

ZOOLOGICAL RESEARCH IN HUMAN WELFARE



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ZOOLOGICAL RESEARCH IN HUMAN WELFARE

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EMERGING PERSPECTIVE-BIODIVERSITY AND ITS CONSERVATION IN INDIA

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ABSTRACT

This keynote address summarizes what is known of the biological diversity of India and their various ecosystems, from past literature, museum records and other lesser-known sources of information. The synthesis suggests that the number of species known could be of the order 45,000 species of flora and 90,000 species of fauna or higher. However, the inventory is very detailed only in the case of commercially important groups and is very weak with respect to minor phyla or microbial organisms. In terms of spatial coverage, probably only two-thirds of the total area has been covered till today and the remote islands and other ecosystems still virtually remain untouched. It is, therefore, likely that true inventory of biodiversity could be several times higher than what is known today. Lack of trained taxonomists, however, is a serious constraint to achieve this. Conserving what we have today is hampered by lack of management measures including outreach and our ability to predict what would live in India and lack of data relating changes in biodiversity to those of environment.

Keywords : Conservation, Biodiversity, ecological communities.

INTRODUCTION

Biodiversity encompasses the variety of all life on earth. India is one of the 12 mega biodiversity countries of the world. With only 2.5% of the land area, India already accounts for 7.8% of the recorded species of the world. Biodiversity also includes countless millions of races, subspecies and local variants of species and the ecological processes and cycles that link organisms into populations, communities, ecosystems and ultimately the entire biosphere. A more easily recognized element of biological diversity is the distinct species. An association of species in an area is another recognizable element of biological diversity which is termed as community. Communities form the biotic components of ecosystems. Biologically diverse communities contain sufficient compositional, structural and functional variety that they are

assured a high prospect of continued presence and ecological influence in an area. Biodiversity is mainly recognized at three levels, namely species level, genetic level and ecosystem level. Genetic diversity refers to variation within individual species; species diversity pertains to be variety of species; and ecosystem diversity refers to diversity of ecosystems and habitats. Biodiversity is dynamic at all three levels, the genetic composition of species changes over time in response to natural and human-induced selection pressures; occurrence and relative abundance of species in ecological communities change as a result of ecological and physical factors, ecosystems strongly respond to external dynamics and internal pressures.

PHYSICAL FEATURES OF INDIA

India is located in the South of Asia, between latitudes 6° and 38° N and longitudes 69° and

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97° E. The Indian landmass, extending over a total geographical area of about 329 m ha, is bounded by the Himalaya in the North, the Bay of Bengal in the East, the Arabian Sea in the West, and Indian Ocean in the South. In terms of landmass, it is the seventh largest country in the world. Its coastline of about 8000 km extends over 200 nautical miles in the off-shore forming an Exclusive Economic Zone (EEZ) of 2.02 million sq km. India has a tropical monsoon climate. The south-west monsoons and North-east monsoons bring rain into India. Rainfall is unevenly distributed and it varies both temporally and spatially. Western Ghats, along the States of Goa, Maharashtra, Karnataka and Kerala, West Bengal, and Assam receive an annual rain fall of 2000 mm. Maharashtra, Bihar, and Madhya Pradesh along the Vindhya Mountains receive annual average rainfall of 1000-2000 mm. South coastal plains and North Western Deccan and upper Gangetic plains receive an annual rain fall of 500-1000 mm. Hot desert areas of Rajasthan and Gujarat and the cold desert areas of Ladakh in Jammu and Kashmir and Lahul-Spiti in Himachal Pradesh receive an annual rainfall of 100 mm.

ECOSYSTEMS OF INDIA

The wide variety in physical features and climatic situations have resulted in diversity of ecological habitats like forests, grasslands, wetlands, coastal and marine ecosystems and desert ecosystems, which harbour and sustain the immense biodiversity.

Forest Ecosystems

Forest cover of the country is 7,65,210 sq km (23.42%) while forest cover analysed by the satellite is 6,39,900 sq km (19.47%) (ICFRE, 2000). India is endowed with diverse forest types ranging from the Tropical wet evergreen forests in North-East to the Tropical Thorn forests in the Central and Western India. The forest of the country can be divided into 16 major groups comprising 221 types. The following are the forest types : 1. Tropical wet evergreen (North East and South, and Andaman and Nicobar Island), 2. Tropical semi evergreen (South and East), 3. Tropical moist

deciduous (Central and East), 4. Tropical littoral and swamp (Along the coast East and West), 5. Tropical dry deciduous (West and Central), 6. Tropical thorn (West and Central), 7. Tropical dry ever green (Central and South), 8. Subtropical broad leaved hill forests (South), 9. Subtropical pine (Sub-Himalayan tract), 10. Subtropical dry evergreen (North-East and South), 11. Mountain wet temperate (Himalaya and Nilgiris), 12. Himalayan Moist temperate (Temperate areas of Himalaya), 13. Himalayan dry temperate (Dry temperate areas of Himalaya), 14. Sub-alpine (Himalaya), 15. Moist Alpine shrub (Himalaya) and 16. Dry alpine shrub (Himalaya).

These forests provide several essential services to mankind. Forests are the source of a number of food items, fuel, wood, fodder, medicine and timber. Other economic uses include providing raw material for forest based industries. Some of the minor forest produce include gums, resins, honey etc. Forests perform important ecological functions such as maintaining delicate ecological balance, conserving soil, controlling floods, drought and pollution. Forests provide habitats for innumerable plants animals and microorganisms. Forests are a source of recreation and religious inspiration.

Most of the forest ecosystems in India are under acute form of degradation mainly due to i. loss of forest land due to agriculture, industries and human settlement, ii. loss of forest land due to multipurpose projects, construction of roads, erection of transmission lines, quarrying, shifting cultivation etc. iii. Degradation due to illicit felling lopping for fodder and fuel wood, overgrazing, forest litter removal, forest fires, over felling, conversion to monoculture, mining, army operations, introduction of exotics, fire and pollution and iv. human and cattle population exploitation 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.

Grassland Ecosystems

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. In India grasslands occur in the form of village grazing grounds to extensive low pastures of dry regions to alpine Himalaya. The total area of grassland is estimated to be 3.9% or 12 m ha. Grasslands in the country also exhibit a diversity range from semi-arid pastures in Deccan peninsula, humid semi water logged grasslands of Terai belt, rolling shoal grasslands on the hilltops of Western Ghats, and the high altitude alpine pastures of Himalaya. There are five types of grasslands which have been recognized in the country *viz.* i. Sehima-Dichanthium type, ii. Dichanthium-Cenchrus-Leaiurus type, iii. Phragmites-Saccharum-Imperata type, iv. Themeda-Arundinella type and v. Temperate-Alpine type. It is also estimated that the Indian grasslands harbour about 1,256 species belonging to 245 genera. Grasslands are of considerable economic value. Grasslands primarily support a large number of herbivore species from minute insects to the largest land animal—the elephant. This in turn makes grasslands hunting grounds of various carnivorous species of different sizes. Most of grasslands are used for production of milk, meat, wool and hides. A good stand 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. They are home for variety of organisms including wild mammals and birds. Some grasses are of medicinal value. Grasses exhibit a fairly good degree of endemism in India. There are about 18 genera endemic to India of which 13 of them are restricted to peninsular India. 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. 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.

