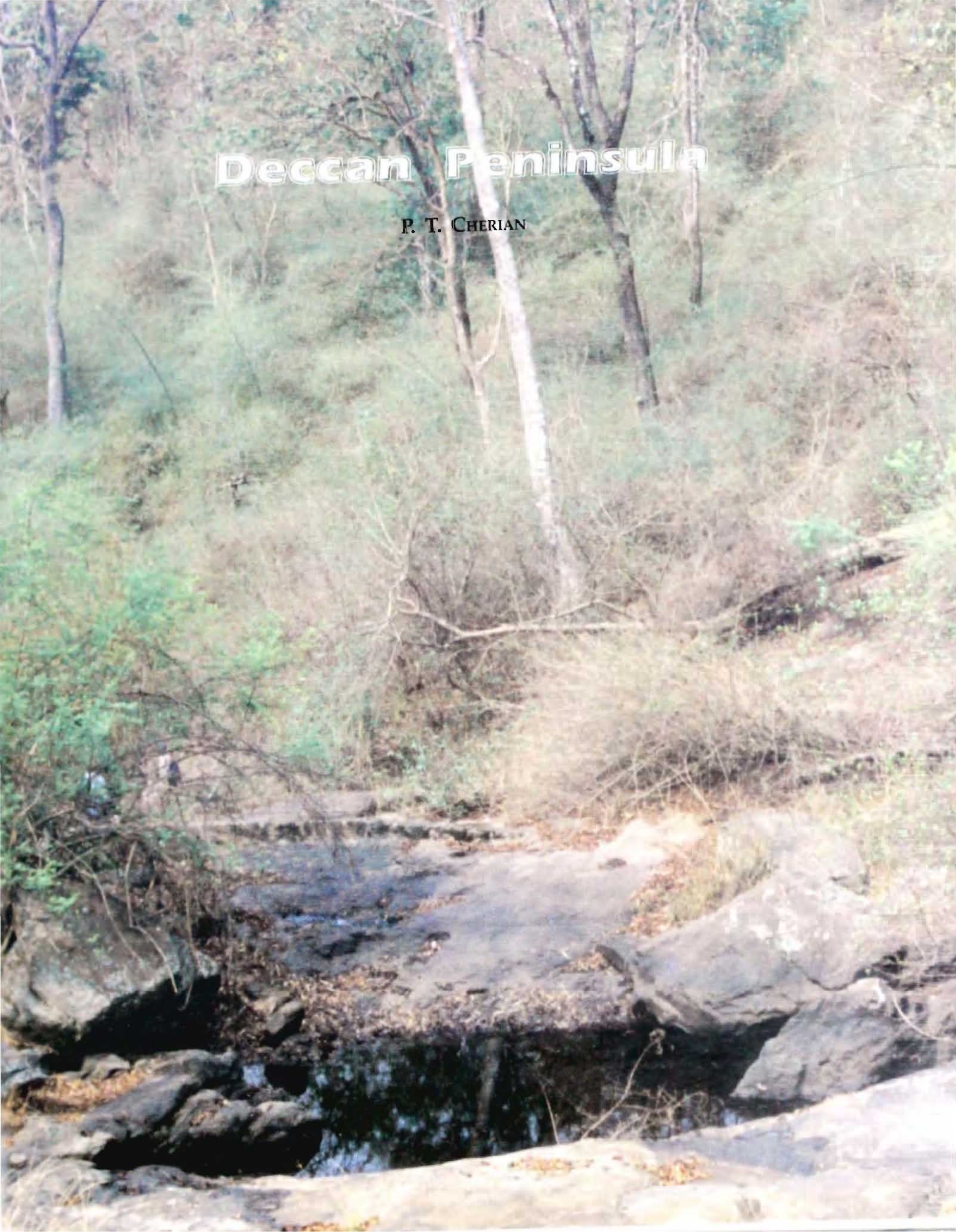
Senthi Kumar, T. and K.V. Krishnamurthy 1993. Flora of Shevaroy hills of Eastern Ghats. *J. Econ. Tax. Bot.* **17** : 729-748.

Srirama Murthy, K., P. Rajasekhar Reddy and T. Pullaiah. 1998. Legumes of Eastern Ghats, *Proc. Nat. Seminar on Conservation of Eastern Ghats. EPTRI, Hyderabad;* 135-144.

Venkatappa, N., T. Pullaiah, K. Srirama Murthy and S. Sandhya Rani. 1998. Convolvulaceae in Eastern Ghats. *Proc Nat. Seminar on Conservation of Eastern Ghats, EPTRI,* Hyderabad : 106-113.

Deccan Peninsula

P. T. Cherian



ENVIS–*Zool. Surv. India*
Ecosystems of India : 387-410, 2001.

Deccan Peninsula

P. T. CHERIAN

Zoological Survey of India
100, Santhome High Road, Chennai 600 028

1. INTRODUCTION

The name Deccan is derived from the sanskrit Dakshina (south) and covers the entire Indian Peninsula south of the Narmada river. The Deccan Biogeographic Zone of peninsular India is by far the most extensive zone in India, covering 1,421,000 sq km or 43% of the total land mass. It is a stable mass of Archaean and Pre-Cambrian formations and also the areas covered by Gondwana and later formations, as also by the Deccan lava flows. The major mountain-building disturbances in the peninsula ceased in the Pre-Cambrian times but some minor folding, block-faulting and epeirogenic movements affected the region in Post-Cambrian times. The Peninsular Plateau is the

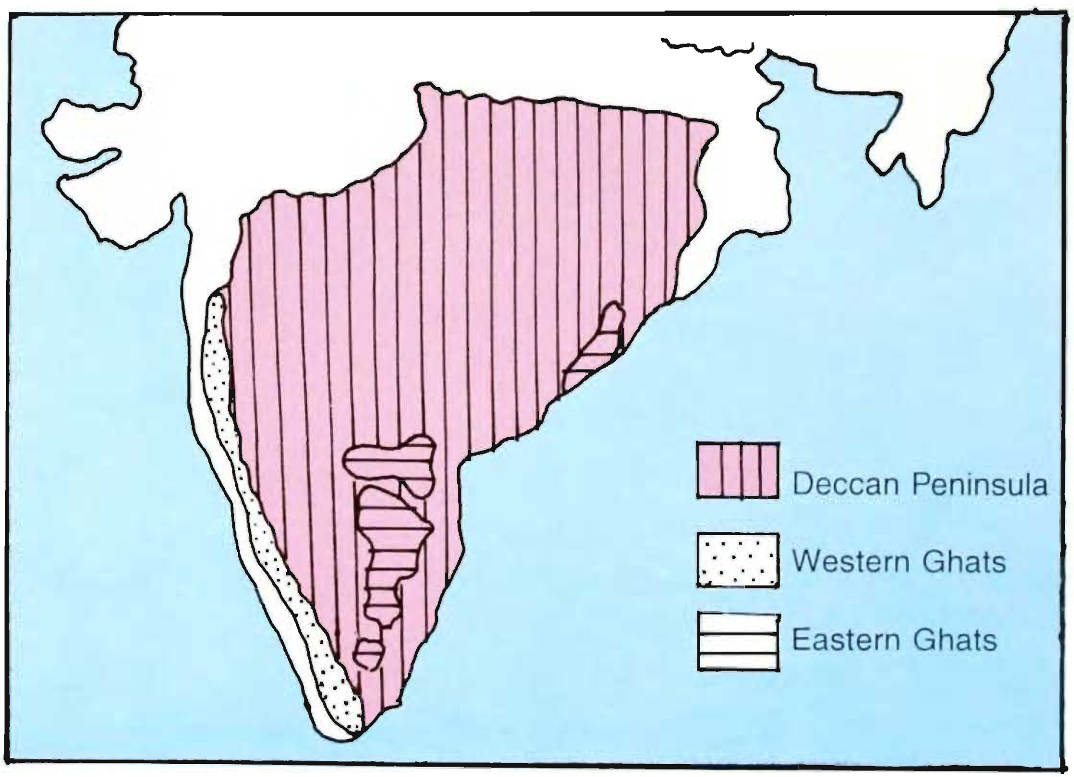


Fig. 1 : Showing location of Western Ghats, Eastern Ghats and Deccan Peninsula (only coloured area dealt with in the article)

highest in the south and west and slopes eastwards. Large areas in the south exceed 600 m. The western edge of the plateau forms the escarpment of the Western Ghats or Sahyadri mountains. The eastern edge is much broken and is known as the Eastern Ghats. In the north, some lines of mountains rise above the general surface of the plateau from the west to the east. The Satpura is the most important of these and forms an important biogeographical barrier. Two other lines of mountains, the Vindhya and the Ajanta Ranges reinforce the Satpura barrier. The general surface of the Peninsular Plateau is deeply dissected by river erosion.

2. DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

The peninsula of India is a compact natural unit of geomorphological and biogeographical evolution. Yet at the present time it is merely a relic of a once much larger land mass, the major part of which now lies concealed under the alluvium of the northern plains and thrust under the High Himalayas and Tibet. The Peninsula consists at present of a block of plateau, with a general slope to the east and is characterised by its senile topography. The geomorphology of the peninsula is, on the whole, marked by its advanced maturity or even senility, except perhaps along the escarpment of the Western Ghats and a few hillier localities. The erosion surfaces present more than one cycle and reveal important and relative recent changes of level, although mostly of a negative nature. The deposits of alluvium, about 150 m thick, in the river Narmada through and somewhat less in the river Tapti trough, occupy definite rocky basins and indicate faulting. The straightness and the relative steepness, with two waterfalls, of the lower 480 km length of the river Narmada from Handia to the sea, indicate a relatively recent origin (Mani, 1974).