NATURAL AQUATIC ECOSYSTEMS

Wetland Ecosystem

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, peat land 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 meters. Wetland is defined as transitional zones that occupy intermediate position between dry land and open water. These ecosystems are dominated by the influence of water, they encompass diverse and heterogeneous habitats ranging from rivers, flood plains and rain fed lakes to swamps, estuaries and salt marshes. India by virtue of its extensive geographical stretch and varied terrain and climate, supports a rich biodiversity of inland and coastal wetland habitats. It is estimated that India has about 4.1 m ha of wetlands (excluding paddy fields and mangroves), of which 1.5 m ha are natural and 2.6 m ha are man made.

Indian wetlands cover the whole range of the ecosystem types found. In addition to the various types of natural wetlands, a large number of man-made wetlands also contribute to the faunal and floral diversity. These man-made wetlands, which have resulted from the needs of irrigation, water supply, electricity, fisheries and flood control, are substantial in number. The various reservoirs, shallow ponds and numerous tanks support wetland biodiversity and add to the country's wetland wealth. Wetlands in India occupy 58.2 Million hectares, including areas under wet paddy cultivation (Directory of Indian Wetlands).

Majority of the inland wetlands are directly or indirectly dependent on the major rivers like, Ganga, Bhramaputra, Narmada, Godavari, Krishna, Kaveri, Tapti.

Lotic Ecosystems

The Indian sub-continent, bounded by the Great Himalayan Arc in the north and by deep sea in the east, west and south, is traversed by large number of rivers, which played a major role in shaping the history of human civilization in the sub-continent. It has very rightly been said that the River Ganga has been the cradle of civilization in the Indian sub-continent. The rivers have extensively been used for various purposes including irrigation, drinking water, recreation, fishing, transport etc. The rivers in India have been revered as mothers and worshipped as goddesses in this part of the world. In the last few decades, an exponential growth in human population, rapid urbanization and industrialization, intensive agriculture and growing demands for energy have severely affected the rivers of the region. The regulation of river flows and the discharge of domestic wastewater and industrial effluents have degraded the water quality of the rivers and declined the biological resources.

Wetlands are one of the most threatened habitats of the world. Wetlands in India, as elsewhere are increasingly facing several anthropogenic pressures. Thus, the rapidly expanding human population, large scale changes in land use/land cover, burgeoning development projects and improper use of watersheds has all caused a substantial decline of wetland resources of the country. Significant losses have resulted from its conversion threats from industrial, agricultural and various urban developments. These have led to hydrological perturbations, pollution and their effects. Unsustainable levels of grazing and fishing activities have also resulted in degradation of wetlands. Most problems pertaining to India's wetlands are related to human population. In the Indian subcontinent due to rice culture, there has been a loss in the spatial extent of wetlands. Alternative farming methods and

fisheries production has replaced many mangrove areas and continues to pose threats. The shrimp farms also caused excessive withdrawal of freshwater and increased pollution load on water like increased lime, organic wastes, pesticides, chemicals and disease causing organisms.

Pollution is a major cause for the degradation of lotic ecosystems. While urbanization is often an integral part of development, rapid and unplanned growth may result in a wide impact on natural resources and the environment. Water pollution and freshwater depletion are currently viewed as the top environmental problem in Asian region. In India, pollution of surface waters has become more severe and critical near the urban areas due to high pollution loads discharged within short stretches of rivers from urban activities.

It is believed that the major sources of pollution in Indian rivers are point sources, viz. domestic sewage, industrial effluents etc., as most of the information available concerning pollution in Indian rivers are those of point sources of pollution. Very little is known about the non-point sources of pollution. Moreover, many of the Indian rivers have large catchment area from where the pollutants from non-point sources flow into the rivers. The pollutants like organochlorines, organotins, and heavy metals in the rivers are mainly from the non-point sources of pollution.

Coastal and Marine Ecosystems

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 7,516 km of which the mainland accounts for 5,422 km, Lakshadweep 132 km and Andaman and Nicobar islands for 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, urbanization 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 to the management of coastal resources are not capable of sustainable development and the coastal environments and resources are being rapidly degraded and eroded in India.

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-Lakshadweep in the south Arabian Sea, Andaman group and Nicobar group, both in the eastern Bay of Bengal. The east and west coasts are markedly different in their geomorphology. 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 characterized by different types of coastal and shore ecosystems like promontories (near Beypore in Kerala State), sand spits (at Karnataka and Andhra Pradesh), barrier beaches (along Kerala coast), embayments (Mirya bay in Maharashtra), estuaries and offshore islands

Further, the coastal zone of India is also endowed with a very wide range of coastal ecosystems such as estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs which are characterized 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 rocky flats or lime stone rocks, often with overhanging cliffs formed of green to black basalt. Sandy areas, rivers and creeks interrupt the rocky coasts, and back waters of the coastal regions of India. On the East Coast, small stretches of rocky formations occur along Tamil Nadu and Andhra Pradesh.

Realizing the importance of the coastal ecosystems and their multiple uses, the ever-increasing human populations exploit not only the biological resources but also interfere and modify the basic coastal processes.

Traditionally, coastal areas are highly populated and developed because they are the places where trade, transport, communication and civilization are well developed. In India, out of the three mega cities with population more than 10 million, (Delhi-13.2 million, Bombay-16 million and Calcutta-16.5 million), two are coastal cities ie. Bombay and Calcutta. The population density is also much more in coastal areas than the national average. For example, in the state of Tamil Nadu, the population density in coastal areas is 528 per sq. km against 372 per sq. km, which is state average. In parts of coastal metros like Bombay, Calcutta and Madras the population density ranges from 20,000 to 50,000 per sq km. The increased population pressure has led to resource depletion and environmental degradation due to coastal pollution, disposal of domestic wastes and industrial wastes. As in most of the developing nations, the coastal environmental problems and issues in India are also concerned with the following three main conditions: environmental degradation, resources reduction and user conflicts. The Integrated Coastal Zone Management (ICZM) plan has been recognized as a tool for addressing options that ensure livelihood security and environmental stability in coastal zones.

Coral Reef Ecosystems

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 ability to retain and recycle nutrient elements within the ecosystem as well as within animal-plant associations. 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. Coastal populations mostly depend upon the coral reef ecosystem for their day-to-day life.