The plateau part of the peninsula is the largest and covers an area of 7,00,000 sq km and slopes eastwards and northwards. The northern and eastern boundary may be defined by the 300 m contour line. The valleys of the Godavari and the Krishna rivers are flanked by flat-topped, steep-sided hills. The topography is characterised by rounded hills and rolling plains. The plateau is bounded on the east and west by the Ghats, escarpments that meet at the plateau's southern tip. Its northern extremity is the Satpura mountain range. The Deccan's average altitude is about 2000 ft. (600 m), sloping generally eastward. Its principal rivers flow from the Western Ghats eastward to the Bay of Bengal. The plateau's climate is drier than that on the coasts and is arid in places.

This large zone is relatively homogenous and is distinct from the neighbouring zones the Western Ghats, Semi-arid and Gangetic plain zones. There are a number of recognisable subdivisions within this zone. Five of these are made at provisional level. These are :

1. **Deccan plateau south :** This covers the thorn forest communities of southern India. The river Krishna is used as a border between this and the four northern provinces.

2. **Deccan plateau north :** This large unit covers the central Indian dry plateau.

3. **Eastern Highlands :** This is a small province but biologically the richest, containing the Eastern Ghats and the moist hills and valleys of the Chattisgarh-Dandakaranya areas. Only the northern half of the Ghats, north of Cauvery is included here. The southern and more fragmented half lying south of the Krishna is more difficult to demarcate on the map and is included as two lesser sub-units in province A.

4. **Chota Nagpur :** This moist plateau in the north-west of the zone is a continuation of many of the distributional trends found in B and C. However, botanically and in terms of lesser vertebrates, it is distinctive.

5. Central Highlands : This province includes both the Satpura and the Vindhya Hill Ranges.

Within these provinces, lesser divisions have been recognised as : (i) Tamil Nadu plains, Eastern Ghats (South), Karnataka Plateau and Eastern Ghats (Central); (ii) Telangana and Maharashtra Plateau; (iii) Eastern Ghats (North) and Chattisgarh Dandakaranya; (iv) Chota Nagpur Plateau and Garhjat Hills; (v) Satpura Maikal Hills and Vindhya-Bagelkhand Hills.

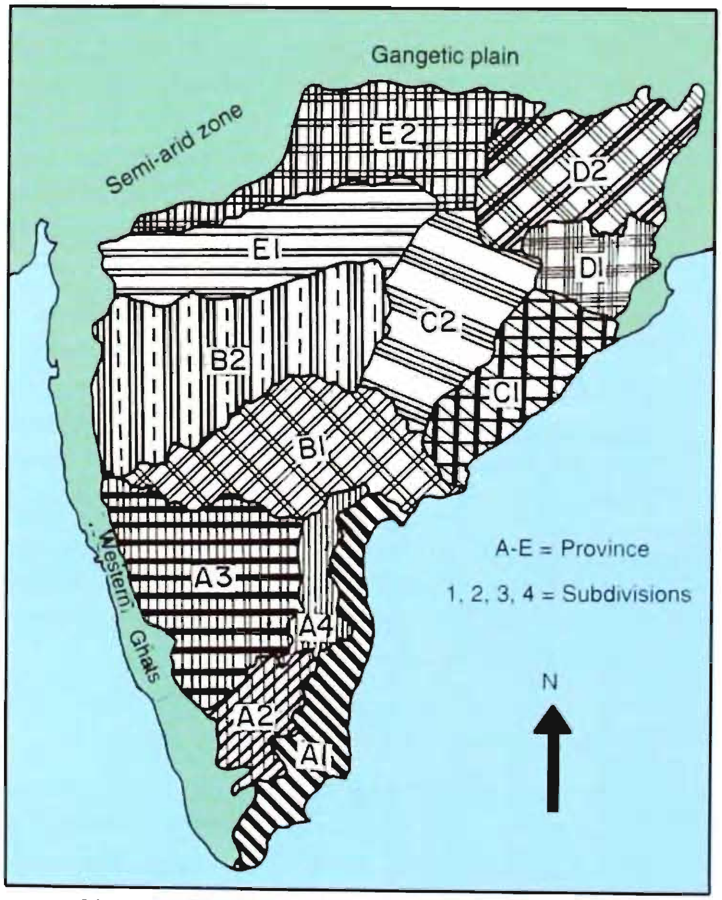


Fig. 2 : Plateau parts of Deccan Peninsula

A Deccan Plateau South

A1 Tamil Nadu Plains = Coromandal
A2 Tamil Nadu Uplands
A3 Karnatak Plateau
A4 Central Eastern Ghats

B Deccan Plateau North

B1 Telangana
B2 Maharashtra Plateau

C Eastern Highlands

C1 Northern Eastern Ghats
C2 Chattisgarh-Dandakaryana

D Chota Nagpur

D1 Garhjat Hills
D2 Chota Nagpur Plateau

E Central Highlands

E1 Satpura- Maikal
E2 Vindhya-Bagelkhand

3. BIOLOGICAL DIVERSITY

3.1 Ecosystem/Habitat diversity

The Deccan Peninsula cannot be said to represent any particular type of ecosystem existing in the world today but is a conglomeration of different types of ecosystems. It has within its confines, areas representing different types of ecosystems like dry deciduous forests, moist deciduous forests, degraded shrublands, dry evergreen forests or thorn shrub and tiny areas of semievergreen forests, besides certain wetland ecosystems and freshwater bodies. Though most of the ecosystem types represented here, are found in some of the other zoogeographical zones in India, yet much of the thorn forests and shrublands of India are confined to the Deccan Peninsula, which comprises a major part of this zone. Hence in the global context, the major part of Deccan Peninsula can be considered under shrubland and dry deciduous forest ecosystems, which incidentally forms part of the wildlands of the globe comprising, apart from forests and wetlands, four components namely : (i) rangelands, (ii) deserts and steppes, (iii) shrublands and (iv) high altitude communities.

Whilst much of the Deccan has been greatly disturbed by man's development, the zone does contain some of India's finest forests, particularly in Madhya Pradesh, Maharashtra and Orissa. The majority of the forests are of a deciduous nature but there are regions of greater diversity in the hill ranges. Relict populations of moist forest species, such as, gaur, buffalo and Swamp deer suggest the much wider distribution of these species in the past. Even though the zone has some of the largest wilderness areas of

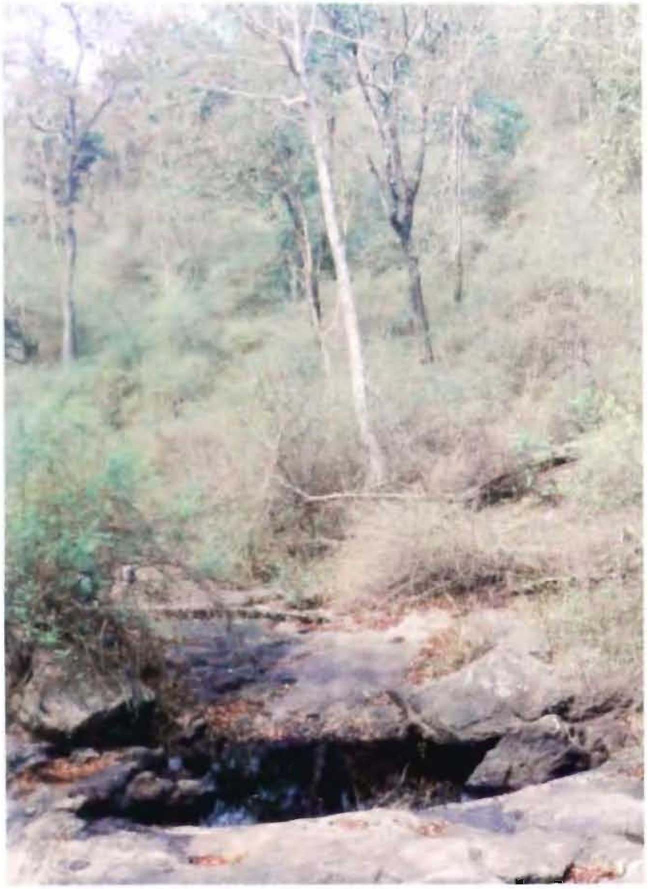


Fig. 3 : A shurb jungle in the outskirts of the Eastern Ghats in Orissa

India, there are growing signs of forest and environmental degradation. The Deccan highlands form the principal catchment for many of southern India's main river systems. Forest loss is already noticeable in the increased frequency of drought, floods, erosion and reservoir siltation. There is thus a need for greater conservation inputs for wildlife, forest resources and water catchment purposes, let alone the total biodiversity of this large zone.

The Deccan zone is principally one of "Deciduous Forest", "Thorn Forests" and "Degraded Scrublands" There are evergreen formations which are limited to tiny areas of semi-evergreen forest on the wetter Eastern Ghats and "dry evergreen forest or thorn scrub" on the eastern coastal side of the plains of Orissa, Andhra Pradesh and Tamil Nadu. Natural grasslands are rare and are confined to a few river valleys. Some areas are maintained as artificial grasslands. Freshwater ecosystems are represented mostly by the rivers Narmada, Tapti, Mahanadi, Godavari, Krishna and Cauvery and their tributaries, besides a few lakes. Some coastal tracts of Tamil Nadu, Andhra Pradesh and Orissa have mangrove vegetation. This large zone is relatively homogenous.

Fig. 4 : A torrential rivulet feeding Mahanadi river in Orissa

3.2 Species diversily

The flora and fauna of Deccan Peninsula is fairly well known for their species diversity and degree of endemism. As is the case with most of the other zoogeographical zones in India, we have a clearer picture of the vertebrate fauna of the Peninsula. As for the lower groups of organisms, especially species rich groups like arthropods, helminthes, annelids, protozoans and the likes, much of the alpha taxonomy is yet to be revealed.