In India, all the three major reef types (atoll, fringing and barrier) occur, and the region

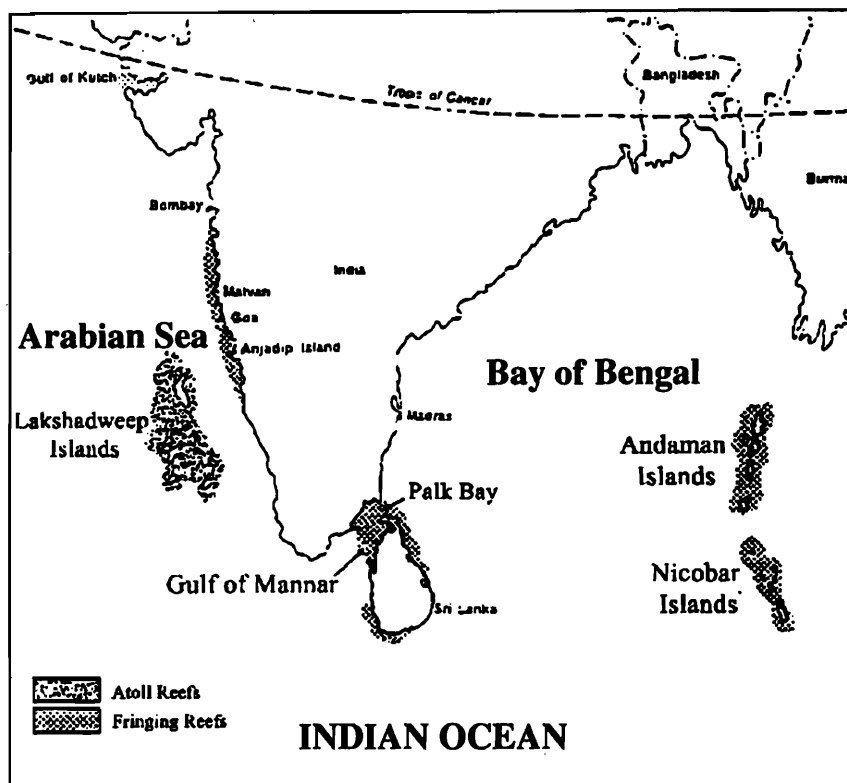


Fig 1. Map showing the major coral reef areas of India.

includes some of the most diverse, extensive and least disturbed reef areas of the Indian Ocean, many of which are among the least scientifically known. The mainland coast of India has two widely separated areas containing reefs: the Gulf of Kachchh 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 at Malvan. The Andaman and Nicobars have fringing reefs around many islands and a long barrier reef (329 km) on the west coast. The reefs are poorly known scientifically but may prove to be the most diverse in India and those in the best condition. The Lakshadweep reefs are oceanic atolls but these are equally poorly studied.

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.

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 coral species 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 comprises of three separate basins, within each of which numerous species evolve. The variety of species on a reef decreases eastwards across the Pacific.

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 Kachchh. 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, Krishna and Godavari. 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.

A total of 199 species divided among 71 genera are recorded from Indian reefs. Out of these 155 species are hermatypes (reef building corals) and 44 are ahermatypes (non reef building corals) (Pillai, 1996). A recent survey conducted jointly with the UNDP GEF and Indian experts in 12 areas of Andaman alone reveals an addition of 111 species of scleractinian corals from the shallow areas (up to 15 m depth). The above study revealed a total of 223 species of *Scleractina* from the Andaman Islands alone including the earlier report by Pillai, (1983).

Mangrove Ecosystems

Mangrove is one of the most extraordinary ecological formations occurring almost exclusively in the tropics. Like the tropical rain forests, the mangroves have also played a very important role in the economy 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, and shoreline and coastal erosion control.

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).

They form highly productive ecosystems 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.

India has only 2.66% of the world's mangroves, covering an estimated area of 4827 sq km. The East Coast is endowed with the world's largest mangrove forest, the Gangetic Sunderbans in West Bengal. The Sunderbans mangroves are of the deltaic type. The 2109 km² area of Sunderbans has 30 of the 50 species of the true mangroves in the world. The mangrove area in Orissa is nearly 200 km² in extent and its degradation is placed at 20 km² over ten years, as per recent estimates. Andhra Pradesh has about 582 km² of mangrove area. The area under mangrove ecosystem in Tamil Nadu is about 225 km². One of the largest and most unspoiled mangrove forests in Tamil Nadu is at Pitchavaram in Cuddalore District, extending over an area of 1100 ha. 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-estuarine and insular categories. The deltaic mangroves occur on the east coast (Bay of Bengal) where the mighty rivers make the deltas. The backwater-estuarine type of mangroves of the west coast exists along the typical funnel-shaped estuaries of major rivers (Indus, Narmada, Tapi) 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. 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.

Sea grass and Seaweed Ecosystems

Sea grasses 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 Coast, and Andaman and Nicobar Islands. They form a dense meadow on sandy and coral rubble bottoms and sometime in the crevices under water. In India, the earlier studies revealed that about 14 species are found along the Indian coast. The dominant species are *Cymodium rotundata*, *Enhalus acorodites*, *Halodule pinifolia pinifolia*, *H. uninervis*, *H. wightii*, *Halophila beccarii*, *H. decipiens*, *H. ovalis*, *H. ovata*, *H. stipulacea*, *Syringodium isoetifolium* and *Thalassia hemprichii*. About 9 species 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 intertidal lagoons, bays, rock pools, and puddles or in creeks and inlets beyond the low tide mark along the infralittoral region of the coast. Different species are abundant along the West Coast, Andaman and Nicobar Islands and Lakshadweep. Except for 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*, *Oidium iyengarii*, *C. tomentosum*, *Halimeda macroloba*, *Dictyota atomarica*, *Ectocarpus breviarcticulatus*, *Polysiphonia variegata*, *Grateloupia indica* and *Sargassum duplicatum*. 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. Detailed studies on Indian seaweeds, their survey, quantitative assessment and different problems for extracting valuable products for commercial export are to be given more emphasis in the future.

Desert Ecosystems

The district Rann of Kachchh or Kutch-Buj in Gujarat state forms separate agroclimatic zone within the Thar Desert of India and it spreads over 62,180 sq km which comes to about 22.34% of the entire Thar. This ecosystem exhibits a spectacular biological diversity because of its evolutionary history, geographical location and ecological uniqueness of the Thar Desert. Unfortunately, this region of Indian desert remains significantly unexplored for biodiversity, especially eastern Kachchh. Because of the unique ecological conditions and habitats some of the species are endemic to this region. The analysis of the literature reveals that there are about 700 species of flowering plants of which 345 species are indigenous to Kachchh. The Kachchh 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

mangrove forest. Fauna of this ecosystem is virtually underexplored. Several groups of marine invertebrates, *viz.* Coelentrates (36 spp of corals), 11 species of echiurans, 72 species of molluscsa, 42 species of bryozoans have been reported from this area. In the hot desert of Thar only a few species of the major phyla like Protozoa, Cnidaria, Platyhelminthes, Nematoda have been reported till date. The members of the phylum Arthropoda constitute the largest and one of the most economically important groups of animals. They are represented by 23 species of Isopoda, 6 species of Diptera, 10 species of Coleoptera, 20 species of Lepidoptera, 6 species of Odonata, 9 species of Metasigmata (Acari) and a few others. The information on the distribution of scorpions, pseudoscorpions, ticks and spiders is almost nil from this ecosystem. The vertebrate fauna of Thar Desert except the fishes has drawn considerable attention of the zoologists. In all, about 317 species of vertebrates are known from the Great Kachchh region. This includes 20 species of fishes, 6 species of amphibians, 35 species of reptiles, 220 species of birds and 36 species of mammals.

BIODIVERSITY

India is very rich in terms of biological diversity due to its unique bio-geographic location, diversified climatic conditions and enormous eco-diversity and geo-diversity. India embraces three major biological realms, *viz.* Indo-Malayan, Eurasian and Afro-tropical and is adorned with 10 bio-geographic zones and 26 biotic provinces.

PLANT DIVERSITY

About 850 species of bacteria, 14,500 species of fungi 6,500 species of algae and 17,500 species of flowering plants are reported from India till today (Botanical Survey of India web site) (Table 1). At national level the information on flowering plants is being documented in the form of Fascicles of the Flora of India and the Flora of India. So far, 24 Fascicles have been brought out by the Botanical Survey of India. Till date eight volumes covering general aspects of Flora of India, such as physiography, geology, climate, botanical history, phyto-geographical divisions, endemism, centers of diversity and phyto-geographical affinities, exotics; ethno-botanical, medicinal and plants of other economic value, plant based industries, wild relatives of cultivated plants, endangered plants, habitats and their conservation, protected area network, botanic gardens and the statistical analysis of the flora have been published by the Botanical Survey of India.

FAUNAL DIVERSITY

Based on data collected from the experts of different animal groups, a total number of species belonging to the Kingdom Protista (Protozoa) and Animalia reported from India is 89,451 of which insects alone include 59,353 species. Many lower groups of animals that occur in India have not received adequate attention, while others like Nemertinea, Nematomorpha, Priapulida, Pogonophora and Pentastomida are not known at all in India.

Table 1. The number of plant species belonging to major group expected to occur in India/ World.

Group	No. of Species Described		No. species Guess Estimates	
	India	World	India	World
Bacteria	850	8050	85000	400000
Fungi	14500	70000	328570	1000000
Algae	6500	40000	12500	200000
Seed Plants	17500	250000	20247	300000

It reveals that amongst invertebrates, parasitic forms (eg. Mesozoa, Acanthocephala and Platyhelminthes), some Meiofauna (Kinorhyncha, Gastrotricha) and Soil Fauna (Annelida) exhibit a very high degree of endemism at species level. Overall 34.90% of insect species are endemic to the Indian region, whereas more than 40% of Indian leech, freshwater sponges and molluscs also show endemism. Among vertebrates, highest degree of endemism at species level is seen in Amphibia, followed by Reptilia, Aves, Mammalia and Pisces.

Invertebrate Fauna (other than arthropods)

Protista (Protozoa) is represented by 1330 parasitic species (52%) and 1247 free-living (48%) totaling 2577 species in India as against 32% parasitic and 68% free living species in the world. It may be mentioned that the parasitic species are well studied because many of them are associated with certain dreaded diseases of man and animals. However, it is estimated that the number of species in Protozoa so far known is only one-fourth of the species expected to occur in India.

The Mesozoa, known in India by 10 species as against 71 species in the world (approx. 14%) remains as a subject of further research.

Porifera is represented by 486 species of which 455 are marine and 31 freshwater accounting for over 10% of the species known in the world. It may be mentioned that the marine fauna known in India shows a close relationship with those in the Australian region, the Pacific Ocean and the Red Sea.

While there are 842 species of the Cnidaria known in India as against 9916 species in the world (8.49%), the Ctenophores register only 12 in number.

The Platyhelminthes or flat worms are mostly parasitic and constitute only 9.27% of the world-fauna. The free-living Turbellarians with only 47 species (approx. 1% of the world fauna) have received very little attention. Of the trematodes, most of the Monogenea numbering 295 are known from freshwater

fishes, but there is a big lacuna with regard to marine-fishes. The other groups like Trematoda and Cestoda with 750 and 530 species respectively are required to be explored with the multiplicity of hosts available in our country.

Among the plankton, rotifers constitute a dominant phylum with 330 species, a little over 13% of the world fauna. A critical analysis of the Indian freshwater rotifers indicates that various planktonic and semi-planktonic taxa are fairly known from this country but periphytic, benthic, colonial, sessile and bdelloid rotifers are still to be much studied. Of the marine meiofauna, 110 species represent Gastrotricha and Kinorhyncha respectively, accounting for 3.33% and 10% of the species known in the World. It is interesting to note that there is high degree of endemism in these groups. The groups like Sipuncula and Echiura with 35 and 43 species in India account respectively for about 24% and 34% of the world-fauna. All these groups exhibit very high biological diversity in Andaman & Nicobar Islands.

Nematodes constitute about 90% of all metazoa in the world and occur in every possible type of habitat, free-living or predaceous or parasitic in plants and animals. Animal parasitic nematodes numbering 1,000 and plant, soil and other nematodes recording 1850 species account for 9.5% of the world fauna. Our knowledge on the nematode parasites in vertebrate animals is satisfactory, but plant, soil and aquatic (both freshwater and marine) nematodes are poorly known.

Acanthocephala, is known to occur in India, form nearly 29% of the world fauna. Among other minor phyla, Phoronida and Brachiopoda, represented by 3 species each, are the least known groups in India. However, Bryozoa with 200 species is known better than the Entoprocta (10 species) or even the Chaetognatha (30 species) and the Tardigrada (30 species).

Annelida in India constitute about 6% of the world-fauna and though polychaetes are comparatively well known, knowledge of brackish water groups is far from satisfactory.

Molluscs are of great diversity with 5070 species and account for about 8% of the world fauna. Our knowledge on the marine molluscs as compared to the land and freshwater ones is far from satisfactory. It is interesting to note that both the land and freshwater molluscs have a number of endemic genera and species. Echinodermata, represented in India by 765 species (nearly 12.5% of the world fauna), is well studied except for the deep-water forms of the Indian region.

Although the Onychophora as a group is extremely rare, it is known by a single species discovered at the foot of the eastern Himalayas in North-east India.

ARTHROPODA

The phylum Arthropoda is remarkable in having the largest number of classes, orders, families, genera and species in India. Crustacea is one of the major classes of the phylum with 2934 species being over 8% of those in the world. Arachnida, another major class is known by 5818 species, which is also nearly 8% of the world fauna. Chilopoda and Diplopoda with 100 and 162 species are only over 3% and 2% respectively of the fauna in the world. The other groups under the Arthropoda except the Insecta are poorly known. The Xiphosura is of special

interest with 2 species in India. All these groups need special attention because much remains to be known about them.

Insects

Insects so far known in India are grouped in 27 orders, of which 4 are apterygotes and the remaining 23 are pterygotes.