3.2.1. Fauna

Vertebrates :

Fishes : 168 species of primary freshwater fishes are found in the Deccan Peninsula, which accounts for 37% of the freshwater fish species reported from India. Many of these Peninsular fishes are common to the adjacent Western Ghats also.

Amphibians : Out of 209 species reported from India, 25 species under 9 genera, 5 families and 2 orders occur in the Deccan Peninsula. This accounts for about 12% of the species known from India. The humid evergreen tropical forests which harbours the majority of amphibian fauna are not represented in the Deccan Peninsula. This is the primary reason for the poor representation of the group in this zone.

One limbless amphibia, *Ichthyophis peninsularis* was reported from Nellore District in the past. But, concerted efforts made in recent times for collecting this species from its known habitat became futile.

Reptiles : 48 species of reptiles comprising one crocodile, 7 turties and tortoises, 16 lizards and 24 snakes have so far been reported from the Deccan Peninsula. This represents about 10.5% of the 456 species of reptiles known from India. A brief analysis of the reptile fauna of the Deccan shows that it is dominated by the snake fauna, followed closely by the lizards. Of the species of reptiles known from here, the crocodile, three species of sea turties and some lizards are on the list of strictly protected species. The deadly venomous snakes of India, namely, the cobra, the krait and the vipers are met with throughout the Deccan.

Fig. 5 : Forest calotes, *Calotes rouxi*

Birds : A very large representation of Indian birds comprising 441 species are known to occur in the Deccan. This accounts for 35.79% of the avian fauna of India. The percentage of endemic forms in relation to

Fig. 6 : A weaver bird in Rangana Thittu bird sanctuary

Fig. 7 : A flock of Painted storks in Mysore Plateau

the total number of species available in this zone is marginal in comparison to the condition prevailing in the nearby zones like Western Ghats where more endemic forms are present *vis-a-vis* the total avian fauna.

Mammals : In comparison to fishes and birds, the representation of known species of mammals in the Deccan Peninsula is rather poor. About 55 species and 91 races of mammals occur in the Deccan. This accounts for 14.78% of the Indian mammals. Representation

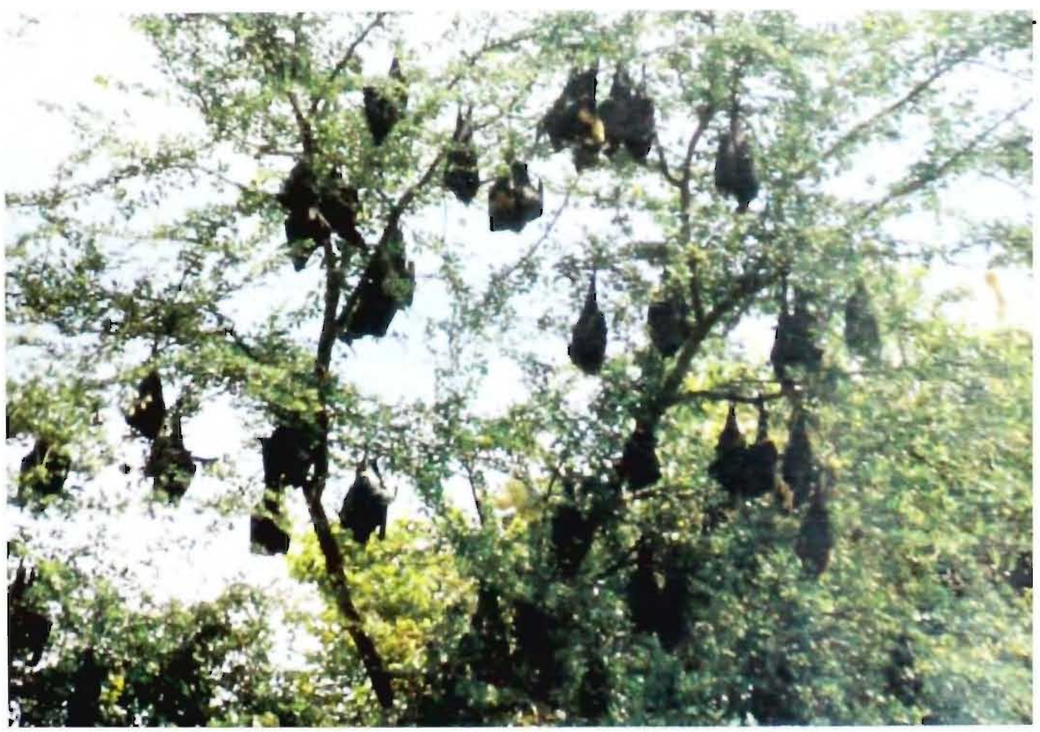


Fig. 8 : Roosting Fruit bats in a scrub jungle in Mysore Plateau

of less than 15% of the mammalian species reported from India in this zone pales in comparison to nearly 36% of the avian and 37% of the piscean representatives of species of these groups known from India. But mammalian representation in the Deccan is comparable to the amphibian and reptilian fauna as indicated by the data presented earlier.

Invertebrate: Some information on our present day knowledge of the major groups of invertebrates found in the Deccan, is discussed below.

Protozoa: Our knowledge of the protozoans represented in the Deccan is very fragmentary. Except in Orissa, one isolated area each in Madhya Pradesh and Tamil Nadu and some places in Maharashtra, Karnataka and Andhra Pradesh, our information on this group is very fragmentary. Approximately, about 25% of the species known from India have been recorded from this zone so far.

Porifera: In the Deccan Peninsula, 16 and 7 species are represented in Maharashtra and Karnataka (including areas of Western Ghats) respectively, 8 in Tamil Nadu, 1 in Andhra Pradesh, 7 in Orissa and 4 in Bihar. No species is so far known from Madhya Pradesh. Leaving aside the species common to different areas of Deccan, 19 species can be said to be available in this zone. While 13 species of freshwater sponges are endemic in India only one of these is endemic to Deccan Peninsula. While some of the areas of this zone are fairly well explored much work needs to be done in Andhra Pradesh and the whole of madhya Pradesh.

Platyhelminthes: Only a few of the species of Monogenea, parasitising the freshwater fishes of the Deccan have so far been recorded, which includes the endemic species *Polystomides sinhai* occurring in the gall bladder of *Kachuga tactum tentoria* found in the waters of River Godavari. Most of the forms recorded from marine fishes found in the coastal waters of the zone are endemic. Of the Trematoda species recorded from India, about 30% have been reported from the Deccan. Of the total host species found in the region, only a small percent has so far been screened for helminth infection. Many of the species occurring in the Deccan have been recorded from other zoogeographic zones in the country. Between 30 to 35% of the Cestoda species known from India are reported from the Deccan Peninsula, including a few endemic species of *Monophyliddium*, *Indoternia*, *Moneiezia*, *Ptychobothrium*, etc. Most of the species belonging to this group are parasitic on vertebrates.

Rotifera: 25 species are known from Madhya Pradesh, 20 from the Deccan part of Maharashtra, 79 from Orissa, 61 from Andhra Pradesh, 30 and 50 each from the Deccan part of Tamil Nadu and Karnataka respectively. Leaving aside the species common to these states, about 40% of the 310 species occurring in India are represented in the Deccan Peninsula. This includes, some endemic genera and species discussed later.

Nematoda: The nematodes parasitic of Indian invertebrates are poorly known. Out of 1250 species of animal parasitic nematodes known from India, 255 have been reported from this zone, which include many endemic species.

Annelida: (i) Oligochaeta - More than 100 species are known from the Deccan. Our knowledge of Oligochaetes of Orissa, some areas of Karnataka, Andhra Pradesh and parts of Tamil Nadu are fairly good while much work needs to be done with respect to other states in the Deccan Peninsula. *Deccania*, *Barogaster*, *Dichogaster*, *Eudichogaster*, *Hoplodractella*, *Lennogaster*, *Octochactona*, *Ramiella*, *Megascolex*, *Notoscolex*, *Lampito*, etc., are some of the genera commonly occurring in the Deccan. (ii) Hirudinea : From the Deccan Peninsula, leech fauna of Maharashtra is fairly known, while that of Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu and Orissa are poorly studied. Thirty of the 59 species from India are represented in the Deccan region. This represents 51% of the

Indian fauna. Only 6 species known from Deccan and its coastal waters are endemic.

Arthropoda : (i) *Crustacea* : There are 20 species of cirripedes causing fouling of ships in India. Most of these are found in the coastal waters of Deccan. The isopod genera *Sphaeroma* and *Limnoria* are found as borers on piles supporting wharfs and piers.

Cyprididae of Deccan waters is fairly well studied and 35 to 40% of the Indian fauna has been recorded from here. Subclass Cirripedia of Indian waters is well known and Daniel (1987) has contributed much to the knowledge of this group from the Madras coast of the Deccan Peninsula. About 30% of the 104 species of the group represented in the Indian waters have been reported from the coast. Of the 99 species of Cladocerans, only 50 (50.5%) species are so far known from the Deccan Peninsula. 7 species of Cladocerans are endemic to India, of which 3 are endemic to the Deccan Peninsula.

Copepods of Andhra Pradesh, Tamil Nadu and Karnataka, have been studied to a certain extent. Much more is yet to be known about the composition of this group in the freshwater lakes, rivers and reservoirs of the Deccan.

(ii) *Myriapoda* : 97 species of Diplopoda comprising 33.45% of the species known from India are known from this zone. Deccan fauna includes 26 species of chilopodes, of which 5 are endemic to this zone.

(iii) *Insecta* : Thysanura : A few of the species of this group like *Lepisma saccharina* and *Ctenolepisma longicaudata* are found in the Deccan. About a third of the Indian species of Thysanura have been reported from the Deccan Peninsula.

Diplura : 6 to 7 species of the group have been reported so for from the Deccan Peninsula.

Protura : Of the 20 species known from India, 75% is known only from Kerala. Only one or two species of this group is known from the Deccan.

Collembola : Knowledge on the Collembolans of the Deccan is very scanty. But for Bombay and Nasik areas of Maharashtra, Chilka area in the Orissa and part of the Eastern Ghats, practically not much is known about this group from the Deccan. The Deccan fauna known so far, numbering a few species, is only a fraction of the total wealth of this group available here and forms only a small fraction of the Collembolan fauna of India.

Ephemeroptera : From the Deccan, 6 species are known from Madhya Pradesh, 10 from Maharashtra, 4 from Karnataka, 5 from Tamil Nadu, 7 from Orissa, 1 from Andhra Pradesh and 2 from Chota Nagpur. Leaving aside the species common to all these states, the group is represented by 30 species in the Deccan Peninsula. This represents 32% of the species known from India. About 20 species occurring in the Deccan are endemic to the area.

Odonata : Much of the Odonate fauna of the Deccan is yet to be revealed. But for reports on 37 species from Central India, 44 speciec from Orissa (including 29 new records), some additional species from Orissa coast, a few from Eastern Ghats and Tamil Nadu, much of the rest of the area of Deccan needs exploration. Approximately, between 25-30% of the species known from India have been recorded so far from the Deccan, of which only a few are endemic to the zone.

Plecoptera : Hardly a few species have been recorded from the Deccan zone, probably because of the climatic conditions and altitudinal limitation existing in this region.

Orthoptera : These insects comprise grasshoppers, locusts, grillids and their relatives and constitute a major component of any given ecosystem. They are found in the forests, cultivated fields and in human dwellings. Same is the case with Acrididae, known to be represented in India only by 310 out of a world total of 6000 species. We have reasonably good information on their distribution in Maharashtra and Orissa and on gryllids from many other areas of the Deccan. There is paucity of information in respect of the faunal picture of the group from the Deccan.

Phasmida: Our knowledge on this group from the Deccan is restricted to the record of a few species from the Eastern Ghats and some areas of Maharashtra and Orissa.

Dermaptera: Of 320 species known from India, 112 are Paninsular forms including those from the Western Ghats also. The Deccan part of Peninsular India accounts for about two thirds of these species, some of which are Deccan endemics.

Embioptera: In the Deccan, this group has been studied only from certain areas of Tamil Nadu, Orissa and Karnataka, leaving the whole of Andhra Pradesh and Maharashtra and much of the areas of the other states untouched.

Dictyoptera: This group comprising the cockroaches and praying mantids is well represented in India. From the Deccan, detailed information on cockroaches is available only in respect of Orissa state, while no indepth studies have been carried out covering other areas. About a third of the species recorded from India occur in the Deccan.

Out of 162 species of Mantids reported from India, 55 species have been recorded from South India, which includes areas of the Western Ghats also. Madhya Pradesh, Andhra Pradesh and Orissa are practically unexplored with respect to the fauna of mantids.

Isoptera: Out of 253 speceies reported from India 100 species are known from southern India, including the Western Ghats. Another 25-31 have been reported from other areas of the Deccan. Leaving aside the species confined to the Western Ghats, the Deccan components of this group may comprise about one-third of the total number of species available in India. Most of them are widely distributed and are present in other zoogeographic zones in India. Of these, a few are endemic to the Deccan.

Psocoptera: As far as the fauna of this group from the Deccan is concerned, we have only some information from certain areas of Orissa, Karnataka, Tamil Nadu and records of a few species from other states. Hardly about a third of the Indian fauna is so far recorded from the Deccan Peninsula.

Phithiraptera: Only 39 of the species have so far been recorded from this zone, none of which is endemic to the zone.

Hemiptera: While information on a few selected families like aphids, coccids, aquatic hemipterans and cicadellids distributed in the Deccan is fairly adequate much is yet to be known about other families. The fact that 84 species of cicadellids representing 26.2% of the Indian fauna of the family so far known speaks for the richness of this group in the Deccan. Many of the hemipterans found here are rare and a few are endemics.

Thysanoptera: The majority of speices known from India have been recorded from the Western Ghats and areas of Southern India. More than half of the total Indian species have been reported from the Deccan Peninsula, many of which are endemic to the area. Only when more unexplored areas in the eastern, north-eastern and north-western parts of India are thoroughly studied, the true endemics of this area will be revealed.

Neuroptera: 335 species have been reported from India, of which 25 to 30 have been recorded from the Deccan peninsula. The faunal composition of this group from many areas of Tamil Nadu, Karnataka and Andhra Pradesh in the Deccan is yet to be revealed.

Coleoptera: An analysis of the information available on the groups, Caraboidea, Hydrophiloidea, Scarabasoidea, Dermestoidea, Cucujoidea, Curculionoidea and Chrysomeloidea reveals that hardly about 25-30% of the species in these groups known from India have been reported from the Deccan peninsula.

Strepsiptera : Only 18 species are known from India. Out of these, only two species have been recorded from the Deccan.

Mecoptera : Of the 2 families and 15 species so far reported from India, only 1 species is known from the Maharashtra part of the Deccan.

Siphonoptera : From the Deccan Peninsula, our information on the group is mostly confined to certain areas of Maharashtra, Karnataka and Tamil Nadu, with the rest of the areas remaining practically uncovered so far. About 15 to 20 species have been recorded from the Deccan part, which includes species like the Indian rat flea *Xenopsylla cheopsis*, the transmitter of *Bacillus (Pasteurella) pestis* which cause human bubonic plague, *Pulex irritans* another human flea which also attacks cats, dogs and horses, *Ctenocephalides felis* and *C. canis*, the cat and dog fleas and the poultry pest *Echidnophaga gallinacea*.

Diptera : A persusal of data available on a few families in which work has reasonably progressed in India reveals that about 10 to 12% of the fauna known from the world occurs here, out of which 18 to 56% are represented in the Deccan Peninsula. Thus in Tephritidae, 105 of the 187 species (representing 56% of the Indian species) occurring in India have been recorded from the Deccan. In Chloropidae, out of more than 330 species (based on partly unpublished material with the author) recorded from India, 99 species have been reported from this zone, which represents 30% of the Indian fauna of the group. In Muscidae, out of 294 species known from India and adjacent countries belonging to a few of the subfamilies and dealt with in the Fauna volume of Van Emden (1965), 54 have been recorded from the Deccan Peninsula which represents 18.4% of the Muscidae fauna known. In Asilidae, out of a total of over 484 species (partly unpublished) recorded from India about 120 occur here. In Agromyzidae also, out of about 140 species known from India about 25% have been found in the Deccan peninsula. In Tipulidae, out of a world total of more than 14,000 species, 1,300 are known from India, most of which have been reported from the Himalaya and the Western Ghats. The Deccan elements represent about 20% of the species known from India.

Lepidoptera : An analysis of the data available on the Indian fauna reveals that about 43% of nearly 15,000 species recorded from India occur in the Deccan Peninsula. Majority of the microlepidopteran fauna of India known so far is found in the Deccan.

Hymenoptera : On the basis of information available, it can be said that Deccan component of Hymenoptera represents 20 to 35% of the species known from India. In the Deccan but for Tamil Nadu and certain isolated areas in the other states, much of the rest of the areas are yet to be thoroughly surveyed.

(iv) Arachnida : Order Scropionida is represented in India by 102 species. From the Deccan zone, the group is so far known by only 27 species (26.56%). This group shows a high degree of endemism in this zone. Almost the same is the case in respect of other related groups.

Acari : Deccan components so far known only accounts for about 20-30% of the species known from India. States like Madhya Pradesh, much of Maharashtra, Andhra Pradesh and Karnataka are yet to be thoroughly surveyed and studied.

Araneas : The faunal components of spiders occurring in the Deccan zone have been fairly well studied through the years. The studies date back to contribution made by Stoliczka in 1869 on species from Bombay, Madras and Southern India. Later, Gravely, Narayan and others have dealt with species from the Deccan as also Tikadar (1980), who described 164 species from the Deccan, including many new species. From Orissa alone, 29 species are known. Many of these are endemics.

Mollusca: In recent years from this zone, 130 species have been reported from Maharashtra and 71 from Pune. Besides, 428 and 337 species have been collected from the estuarine and coastal waters of Orissa and Coromandal Coasts respectively. Approximately, about 30 to 35% of the land and freshwater species known from India have been reported from this zone, only a few of which are endemic to this region. Mani (1974), while discussing the Gondwana derivates of molluscs has drawn attention to the fact that *Muelleria dalyi* found in River Krishna has its congeneric relative in South America also and the distribution of *Streptaxis* sp. (Pulmonata) found in Shevroy and Orissa Hills of Eastern Ghats, occurs in South America and South Africa, besides many areas of the Orient.

4. SPECIAL FEATURES

4.1 Endemicity and status of threatened animal taxa

Because of the topographical and climatic peculiarities of the Deccan Peninsula, generally the endemics in relation to the total fauna of the area are relatively low in comparison to the nearby area of the Western Ghats where one comes across rich endemicity. In comparison endemism in the Deccan is far less.

4.1.1 Vertebrates:

Fishes: A high degree of endemism prevails among the primary freshwater fishes of India. In the Deccan Peninsula, 14 species are endemic. The Deccan component thus comprises about 6% of the 235 endemic species reported from India.

As for the rare/endangered/vulnerable species of fishes occurring in this zone *Enobarbichthya maculatus* has not been recorded from here after it was first reported from the Deccan plateau of Tamil Nadu and, therefore, can be considered extinct. The following is a list of some rare/vulnerable and endangered taxa of fishes reported from the Deccan. The list is based on partly unpublished work of Dr. A.G.K. Menon. In recent years bigger carps are not represented in the collections being made from this zone.