Apterygota

Among apterygotes in India, Collembola is known better than the other 3 groups. It is represented by 210 species (above 4.0% of the world fauna) under 86 genera as against 451 genera in the world. The other 3 groups, viz., Thysanura, Diplura and Protura are known by 31 species (nearly 2.5%) under 16 genera, 16 species (4.5%) under 7 genera and 20 species (nearly 7.7%) under 8 genera respectively. It may be mentioned that the endemism is quite remarkable in the groups with 22 genera and 45 species in the Collembola, 12 genera and 23 species in the Thysanura, 3 genera and 12 species in the Diplura, and 4 genera and 16 species in the Protura are found only in India. Indeed, our knowledge on the Indian apterygote groups is poor and therefore, much more attention requires to be paid in order to reveal the tremendous biodiversity among them.

Table 2. The number of species of major group of plants and micro organism described and estimated form India and world

Plant Groups	No. of species described		Ratio of Indian sp./ World sp.	Estimated number World
	India	World		
Virus Bacteria	850	8,050	10.6	9,00,000
Algae	6,500	40,000	16.3	3,50,000
Fungi	14,500	72,000	20.1	10,00,000
Lichens	2,021	13,500	15.0	20,000
Liverworts	845	7,500	11.3	9,000
Mosses	1,980	7,000	28.3	9,000
Pteridophytes	1,200	10,000	12.0	12,000
Gymnosperms	48	650	7.4	650
Angiosperms	17,500	2,50,000	7.0	3,00,000

Pterygota

Of the pterygotes, Coleoptera is the largest of all the Orders and is known by 15,500 species (nearly 4.5% of the world fauna), followed by Lepidoptera with 15,000 species (over 10.5%), Hymenoptera with 10,000 species (over 8%), Hemiptera with 6,500 species (over 8%) and Diptera with 6,093 species (over 6.0%). As regards the endemic species of these groups in India, it is estimated that Hymenoptera contains 9,000 species and 516 genera in 65 families, Coleoptera with 3,100 species and 923 genera in 104 families, Hemiptera has 2,421 species and 579 genera in 77 families, Diptera with 2,135 species and 107 genera in 87 families and Lepidoptera nearly 1,500 species and 100 genera in 84 families.

Besides the above major groups, Orthoptera is ranked next with over 1750 species that account for over 10.0% of the fauna in the world. There are 77 endemic genera and over 200 species in this order.

So far in India, two orders, *viz.*, Trichoptera and Thysanoptera that register 812 species under 112 genera and 693 species under 249 genera respectively. Trichoptera has 650 endemic species while Thysanoptera possess 520 species.

The diversity of the following 5 orders is extremely interesting, *viz.*, Odonata with 499 species under, 139 genera, Phthiraptera with 400 species under 85 genera, Neuroptera with 335 species under 125 genera, Dermaptera with 320 species under 74 genera and Isoptera with 253 species under 54 genera. Endemicity in these groups are high, Odonata with 115 species, Phthiraptera with 16 species, Neuroptera with 262 species, Dermaptera with 117 species and Isoptera with 170 species.

Five groups of insects that register less than 200 species are *viz.*, Blattaria represented by 186 (nearly 4.0% of the world fauna), Mantodea with 162 species (a little over 7.0%), Phasmida with 146 species (nearly 6.5%), Plecoptera with 113 species (nearly 5.5%) and Ephemeroptera with 106 species (nearly 5.0%), that includes 60, 86, 70, 66 and 72 species respectively as endemic to India.

The fauna of the last five remaining orders, *i.e.*, Psocoptera, Siphonaptera, Embioptera, Mecoptera and Strepsiptera are insignificantly known with 90 species (over 3.0%), 52 species (over 2.5%), 33 species (16.5%), 15 species (over 4.0%) and 18 species (over 3.0%) respectively.

Vertebrate Fauna

Protochordates includes two subphyla *viz.*, Cephalochordata and Tunicata exclusively distributed in marine environment, the total number of species from the Indian marine water is 119, thus a share of 5.65 percent of the estimated taxa of the world.

Pisces

Fishes comprise about the half the number of vertebrate species described so far from the world. The world's fish diversity is estimated to be 21,723 extent species under 4,044 genera, 445 families and 50 orders. The Indian fish diversity represents 11.72% of the world, comprising of 2546 species under 969 genera, 254 families and 40 orders. The class Chondrichthyes comprises 131 species under 67 genera, 28 families and 10 orders, while the class Osteichthyes is represented by 2415 species belonging to 902 genera, 226 families and 30 orders.

Amphibia

The Indian amphibia comprises of 211 species under 38 genera, 9 families and 3 orders. The amphibian species are not evenly distributed throughout India, the highest concentration is found in Western Peninsula followed by Northeast. Interestingly all the three living orders of Amphibia *viz.* Gymnophiona, Caudata and Anura are distributed in North-east India, the Western Peninsula has Gymnophiona and Anura while the rest of the country harbours only Anura.

Reptilia

Reptiles were the dominant group of vertebrates during the mesozoic period, the end of Triassic established most of the orders of

reptiles and some became extinct at that time. Of the 19 orders of reptiles, only 4 survive today (Crocodilia, Testudines, Squamata and Rhynchocephalia). Reptilian fauna has great affinity to the Oriental Region as well as a close relationship to the Indo-Chinese and Indo-Malayan Region.

Aves

Birds evolved about 150 million years ago, occupied all ecological niches and are distributed in all habitats. The sub-continent avifauna includes Palearctic, Oriental, Ethiopian, and Australasian zoogeographic elements, and has about 176 endemic forms and 350 species and subspecies which winter in the Indian territory, while a few migrate from India. 9026 species under 1800 genera, 182 families and 30 orders of birds are recorded till date in the world. About 437 are designated as threatened for their survival. The Indian subcontinent has 1232 species, 2123 species and subspecies under 78 families and 20 orders representing 13.66% of the world diversity. About 47 species have been designated as threatened, 3 are suspected to be extinct.

Mammalia

The mammalian fauna of the world is represented by 4629 species belonging to 1135

genera, 136 families and 26 orders (Wilson and Reeder, 1993). Of these, 390 species belonging to 180 genera, 42 families and 13 orders are found in the Indian Union. Another 13 orders do not occur in our country. The egg-laying mammals belonging to the order Monotremata are found only in Australia, Tasmania and New Guinea; 7 orders of Marsupials in Australia, Indonesia and South America, orders Hyracoidea, Tilidentata and Macroelidea in Africa; order Xenarthra in South America; and order Dermoptera in Java, Sumatra and the Philippines.