(i) Rare (11 Species):

1. *Parapsilorhynchus tentaculatus*, 2. *Noemacheilus moreh*, 3. *Thynnichthys sandkhol*, 4. *Osteochilus (Osteochilichthys) godavariensis*, 5. *Puntius arenatus*, 6. *P. deccanensis*, 7. *P. fraseri*, 8. *P. sharmai*, 9. *Neotropius kavalchor*, 10. *Gagata itchkees* and 11. *Mystus krishnensis*

(ii) Vulnerable (3 species)

1. *Rohtee egilbii*, 2. *Labeo kontius*, 3. *Labeo potail*.

(iii) Endangered (7 species)

1. *Cirrhinus cirrhosa*, 2. *Puntius roseipinnis*, 3. *Barbodes bovanicus*, 4. *Hypselobarbus kurali*, 5. *H. kolus*, 6. *H. musullah*, 7. *Osteobrama neilli*.

iv. Extinct (Not reported since original description and hence believed extinct): 1. *Enobarbichthya maculatus*.

Amphibia: No endemic species of amphibians have been reported from this zone. Only two species reported from here can be said to belong to the endangered/rare category. Of these, the limbless amphibian *Ichthyophis peninsularis* has been reported from Kambakkam hills in the Nellore District of Andhra Pradesh. Recent attempts to collect the species from that area were not successful. Another rare species, *Bufo hololius* was recently collected, after a lapse of 111 years, from the Nagarjuna Sagar area of Andhra Pradesh.

Reptiles: A brief analysis of the reptile fauna of the Deccan shows that *Parkudia insularis*, the limbless lizard, occurring in the eastern ghats and nearby areas is the only endemic species found in the Deccan. The Deccan fauna is dominated by the snakes followed by the lizards. Of the 48 species of reptiles reported from here, *Crocodylus palustris*, *C. porosus*, *gavialis gangeticus*, *Varanus griseus*, three species of sea turties and one snake, *Python molurus* (Indian Rock python), have been included in the endangered list of species.

Birds : Among the birds found in the Deccan Peninsula, two species *Cursorius bitorguatus* (Jerdon's Courser) and *Athene blewitti* (Forest Spotted owlet) are endemic to Deccan, besides 5 subspecies, namely, *Turdus merula spenci* (Eastern Ghats Blackbird), *Athene brama brama* (Southern Spotted owl), *Ammonanes phoenicurus testaceus* (Rufoustailed Finch-lark), *Losterops palpebrosa salimalii* (Andhra White eye) and *Francolinus pondicerianus pondicerianus* (South Indian Gray Patridge). Among the birds known from the Deccan Peninsula, three species, namely, *Pandion haliaetus haliaetus, Falco peregrinus peregrinator* (Shahin falcon) and *Ardeotis nigriceps* (Great Indian Bustard) belong to the endangered category, while 5 species, *Sypheotides indica* (Lessar florican), *Athene blewitti* (Forest Spotted owlet), *Bubo bubo* (Great horned owl), *Anthracoceros malabaricus malabaricus* (Indian Pied hornbill) and *Anthracoceros coronatus* (Malabar Pied hornbill) are among the rare ones. *Pavo cristatus* (Indian peafowl) is a protected species found here. Two species known from the Deccan *Rhodonessa caryophyllacea* (Pink-headed duck) and *Athene blewitti* (Forest Spotted owlet) have become extinct.

Mammals : Out of 55 species and 91 races of mammals found in the Deccan Peninsula, Grizzled Giant equirrel *Ratufa macroura dandolena* is endemic to the zone. Some of the vulnerable/endangered categories of mammals are found here which have a range extending beyond the geographical limits of the Deccan. Some of the races found here are mostly confined to this area though their range exceeds beyond the geographical limits of the zone. In relation to the number of mammals existing in the area those coming under vulnerable/endangered category account for 40% of the total number. 22 species and 3 subspecies of mammals known from the Deccan Peninsula belong to the endangered/vulnerable/indeterminate category. They come under 16 genera. Of these, 4 species and 2 subspecies, namely, *Ratufa macroura dandolena* (Grizzled Giant squirrel), *Canis lupus* (wolf), *Felis rubiginosa* (Rusty Spotted cat), *Felis caracal schmilizi* (Caracal), *Bubalus bubalis* (Wild buffalo) and *Antilope cervicapra* (Blackbuck) are considered endangered while 16 species and 1 subspecies, viz., *Loris tardigradus* (Slender loris), *Canis aureus* (Jackal), *Vulpes bengalensis* (Indian fox), *Cuon alpinus* (Indian wild dog), *Melursus ursinus* (Sloth bear), *Mellivora capensis* (Honey badger), *Hyaena hyaena* (Striped hyena), *Felis chaus* (Jungle Cat), *Eelis silvestris ornata* (Indian desert cat), *Felis bengalensis* (Leopard cat), *Felis viverrina* (Fishing cat), *Panthera pardus* (Panther), *Panthera tigris* (Tiger), *Traqulus meminna* (Mouse deer), *Tetracerus guadricornis* (Four-Horned Antelope), *Bos gaurus* (Gaur) and *Gazella dorcas* (Chinkara) are considered vulnerable. The status of 2 species *Manis crassicaudata* (Indian Pangolin) and *Delphinus delphis* (Common dolphin) is considered indeterminate. Grizzled Giant squirrel is extremely rare and is represented by a few scattered populations in Tamil Nadu and the adjoining state of Kerala.

4.1.2. Invertebrates

Porifera : One species, *Eunapius geminus* found in Bangalore is so far known to be the only endemic species of freshwater Porifera found in the Deccan Peninsula.

Platyhelminthes : As many of the species are host specific, they occur wherever infected hosts are available. Many species recorded from the marine fishes found in the coastal waters of this zone have not been reported from any other areas of India. The genera *Monopyliddium, Indoternia, Moneiezia* and *Ptychobothrium* have at least one or more species each, which are endemic to the Deccan.

Rotifera : Of the Indian endemics, 4 species, namely, *Lecane (Lecane) sola* from Tamil Nadu, *L. (L.) donnerianus, L. (L.) bedentata* and *L. (L.) eswari* from Andhra Pradesh belonging to Lecanidae are confined to the Deccan. One species *Brachionus durgae* and a subspecies *Platyias quadricornis andhraensis* known from Andhra Pradesh and belonging to Brachionidae are also endemic to this zone. Besides, two species of Euchlanidae, namely, *Euchlanis brrahmae* and *Pseudoeuchlenis longipedis* confied to Andhra Pradesh and Gastropoidae species *Trichocerca tropis* from Tamil Nadu and *Asplanchnopus bimavaerensis* from Andhra Pradesh are also Deccan endemics. Family Conochilidae has 1 species and 1 subspecies belonging to the endemic category in the Deccan. They are *Conochilus aeboreus* reported from Tamil Nadu and *C. dossuarius asetosus* known from Maharashtra. Family Floscutandae is represented by the endemic species *Sinantherina triglandularis* in Maharashtra. Besides, monotypic genus *Pseudoembata* found in Tamil Nadu is endemic to Deccan. Thus, out of a total of 26 endemic species found in India, 11 species and 2 subspecies are endemic to the Deccan Peninsula, besides one genus which is also endemic to the zone.

Nematoda : Out of 255 species known from the Deccan Peninsula, 143 are endemic to this zone. Majority of the endemic species occurring here have been reported from Hyderabad in Andhra Pradesh.

Annelida : Among the Oligochaetes, the family Octochactidae represented by 33 species in the Deccan out of a total of 145 species reported from India has 9 species endemic to the zone. These belong to 5 genera, namely, *Barogaster, Eudichogaster, Holochaetella, Limnogaster* and *Pellogaster*. The species are *Barogaster annandalei, B. prashadi, Eudichogaster achwarthi, E. indicus, E. kinneari, E. nitllani, Hoplochaetella panchyaniensis, Lennogaster trichochaetus* and *Pellogaster simie*. Among the Ocnerodrilidae, the genera *Malabaria* and *Thatonia* comprising 9 species occur here. Of these, *Deccania* known by only one species is endemic to Deccan. Among Moniligastridae, the genera *Drawida, Moniligaster* and *Desmegaster* have a few endemic species represented in the Deccan. Among Megascolecidae, the genera *Megascolex* and *Notoscolex* have some species with their ranges restricted to the Deccan zone.

Six species of Hirudinea are endemic to Deccan. These endemics are *Ozobranchus polybranchus, Piscicola caeca, Pterobdella amora, Batracobdella mahabiri, Placobdella .fulva* and *Myxobdella annandelei.*

Arthropoda

(i) *Crustacea* : A good number of species of Crustacea belonging to Cladocera, Ostracoda, Copepoda, etc., are endemic to this zone. In Cladocera, out of 12 species known from the Deccan, 3 are endemic. These species are : *Latonopsis fasciculata, Alona taraporevalae* and *Moine oryzae.* Among the known species of Copepoda, Cirripedia, Cyprididae, *etc.*, there are many endemic species in this zone.

(ii) *Myriapoda* : Diplopoda is represented by 97 species in the Daccan Peninsula, of which 66 are endemic species. Thus the Deccan endemics account for 68.04% of the number of species reported from the zone and 22.76% of the total number of species known from India.

Among the Chilopodes, only 5 of the 26 species reported from the Deccan have a range restricted to this zone, which accounts for 19.23% of the species available here and 6.85% of the total number of 73 species recorded from India.

(iii) *Insects* : Precise data on endemic insects of this region are lacking. Therefore, some estimated number of endemic species belonging to some insect orders are as follows : Ephemeroptera (about 20 spp), Dermaptera (20-25 spp), Embioptera (less than 5 spp), Isoptera (17 spp), Thysanoptera (about 40 spp), Siphonoptera (less than 5 spp) and Diptera (about 95 spp; family-wise break up — Tephritidae : 29 spp; Muscidae : 3 spp; Asilidae : about 24 spp; Agromyzidae : 4 spp and Chloropidae : 35 spp).