THREATS TO BIODIVERSITY

Biological resources have traditionally been a major source of food for local inhabitants and of major economic value in terms of commercial exploitation. The human exploitation of biological resources has increased dramatically in the last few decades for reasons, both commerce and subsistence living. Ecosystems and biological diversity of India have been exploited since long time but it is only in the last century that the rate of exploitation has increased dramatically, due mostly to the increase in the human population. Except for some of the Andaman-Nicobar Islands, no pristine area exists today. At the end of the last century or in the beginning of this century, very

Table 3. The dominant plant families of India and there proportion to the global diversity

Family	Number of Genera		% of India to The World	Number of species		Percentage of Indian species
	India	World		India	World	
Poaceae	260	500	52.0	1200	8000	15.0
Fabacea	191	590	32.4	1152	14200	8.1
Orchidaceae	166	800-1000	20.7-16.6	1141	25-35000	4.6-3.3
Asteraceae	167	1100	15.2	950	20000	4.75
Rubiaceae	115	450	25.6	659	6500	10.14
Cyperaceae	38	70	54.3	545	4000	13.6
Euphorbiaceae	84	300	28.0	528	7500	7.0
Acanthaceae	92	250	36.8	510	2500	20.4
Roseceae	40	100	40.0	492	3000	16.4
Lamiaceae	72	200	36.0	454	3200	14.2

few areas of India remained unaffected, whereas most were partially deteriorated and a few were severely affected.

Natural threats

The major stresses on terrestrial ecosystems removal of top soil by flash flood and destruction by earth quake, and the marine ecosystems by storm and waves, particularly cyclones. Cyclonic disturbances develop during

October-November along the coast. These cyclones have sustained winds with speed ranging from 65 to 120 km per hour. High-speed winds cause extreme wave action that kills many fauna and flora, also breaks coral into rubbles and sometimes-large amounts of sand and other materials may be dumped onto the coral reef. Also freshwater runoff kills many fauna and flora in semi-enclosed bays and lagoons by lowering salinity and depositing large amounts of sediments and nutrients.

Estimated number of described species

Taxonomic group	No. of species		Percentage of Indian species
	World	India	
PROTISTA (Protozoa)	31250	2577	8.24
ANIMALIA			
Mesozoa	71	10	14.08
Porifera	4562	486	10.65
Cnideria	9916	842	8.49
Ctenophora	100	12	12.00
Platythelminthes	17500	1622	9.22
Nemertinea	600	—	—
Rotifera	2500	330	13.20
Gastrotricha	3000	100	3.33
Kinorhyncha	100	10	10.00
Nematoda	30000	2850	9.50
Acanthocephala	800	229	28.62
Sipuncula	146	35	24.14
Mollusca	66535	5070	7.62
Echiura	127	43	33.86
Annelida	12700	840	6.61
Onychophora	100	1	1.00
Arthropoda	987949	68389	6.90
Crustacea	35534	2934	8.26
Insecta	867391	59353	6.83
Arachnida	73440	5818	7.90
Pycnogonida	600	16	2.67
Chilopoda	3000	100	3.33
Diplopoda	7500	162	2.16
Symphyla	120	4	3.33
Merostomata	4	2	50.00

Taxonomic group	No. of species		Percentage of Indian species
	World	India	
Phoronida	11	3	27.27
Bryozoa (Ectoprocta)	4000	200	5.00
Entoprocta	60	10	16.66
Brachiopoda	300	3	1.00
Chaetognatha	111	30	27.02
Tardigrada	514	30	5.83
Echinodermata	6223	765	12.29
Hemichordata	120	12	10.00
Chordata	48451	4962	10.22
Protochordata	2106	119	5.65
Pisces	21723	2546	11.72
Amphibia	550	219	4.20
Reptilia	5817	456	7.84
Aves	9026	1232	13.66
Mammalia	4629	390	8.42
Total (Animalia)	1196903	86874	7.25
Grand Total (Protista + Animalia)	1228153	89461	7.28

Human impacts

Varied human activities, which are, a cause for concern over and above the natural disturbances, include habitat destruction due to development, industrialization, pollution, eutrophication due to bad agricultural practices, runoff and sedimentation from development activities (projects), eutrophication from sewage and agriculture, physical impact of maritime activities, dredging, collecting, and destructive fishing practices, pollution from industrial sources and oil refineries and the synergistic impacts of anthropogenic disturbance. A general rule for coastal zone is: whatever is used on land today ends up in the aquifer or coastal zone tomorrow. The amount of sediments and chemicals the runoff water carries to the sea has profound effects on fertilization of eggs of marine species. Likewise, the quality of runoff water can affect the metamorphosis of the larvae of many species. Oil pollution induces mortality, decrease

fecundity and fail recruitment. India has three mega cities, many small, medium and major ports and industries around the 8000 km coast. The enactment of Water Pollution Act in 1974 and Environment Protection Act, 1986 have helped in regulating the disposal of wastes from the industries. These measures have resulted in reduction of pollution loads of the coastal waters to certain extent. Major industries like fertilizer, petro and agrochemical and chemicals are mainly located along the coasts. Besides industrial and municipal wastes, port related operations such as continuous movement of marine vessels in the major ports including oil transport as also the wastes of aquaculture and agriculture farms are increasingly posing threats to the coastal water quality and to the biodiversity.

Fishing is a major activity in the coastal regions of India and at present in the 3651 fishing villages situated along the 8129 km coastline of India, about one million are

occupied full time in marine capture fisheries. The value of the annual marine fish production of 4.6 million tones during the year 2002-2003 and the value of marine products export was Rs 6,881.31 crores (US \$ 152.92 m). This is mainly due to the introduction of bottom trawlers, which was introduced in the Indian water in the early 1960s. Several types of net fishing have also been responsible for over-exploitation of marine resource. 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, continue to capture fish, which eventually starve. Fishing operations with latest technologies are causing

damage to the marine living resources. Along with increase in the targeted catch, a number of untargeted fish and other biota are removed from their habitat and discarded as waste. Shrimp trawlers probably have the highest rate of by catch bringing in up to 90% more of "trash fish" Random capture techniques destroy immature fish and other non-targeted marine species. Gill nets used to catch fish bring in a host of other animals such as dolphins, turtles etc. 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, awareness appears to be more successful than legislation in controlling these practices.

LITERATURE CITED

- ALFRED, J.R.B., DAS, A.K. and SANYAL, A.K. 1998. Faunal Diversity in India. (Published-ENVIS Centre, Zoological Survey of India, Kolkata), 1-495.
- ALFRED, J.R.B., DAS, A.K. and SANYAL, A.K. 2002. Ecosystems of India. (Published-ENVIS Centre, Zoological Survey of India, Kolkata), 410 pp.
- ANON. 1999. National policy and Macrolevel action strategy on Biodiversity, Government of India, Ministry of Environment and Forests, New Delhi, 1-74.
- ANON. 2003. Biodiversity. C.P.R. Environmental Education Centre, Chennai, 1-91.
- VENKATARAMAN, K. 2003. Natural Aquatic Ecosystems of India, National Biodiversity Strategy Action Plan, Thematic Biodiversity Strategy and Action Plan. (Published: Zoological Survey of India), 1-272
- VENKATARAMAN, K., CH. SATYANARAYANA, ALFRED, J.R.B. and J. WOLSTENHOLME. 2003. Handbook on Hard Corals of India. (Published : Director Zool. Surv. India, Kolkata), 1-266.
- VENKATARAMAN, K., JEYABASKARAN, R., RAGHURAM, K. P. and ALFRED, J.R.B. 2004. Bibliography and checklists of coral and coral reef associated organisms of India. *Rec. Zool. Surv. India, Occ. Paper No., 226* (Published by the Director Zool. Surv. India, Kolkata), 1-468.