(iv) *Arachnida* : A very high degree of endemism prevails in the Deccan in respect of the arachnid fauna. In Scorpionidae, 27 species are represented here. Out of this 22 are endemic to this zone.

4.2 Distribution pattern

From the zoogeographical point of view, out of all the vast expanse, only the peninsular region (Vorderindian) is India vera (true India), with the rest of the country forming merely a zoogeographical appendage. It is indeed here that we find the relicts of everything Indian. The Himalayan forest fauna in the east (up to the Sutlej defile) is largely Tertiary tropical mountain forms of the Indo-Chinese Subregion of the Oriental Region, with some Mediterranian and Ethiopian to the west of the Sutlaj defile. Above the timberline, the Himalayan fauna belongs to the Turkmenian Subregion of Palaearctic region. The Indo-Gangetic plain of north India is zoogeographically a neutral, transitional area, with outlines of the peninsular and transitional forms. The zoogeographical affinities of the Peninsula lie with the Gondwana faunas of Madagascar and tropical east Africa. There is considerable Indo-Chinese and some small numbers of Malayan forms also, formerly continuously distributed from Myanmar, Assam, through the Eastern Ghats to the peninsular south and Sri Lanka, but now with the destruction of natural habitats confined as relicts in small isolated pockets on south Indian hills. The Ethiopian forms are also conspicuous in the western border lands and parts of Deccan. The Malayan and Indo-Chinese elements intruded into India when the Gondwana land mass met the Laurasian mass in the early phase of the tertiary orogeny and continental drift in the area known as Assam in British India. From here they spread along the wooded slopes of the Himalaya and across the Eastern Ghats to the peninsular south. During pleistocene glaciations on the Himalaya, many palaearctic forms spread to the south and now occur as relicts in south India or as the so called "winter-forms" in the north Indian plains.

The outstanding characters of the distributional patterns of animals in the peninsula at present may be summarised as follows: (i) a high degree of localised concentration of all component elements; (ii) more or less complete intense and wide isolation; (iii) marked discontinuity; (iv) almost complete absence of altitudinal zonation of species in a region stretching from sea level to higher elevations; (v) progressive limitation eastwards and northwards and (vi) total obliteration of geographical radiation. These peculiarities are not associated with ecological and faunal climax trends and distributional stability, but must be correlated with retrogressive distributional changes and departure from stability. The retrogressive trends in the distributional patterns, however, are of recent origin, indeed within historical times. The limits of the peninsular fauna lie at present in the transitional zone of river Ganga in the north and about the Mahanadi Basin in the north east.

A striking feature of the present day distribution of animals in the Peninsula is the heavy concentration of the character forms in the extreme southwest in the southern block and in certain other areas, like the Chota-Nagpur plateau. These concentrations do not represent the centres of faunal differentiation and radiation, but refugia which are the results of disappearing habitats and areas of concentration, are precisely the places where the original forest cover has not yet been completely destroyed. These areas of concentration are, therefore, refugial centres or niches and in effect only islands of favourable conditions to which the peninsular character fauna has retreated (Mani, 1974). In the Peninsula, we find almost complete absence of speciation among the phylogenetic, geographical and pleistocene relicts now found isolated in the refugial pockets. Concentration and isolation are thus symptoms of faunal regression. From biogeographical point of view, the fauna of the Peninsula are composed almost exclusively of phylogenetic and geographical relicts. The fauna represent essentially the impoverished remnants of a vanished fauna.

5. INTRODUCED BIODIVERSITY

The number of animal species introduced to the Decccan zone from other areas are rather minimal. Among the insect groups, a few coccinelids were introduced here for controlling Citrus scale. A few reduvids and hymenopteran parasites were introduced here for the control of the coconut pest *Nephantis serinopa*. Two species of Tachnids were brought in for biological control measures. Migratory birds are expected to have brought in some ectoparesites. The Tephritid fly *Procecidochares utilis* was brought in here from the Neotrophical Region for controlling eupatorium weeds. Among land snails *Achatina fulica* was accidently introduced here from Africa *via* Andamans and it has become a pest here. A few mites and ticks not occurring here earlier have also been introduced here inadvertently.

Among vertebrates of the Deccan, introduced biodiversity is almost confined to the fishes only. Of those introduced here, some are edible ones while the rest were for the control of mosquitoes and also to keep in the aquaria. Some important species of fishes introduced into the Deccan zone are the following :

a. **Food fishes**

1. *Oncorhynchus mykiss* Rainbow trout; 2. *Hypophthalmichithys molitrix* Silver carp; 3. *Ctenopharyngodon idella* Common carp; 4. *Cyprinus carpio carpio* Common carp; 5. *C. carpio communis* Scale carp; 6. *C. carpio specularis* Mirror carp; 7. *C. carpio nudus* Leather carp; 8. *Carassius auratus* Gold fish (kept as aquarium pets); 9. *C. carassius*, (kept as equarium pets); 10. *Oreochromis mossambica* Tilapia and 11. *O. niloticus* Tilapia

b. **Larvicidal and aquarium pets**

1. *Gambusia affinis patruelis*; 2. *Poecilia reticula* Guppy; 3. *Fundulus heteroclitus* Killifish; 4. *Xiphophorus helleri* Green sword tail; 5. *X. maculatus* Platy

6. VALUE

6.1 Ethical and economic value

The Deccan Peninsular zone is the only area in India where we find a concentration of shrub/thorn forest ecosystems, besides elements of other types of ecosystems like mangroves, dry deciduous and semievergreen forests, wetlands and aquatic ecosystems. Diverse habitats and species can have non-consumptive use-value, such as tourism. Tourist revenues are clearly affected by the diversity of the species that can be seen and the range of habitats that can be visited. Species like elephants, tigers and their likes is a selling point. The Deccan zone possesses 17 national parks and 98 sanctuaries. Many of these areas attract tourists in fairly good number.

As discussed earlier, this zone has a very large and diverse fauna. Many of the areas can serve as gene reserves for many domesticated species of animals. Besides, large areas under grasslands and shrubby and thorn forests serve as feeding grounds for India's large population of cattle, sheep and goats. Hence, the economic value of this zone to man is immeasurable. Apart from the waterbodies in this zone providing large quantities of fish and other aquatic products, many terrestrial species also serve as souce of food and biproducts, part of which are exported. Again as has been brought to light by Joseph (1982) on the basis of studies carried out in Madhya Pradesh and Andhra Pradesh, many species are used by man especially the tribal population, for their therapeutic value. The value of medicinal diversity is significant. This would be either at. the cost of subsequent untreated disease and/or the additional costs of commercial alternatives. Undeveloped and untested but naturally occurring chemical compounds found in the organisms used by man for medicinal purposes are readily available and are very cheap for this reason. The value attached by the market to biodiversity at source is low even though the potential economic value to society may be considerably higher.

6.2 Scientific, Ecological and Social Value

Fauna of various groups reported from this zone represents on an average 20-40 and rarely more percent of the Indian fauna. Hence the area is a store house of genetic resources. The germplasm existing in the wild varieties of many species occurring in different niches can be made use of for the improvement of many domesticated species. The chemical compounds naturally existing in different species, about the possible usefulness of which the world is still ignorant, can be tapped in the years to come when more information may accumulate.

The potential use of many insects and other lower forms of life present here in biological control is a possibility. The consumptive and productive value of medicines directly or indirectly derived from wild species is a current and future value of biodiversity.

The ecological values of this zone are many. Apart from being home to 20 to as much as even 50% of the animal species found in India, the area also has many endemics. Though in amphibians, reptiles, birds and mammals