BIODIVERSITY CONSERVATION : ISSUES AND CONCERN

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ABSTRACT

The conservation of biological diversity has become an international issue since adaptation of "Convention on Biological Diversity" in 1992. India as a signatory to the convention has completed the current status survey, an action plan for future and enacted a law to conserve and utilize biodiversity in a sustainable manner. The paper discusses the current issues of access and benefit sharing and management of biodiversity at the local level on a participatory mode as also the declining human resources necessary to document biodiversity. Major concerns for future strategic implementation have been focused at the end.

Keywords : Conservation, Biodiversity

INTRODUCTION

'Biological Diversity' has become a global concern since 1992. The United Nation's conference on Environment and Development (UNCED), held at Rio de Janeiro in 1992 after prolonged deliberations agreed on two major conventions—(a) "Convention on Biological Diversity" (CBD) and (b) "Framework convention on Climate Change" (FCC). (UN 1992).

CBD for the first time acknowledged sovereign rights of each country over its territorial biological resources (save and except less than one percent protected under Indian Wildlife Protection Act 1972 as in India or other countries).

CBD placed a roadmap for future conservation of biodiversity and its sustainable use. It proclaimed for the first time a concept of "Prior informed consent" on "Mutually agreeable terms" to access and transfer biological resources between providers and users. It also supported a mechanism of "benefit sharing" between providers and users of biological resources or for uses of traditional knowledge.

INDIAN PROFILE

India with 329 million hectare of land offers an enormous range of diversity at ecosystem, species and genetic level; while the extent of diversity has been fairly well documented at first two levels, the understanding of extent of genetic diversity is yet to emerge.

It is well established that India is one the few developing countries who have gained from old institutional back up system. The Botanical Survey of India (estd 1890) and the Zoological Survey of India (estd. 1916) during colonial period established the bases for floral and faunal explorations in the wild. The setting up of National Bureau of Plant Genetic Resources (NBPGR), Animal Genetic Resources (NBAGR) and Fish Genetic Resources (NBFGR) and more recently Microbial Genetic Resources (NBMGR) offered a strong foundation to domesticated biodiversity at agriculture, animal husbandry and fishery.

The survey consortium was also extended to "Forest Survey of India" and "Fishery survey of India". Historically while such institutional build up was continued, the chain of Indian Universities both general and agricultural

science ensure support by way of human resource development. CSIR and ICAR established ecosystem based research institutes e.g. National Institute of Oceanography, National Botanical Research Institute of CSIR and Central Grass and Fodder Research Institute etc. and series of fishery institute (for cold water, fresh water etc.) under ICAR further lent support to the understanding of biological resources of India, its diversity and dependency of vast rural community on such resource base.

All these happened before 1992. What was lacking is an assessment of our knowledge of Indian biological diversity vis-a-vis its position in the global scenario.

Status of Biodiversity in many parts of the World still remains largely unknown. Based on the available figures some countries have been designated as countries of Mega diversity, (MoEF, 2006) India being one of them. With only 2.4% global space, India has so far documented nearly 8% of global biodiversity. Scientists estimate that only 5% of the global diversity has so far been documented, the vast grey area remains with reference to the knowledge on invertebrates and micro-organisms. As such India's biodiversity status is to apt to rise in scale with more explorations.

The conservation measures so far adopted largely centered around specific ecosystem and biomes. A total of nearly 600 protected areas, in the form of Biosphere Reserves (14), Wildlife sanctuaries (500), National Parks (92), Tiger Reserves (24), Elephant Reserves (30), Mangroves (38), Coral reefs (4) and Wetlands of National Importance constitute this PA system. Much criticism however has been made on the management of species oriented reserves like Tiger reserves in India.

Besides national level designations, wetlands of institutional importance find place in the "Ramsar sites" The numbers of Ramsar sites have been increased from 6 to 22 in recent years. India's commitment in the past has been evidenced in the signing of Convention of International Trade in endangered species of flora and fauna (CITES). (Ghosh, 2007)

CURRENT SCENARIO

The enactment of Biological Diversity Act in 2002 and Rules in 2004 has put India in a select list of countries (GOI, 2005). The act envisaged a three tier decentralized system : a National Biodiversity Authority (NBA) as the apex body, a State Biodiversity Board (SBB) at each State and a Biodiversity Management Committee (BMC) at the local level have now been accepted under the act and rules. Each BMC is supposed to look after local biological resource, document local biological diversity- both wild & domesticated and their current uses as also record the wealth of traditional knowledge. But how such a document will be made? It is envisaged that a Peoples Biodiversity Register (PBR) will be prepared at the local level to empower the BMC for effective management of local resource. The PBR has to make with participation of the local language. A total of 17 states have so far formed SBB but the number of BMC's so far constituted remain unknown. Prescribed format for access and transfer have been made to enable the foreign user to apply to NBA but exact mode of benefit sharing is yet to emerge.

ISSUES

Major Issues that can be flagged of now are :

- ☐ Whether PBR will make the community vulnerable to bio piracy?
- ☐ To exact mode of benefit sharing – who decides?
- ☐ The vast agro bio diversity is based on wild relatives and farmers varieties (not breeders varieties)–How farmers rights are to be ensured?
- ☐ A dangerous trend of decline in the number of professional taxonomist will make documentation questionable or impossible- How to overcome such problem?
- ☐ How to protect illegal transfer from seaports and airports unless a trained and vigilant group of customs and immigration officials are put to work?

- ❑ What may be the impact of global warming and climate change on the Indian biodiversity.

Each of these issues can be elaborated. One group of professionals and activists feel that PBR should only be made with consent of the local community and should never be linked with a national network to prevent biopiracy. In case of secret traditional knowledge only codified information with the consent of the community should find place in the PBR.

The mode of benefit sharing continues to be a major issue. The situation becomes more complicated if the same traditional knowledge exists in two unrelated communities. How to decide the quantum of share?

The Government while ensuring Farmers Right earlier has drafted a new "Seed Bill" seriously challenging the concept by way of prescribing compulsory registration of all seeds and importing a threat to penalise for use of so called unregistered seeds. Will this be a disincentive to save farmers varieties? How millions of farmers can go through the process of registration?

The major Survey Departments have all time lowest number of experts. Why taxonomy has never been made a thrust area for study and research? In absence of trained taxonomists can parataxonomists be trained? India has a large pool of superannuated taxonomists can they be professionally utilised to help in the process of preparing PBR?

India still lacks a strict system of vigilance to ward off biopiracy. How effectively the current employed officials or future recruits be trained to prevent biopiracy through sea ports and air ports?

There is hardly any research currently being done in India on the impact of changing climate on biological diversity. There is no data on possible change in timing of flowering of plants or change in the pattern of animal migration or change in plankton diversity and bio mass in Indian coastal and marine system: All these are deemed vital to understand the process of unholy alliance between climate change and bio-diversity.