Fig. 9 : Painted Stork *Mycteria lencocephala*

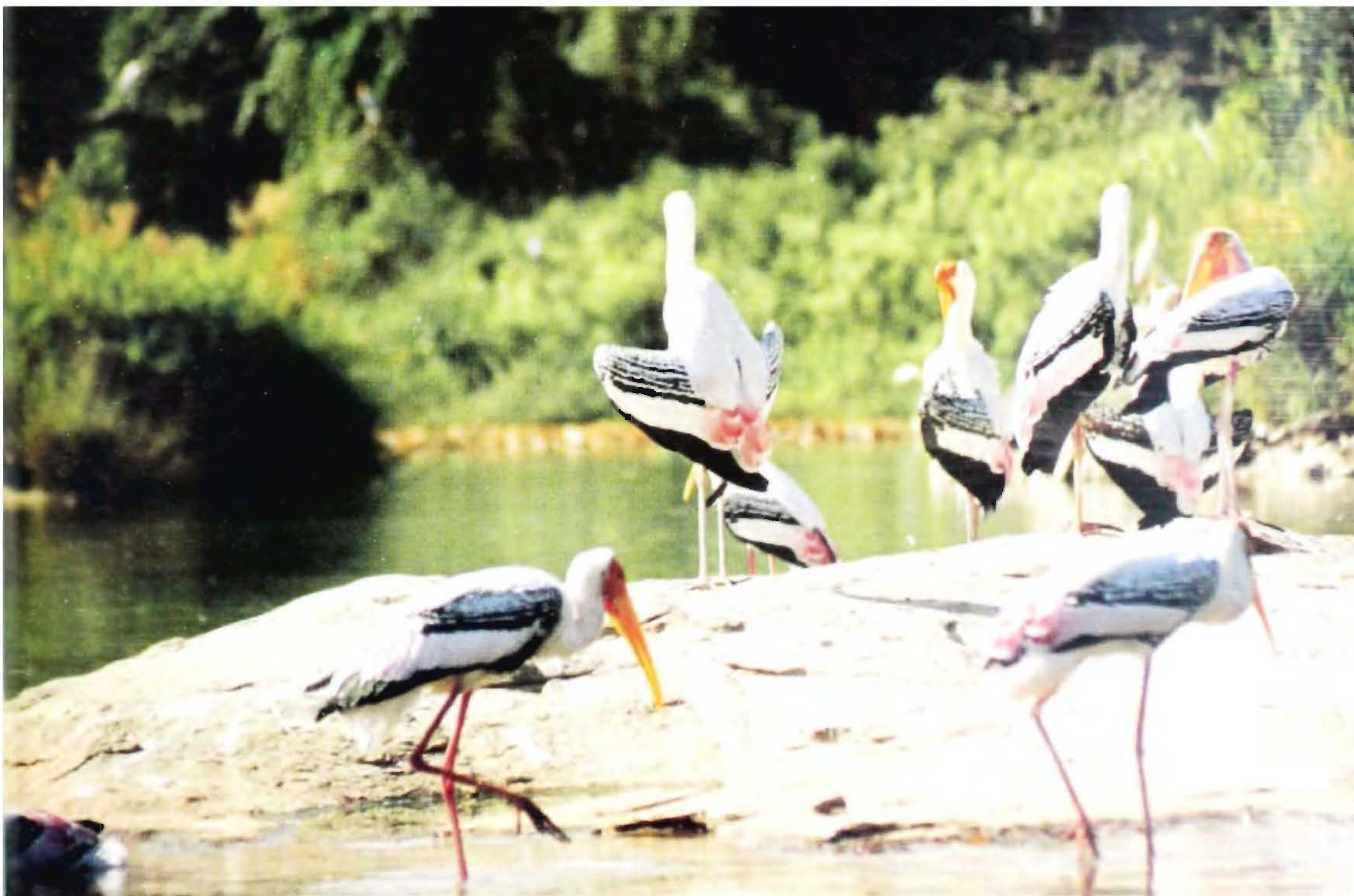


Fig. 10 : A denuded mountain range in Dharmapuri district

endemicity is minimal, in fishes and lower forms of life it represents on an average 5 to 30 or even more of the species. The area is also home to a wide variety of endangered/ rare/threatened animals. The ecological conditions prevailing here are unique in the Indian context.

There are many centres in this zone which appeal to the religious sentiments of man. As a general rule, the direct use value of diversity is most highly valued by local people of developing countries like ours while option and existence values are of more value to developed countries. Many social aspects of biodiversity cannot be quantified, let alone valued. An overall estimation of the value of ecosystem services attributable to biodiversity has not been attempted for obvious reasons. Some types of indirect use value, such as, the welfare gain from television and other media coverage of aspects of biodiversity can to some extent be estimated. There is something in the psychology of man to which faunal diversity never fails to appeal. Aesthetic and social values of biodiversity are always beyond the realm of economics.

7. THREATS

The biodiversity of any zoogeographic zone is of great value. It is an accepted fact that the rate of biodiversity loss the world over and especially in an area like the Deccan is biologically, ecologically and socially excessive. The exact rate of loss is unknown. Few figures are available for documented species loss but it has to be assumed that many plant and animal species are being lost as a result of massive habitat loss which were on the increase in the past decades. Habitat loss would have resulted in a contraction of species distribution and many species would have accordingly suffered genetic erosion, *i.e.*, the loss of considerable part of the genetic variation and variability within their populations. This is particularly serious for species of current economic value where genetic variation is important for breeding new strains and varieties. The threats to the zone and the causes of biodiversity loss are as follows: habitat loss and degradation, resource over-exploitation, species/genetic introductions, ignorance, pollution, market failure and intervention failure.

7.1 Habitat loss and degradation

This is the most important threat. Declining biodivrsity will be both a symptom and a cause of the accelerating degredation of the global environment. Population growth is a powerful force for biotic degradation.

In the Deccan, vast areas have been brought under the plough for the first time within this century. Such trends are on the increase. Added to these are the areas permanently inundated by the hydel and irrigation reservoirs which have come up in the past. Many areas have virtually turned into concrete jungles. All these entail habitat loss on a large scale, besides degrading vast areas of this zone.

7.2 Resources overexploitation

Overexploitation of biological resources is another major threat faced within the Deccan. Developmental activities exert so much pressure on the existing resources. When forests or other lands are cleared, all the organisms associated with it often travel the road to extinction. Often fish and other aquatic resources are so overexploited that big varieties of carps and other fishes have become a rarity.

7.3 Species/genetic introductions

New varieties of crop plants are introduced in many places to increase the yield. Besides, vast areas are being brought under monoculture. All these adversely affect the ecosystems, especially in respect of the invertebrates, due to the disappearance of built-in control mechanisms prevailing in an ecosystem where altered conditions become favourable for the growth and dominance of a few species at the cost of disappearance of many others.

When exotic species of fishes are introduced into an aquatic ecosystem to enhance the yield, it affects adversely the fish fauna prevalent there before. In course of time, introduced species thrives and flourishes at the expense of those already present. This adversely affects the species diversity and genetic resources.

7.4 Pollution

Indiscriminate use of pesticides affects the fauna in many areas. As more areas are brought under the plough and new high yielding varieities are cultivated, more lethal doses of insecticides are let out into the ecosystem, which affects the fauna. It adds to the pollution specially of our waterbodies. All aquatic life is adversely affected.

Added to these, vast quantities of industrial effluents entering the air and water of the Deccan in recent years is adversely affecting the fauna.

8. CONSERVATION

The biological diversity of Deccan Peninsula is now protected by 17 national parks and 98 sanctuaries which together cover 48,110 sq km or 3.4% of the zone. They are still insufficient to give adequate coverage to the geographical extent and biological values of this zone. Major gaps are the southern plains and the Eastern Ghats. Large areas in the north still have good forest cover but do not have protected areas and these have major geographic gaps in the distributional net work. An important example is the Kalibhit tract of the west Satpuras in Madhya Pradesh.

Many protected areas are too small to adequately support their diverse and immense values. To cite a few examples, elephants in Orissa and wild buffaloes in Madhya Pradesh have not received the protection and care needed for the maintenance of viable populations of these species.

An indepth analysis of the protected area coverage in this zone reveals the lack of conservation inputs particularly in Southern Deccan Plateau. Less immediately obvious is the fact that only Madhya Pradesh has an adequate extent nominally under National Park status, but even here there are geographic gaps and as is known many National Parks in this area suffer management problems.

The typical deciduous forest fauna (tiger, leopard, sloth bear, gaur, sambar, chital, chowsingha, boar, etc.) of this zone are fairly well protected. Doubts have frequently been expressed about the long-term viability of the zone's elephant populations. They need much larger conservation units with less internal disturbance than is available at present. Diligent survey and research on the threatened birds of this zone (bustard, florican, courser) have played some dividends. These have led to the creation of specific sanctuaries applying increasingly relevant management technologies for the conservation of these and associated fauna and flora.

Adequate thought needs to be given to the plant resources of this zone. The endemic and valuable red sanders and sandalwood areas are not well protected today. There is need for specific conservation measures for moist teak, southern and coastal sal, umbrella thorn, semievergreen communities of Orissa, especially dry evergreen forests. Measures for the protection of these, apart from ensuring their own preservation will ensure the maintenance and protection of all associated communities of flora and fauna.

Conservation efforts the world over and especially in India are often directed at high profile species which to a degree tend to preserve the habitat of numerous less charismatic plants and animals that are unique to a given ecosystem. Apart from the inadequate attention received so far for the protection and preservation of the rich and varied faunal elements and associated ecological communities of many areas especially of Eastern Ghats and the Southern plains, practically not much thought has so far been spared for the preservation of lower forms of life, especially the microorganisms and invertebrates which are rich sources of biological diversity.

Detailed knowledge of the biodiversity of freshwater ecosystems of this zone is poor and is limited today mostly to such aspects of the system which are of direct commercial importance. The conservation status of the priority lakes and river systems or of the coverage of existing *ex situ* and *in situ* conservation is also poorly documented. In general, there is no effective conservation of freshwater environments. With much of the virgin lands being cleared and brought under the plough and the use of various insecticides, the rivers are getting polluted. Sewage and the effluents from industrial establishments in this zone are adversely affecting the faunal elements of the rivers and lakes in this area. Some of the proposed and already commissioned hydel and irrigation projects in the rivers of this zone have already curtailed and will additionally curtail the regular flow of water in many stretches of these rivers which will wipe out the fauna of these stretches. Besides, freshwater systems can be effectively conserved only if there is a large buffer zone to control terrestrial runoff or other factors affecting the lake of river. This is rarely the case; with the result, the conservation status of freshwater fish and their environment is very low in this zone.

The grazing lands of Deccan Peninsula today support a large mass of domesticated herbivores in place of the indigenous fauna. Only in certain areas of this zone there are today fairly large populations of indigenous herbivores. With much pressure being exerted on the available land by human activities whatever is left of the home of these animals are fast dwindling in the zone. Conservation measures should address this problems in future.

The coverage of wildland ecosystems within protected areas is relatively low the world over compared to the tropical forests. The thorn shurbs and shrublands which in India are predominantly represented and mostly confined to the Deccan Peninsula have so far not received the attention they deserve from the conservation angle. Hence, efforts are to be made to bring large stretches of representatives of these ecosystems under protective cover.

9. FUTURE DIRECTION

Preservation of the biodiversity of a given zone becomes meaningful only when adequate information is available on the faunal wealth which in respect of many areas of the Deccan Peninsula is rather very poor. Hence, concerted efforts are needed to reveal the richness of the general fauna of the area.

(i) Need for conservation of the invertebrate fauna

"Save the whale" has a convincing ring, but 'Save the snail'? Attempts to argue the case for the conservation of invertebrates are often met with derision. Often their existence in the ecosystem is unknown, let alone any threat to their survival. But for every species of higher form of life disappearing, there are thousands of invertebrates that travel the road to extinction. The needs of invertebrates do not always coincide with these of vertebrates. So it is not safe to assume that protection of large areas for vertebrates will automatically safeguard the diversity of lower forms of life. Because of their variety, diversity and germplasm potential, besides the role they play in the maintenance of any viable ecosystem, preservation of invertebrates should also receive the importance it demands.

(ii) Avoidance of adverse impacts of developmental projects

• Need to minimise adverse impacts

The most important factor that is having a telling adverse impact on the biodiversity of any ecosystem is the pressure exerted by man. Apart from bringing more and more virgin forests of various descriptions under the plough the direct and indirect impacts of industrial, hydel, irrigational and related activities are playing havoc with many efforts at conservation. Only in the recent past, general awareness has dawned on man that commercial exploitation of natural resources should avoid extinction, exhaustion and irreversible destruction of habitats of fauna and flora and that sustainable yield should be the key to any developmental programme. But to decide on this sustainable yield, information on the impacts of projects is needed. The lack of data in this regard is disheartening today. Hence in unavoidable instances when developmental projects are to be commissioned, sufficient data on the biodiversity of the area should be collected and built in sáfeguards should be incorporated in the proposal stage itself. This should incorporate the efforts to be made before, during and after the commissioning of the project so as to minimise the adverse impacts. There are many instances where even when built in safeguards are provided for in the proposals they are not implemented or adhered to strictly, which dilutes or nullifies the effectiveness of the measures.

• Need for a proper perspective of the issues involved

A wider perspective from the world angle and especially from Indian context should merit consideration when the question of loss of habitats of flora and fauna of specialised ecosystems is involved. Hence, any developmental activity should avoid, as far as possible, species rich rain forests and areas known to serve as the habitat of threatened fauna.

- **Study and listing of remedial measures to minimise adverse impacts**

Once a decision is taken to start a developmental project, remedial measures needed to minimise the adverse impacts on the fauna should be listed out for implementation before, during and after the commissioning of the project. While chalking out such recommendations, priority for implementation should be assigned in such a way that categories of animals at several levels of risk, namely, endangered, vulnerable, rare, indeterminate, insufficiently known, commercially threatened, threatened community and threatened phenomenon should merit consideration in that order.

- **Adoptation of new techniques**

Apart from loss of habitat to organisms through reduction of area available to them, certain practices followed are not on scientific lines, which affect what is left of the areas of project sites. Hence the now-rare techniques as directional markings, low ground-pressure extraction, rainy season logging bans and careful location of roads meant for transporting logged wood should all be kept in mind to ensure that the gut of the logged plot is not ripped out of it which would affect the environment of the forest, the nutrient levels, the microlimate and the soil-water balance which affects its recovery.

- **Establishment of machinery to oversee implementation of safeguards**

Proper machinery should be instituted to ascertain whether built in safeguards provided for the protection of flora and fauna in the blue print of the project are strictly adhered to. Such a machinery should serve as a watchdog and see to the implementation of the safeguards.

- **Minimising secondary developments**

Secondary developments in the aftermath of the commissioning of developmental projects often cause much damage to the biodiversity of a project area than the actual project itself. Studies carried out in the developmental sites of Idukki and Sabarigiri in the Western Ghats have proved this. Hence, when hydel and other developmental projects are commissioned in forest areas, secondary developments should be kept at the minimum.

- **Development of corridors to connect project areas to nearby practically unaffected ecosystems**

Establishment of corridors, whenever feasible, can serve as routes for migration of major forms of life during the time when habitats are affected, as happens at the construction stages of developmental projects. Later when things stabilise, many species can return and reestablish in the area affected.

- **Re-introduction of species which existed in the project area**

At least a few important and endangered species for which a project area is known as a home can be re-introduced from available sources after the initial adverse impacts caused to the ecosystem are tided over. This may call for gathering of data on the existing fauna of the ecosystem supplemented by feasibility studies.

- **Re-introduction of males/females of a given species**

It is an established fact in many areas in India where studies have been carried out that economically important species like elephants are not represented by healthy and viable populations and males have mostly been hunted out of existence. This has happened at many areas in what is left of the forests in Eastern Ghats and the ranges of Vindhya and Satpura. The removal of forest cover has affected the delicate frogs and toads of the forest floors, besides a number of birds that live in the understorey, particularly babblers, wren-babblers and the likes.

(iii) Need for increasing protected areas

Large number of protected areas of India fall under this zone. But there are some glaring lacunae existing in the measures adopted so far. The protected area network is not evenly distributed over the whole zone. Some areas like the forested tracts of the Satpura and Vindhya hills are fairly well covered. But others with distinctive values, like the species rich areas of Eastern Ghats and the thorn and shrub communities of the southern plains are much less protected. Hence, conservation measures in future should address the problem of paucity of coverage of such areas.

Wildlife Institute of India has in its report of 1988 suggested to increase the national park network in this zone from 17 areas covering at present 7,281 sq km to 34 areas of 13,148 sq km and the number of sanctuaries from 98 to 156 with an increase of area from 40,829 to 42,865 sq km. If accepted and implemented, at least many of the loopholes existing in our protective measures in this zone shall be plugged.

(iv) Some suggested measures for the future

A variety of indices are to use or proposed for conservation planning. Most involve a weighted combination of some of the following: the number of species, the number of endemic species; evenness of abundance of species; the number of taxa higher than species level; spread of classes and trophic emphasis so that priorities should not be determined by ecological or biological criteria alone, such as, concentrating on centres of diversity. A combination of the following criteria should be used to set priorities at any level, whether global, national or zonal. These according to Michael (1991) are: (a) values for the country, (b) diversity and distinctiveness, (c) threat, (d) gaps in the programmes on hand, (e) comparative advantage and (f) likelihood of success.

- **Value:** The choice of priority of conservation of genes/species/ecosystem must be guided by some judgement of the socio-economic value of different biological resources. While these values are not known with certainty some general priorities can be identified. Cultural, ethical and aesthetic values may also be a factor in determining priorities.
- **Diversity and distinctiveness:** This criterion is likely to remain a major determinant of conservation decisions. Other things being equal, priority should be accorded to those habitats and areas with the greatest number of species, the so called "centres of diversity" Areas under ecological stress and the degree of endemism and distinctiveness also should be important considerations.
- **Threat:** Resources should be allocated first to the conservation of the most threatened genes, species and habitats. the severity of threat should depend on the distribution of the aspect of biodiversity in question, its vulnerability and the type of anthropogenic pressures.
- **Gaps in other programmes:** Decisions on priorities for action must take full account of the current and planned programmes of other countries, agencies and institutions and the extent to which this will meet conservation and development needs.
- **Comparative advantage:** Each country, institution or agency has particular expertise or other resources to follow. Hence a co-ordinated approach of various institutions in India and abroad should be made use of in tackling the issues of conservation so that energies are not diluted by repetition.
- **Likelihood of success:** An informed assessment of the relative likelihood of a particular biodiversity project meeting its objectives has to be an important consideration. This is related to the efficacy of different conservation strategies.

10. SELECTED REFERENCES

Ananthakrishnan, T.N. and Sen, S. 1980. Taxonomy of Indian Thysanoptera. *Zool. Surv. India, Handbk. ser.*, **1**: 1-234.

Anon 1990. *Conserving the world's biodiversity.* IUCN/WRI/CI/WWF-US/World Bank.

Anon, 1991. *Animal resources of India: Protozoa to Mammalia.* ed. Director, Z.S.I., Calcutta, 1991. 694 pp.

Daniel, A. 1987. Estuarine animals and their adaptations. *J. Mar. Biol. Ass. India.* **29** (1 & 2): 351-353.

Hall, A.L. 1989, *Developing Amazonia deforestation and social conflict in Brazil's Caraia's programme.* Manchester University Press.

Holloway, J. D. 1986. An Introduction to the Moths of South-East Asia. Kuala Lumpur. In: *Taxonomic Appendix* : 174-271.

Ives, J. and Pitt, D.C. 1988. *Deforestation: Social dynamics in Watersheds and mountain ecosystems.* Toutledge.

Joseph, A.N.T. 1988 (1989). Ethnozoology in the tribal welfare of Madhya Pradesh and Orissa. *Rec. Zool. Surv. India,* **85** (2) : 319-348.

Mani, M.S. (ed) 1974. *Ecology and Biogeography of India.* 773 pp. Dr. W. Junk, B. V. Publishers, The Hague.

May, R.M. 1988. How many species are there on earth? *Science* Vol. **24.**

Mc Neely, J. and Miller, K. 1989. *Conserving the world's biological diversity.* WRI.

Michael, F. 1991. *Biological diversity and developing countries: Issues and options.* British Overseas Development Adminstration Approach paper. 50 pp.

Myers, N. 1989. *Deforestation rates in tropical forests and their climatic implications.* Friends of the Earth.

Pearce, D and Turner, R. 1990. *Economics of natural resources and the environment.*

Sedjo, R and Clawson, M. 1983. Tropical deforestation: how serious. *Journal of Forestry,* **81** (12): 792-794.

Subba Rao, N.V. 1989. *Handbook: Freshwater molluscs of India,* **23**: 1-290. *Zool. Surv. India.*

Tikader, B.K. 1980. *The fauna of India: Aranae* **1** (1-2): 1-443. *Zool. Surv. India.*

Tikader, B.K. 1983. *Threatened animals of India.* : 1-306. *Zool. Surv. India.*

Van Emden, F. 1965. *Fauna of India and adjacent countries. Diptera: Muscidae.* 647 pp.

Wilson, E.O. (ed) 1988. *Biodiversity.* National Academy Press.

World Resources Institute, 1989. *Keeping options alive. Scientific basis for conserving biodiversity.*

World Wide Fund for Nature, 1984. *World Wildlife Fund Yearbook, 1983-84.*