The issues raised above are only illustrative and are not exhaustive but demand serious attention.

CONCERNS

Obviously all the issues raised are matter of serious concern for any conservation biologist. The rich biodiversity of India with an impressive percentage of endemism is facing a crisis of existence specially the elements which have never been documented.

The issue of conservation and sustainable use of biodiversity should not be isolated from the basics of documentation. Unexplored and ill explored regions are likely to yield many new or hitherto unrecorded taxa. Vast array of microbial diversity in the soil from different agroclimate zone remains very poorly known. With land use and land cover changes (identified as the major threat to biological diversity) much of the biological diversity may be lost before being documented.

In such a scenerio, the system of governance has great responsibility. On one side impact of development projects on biodiversity need to be more focussed in E.I.A. exercises and on the other human resource development to document country's vast bio resource seems to be the call of the day. Taxonomy need to be a thrust area having direct linkage with biodiversity survey and documentation. All major funding agencies viz CSIR, ICAR, ICMR, DST, UGC and MoEF need to appreciate the role of taxonomic research and training while Government of India remains primarily responsible for effective action, the role of Civil Society should never be undermined. As such a vigilant network of CBOs and NGOs can sensitize the local community and help them document local bio resources. NBA and SBB need to identify such bodies and effectively co-relate their activities through funding support.

All Panchayat Samities and Gram Sabhas also need to be trained on the need of formation of BMC and preparation of PBR on a time bound programme. Urban Local Bodies (ULBs) have equal responsibility to form BMC and document urban biodiversity.

LITERATURE CITED

- GOI, 2005. *Biological Diversity Act, 2002 and Rules, 2004* National Biodiversity Authority, Chennai.
- GHOSH, A. 2007. *Biodiversity Conservation*. APH Publishing Corporation, New Delhi.
- MoEF. 2006. *Perspective on Biodiversity : A Vision for Megadiverse Countries*. (Desh Deepak Verma, Sujata Arora, R.K. Rai eds.) Ministry of Environment & Forests, New Delhi.
- UNITED NATIONS, 1992. *Convention on Biological Diversity*, New York.

**TAXONOMY, BIODIVERSITY
AND
WILDLIFE MANAGEMENT**

MOLLUSCAN MACROBENTHIC DIVERSITY OF BRACKISHWATER WETLANDS IN WEST BENGAL

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ABSTRACT

A total of 35 species under 19 families, comprising of 26 species of gastropods and 9 species of bivalves have been recorded. *Cerithidea (Cerithiopsis) cingulata* was recorded as the most dominant species in all the stations surveyed whereas *Cerithidea (Cerithidea) alata* was dominant only in the lower littoral zone of the Matla riverbed. Quantitative studies have revealed the highest population density of macrozoobenthic molluscs at manmade Viswabank bheri, Canning (2014.81 ind/m²) in postmonsoon season and at natural Matla char (507.41 ind/m²) in monsoon season. The highest estimated biomass of 447.16gm/m² in premonsoon season was observed at Nikarighata bheri, Canning, while the lowest in the Matla riverbed (124.71 gm/m²). In general, molluscan diversity was observed highest in Sagar Island (28 species) over others. F-indexing analysis has revealed that 10 species of gastropods [*Assiminea beddomeana*, *A. brevicula*, *Neritina (Dostia) violacea*, *Stenothyra deltae*, *Gangetia miliacea*, *Cerithidea (Cerithiopsis) cingulata*, *Cerithidea (Cerithidea) alata*, *Telescopium (T.) telescopium*, *Auricula* sp. and *Pythia plicata*] and 2 species of bivalve (*Pelecypora trigona* and *Meretrix meretrix*) can be distinguished as constant species, 8 species of gastropods [*Nerita (Amphinerita) articulata*, *Stenothyra blanfordiana*, *Littoraria (Littorinopsis) melanostoma*, *Stenothyra blanfordiana*, *Thiara (Mainwaringia) paludomoides*, *Cerithidea (Cerithidea) obtusa*, *Nassarius stolatus* and *Thais blanfordi*] and 5 species of bivalves (*Anadara granosa*, *Strigilla splendida*, *Macoma birmanica*, *Theora opalina* and *Donax incarnatus*) as almost common and remaining 8 species of gastropods and 2 species of bivalve were almost rare at these sites under investigation.

Key words : Brackishwater wetlands, molluscan macrobenthos, diversity, frequency of occurrence, seasonal abundance, biomass, cluster analysis

INTRODUCTION

Brackishwater ecosystems are highly specialized transitional environment between saltwater and freshwater systems. It has attained greater importance for the aquatic species of mixohaline environment and also for the marine species that penetrate these habitats. The mixing of saline and freshwater plays an important role in the distribution and abundance of fauna inhabiting in this ecosystem. The substratum types and different grades of salinity in the bheri system, creeks and mangroves existing in this brackishwater

ecosystem offer diverse niches along with diversity of macrozoobenthic invertebrates. Among the macrozoobenthic community molluscan elements mostly dominate this ecosystem, both in diversity and density. Even then, the molluscan community studies from brackishwater ecosystems of West Bengal are not so well documented (Stoliczka, 1869; Chaudhury *et al.*, 1980; Subba Rao *et al.*, 1983, 1987, 1995; Mandal and Misra, 1985; Misra and Barua, 1987; Patra *et al.*, 1990; Nandi and Das, 2003; Paul and Nandi, 2003; Dey *et al.*, 2005). Since the knowledge about molluscan

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community composition, distribution and abundance in this ecosystem especially from manmade bheries is inadequate, the present work is undertaken to understand the benthic molluscan communities, both qualitatively as well as quantitatively, from six selected areas in and around Hugli-Matla estuarine ecosystem of West Bengal.

MATERIALS AND METHODS

Study Area

The work is based on results obtained from fortnightly surveys in and around Matla estuary, Canning and also from seasonal surveys along Hugli estuary during April, 2004 to March, 2006. During the course of survey six study areas were selected as follows:

Matla char, Canning : This station is located between the latitude of $22^{\circ}17.838'$ north and longitude of $88^{\circ}40.700'$ east in the Matla

riverbed at Canning, close to scattered mangroves. It has a nullah on one side. The littoral region of this station has been demarcated for the purpose of survey work as upper, mid and lower littoral zones from where fortnightly samples were collected.

Viswabank Bheri, Canning : This is an unmanaged brackishwater impoundment used for finfish and shellfish culture, located between the latitude $22^{\circ}18.049'$ to $22^{\circ}17.843'$ north and longitude $88^{\circ}40.606'$ to $88^{\circ}40.627'$ east near river Matla at Canning and fed by salt water from river Matla.

Nikarighata Bheri, Canning : The Nikarighata Bheri is a privately owned fully managed brackishwater system used for finfish and shellfish culture, located between the latitude $22^{\circ}17.691'$ N to longitude $88^{\circ}40.517'$ E near the Matla River. It is also fed by the saltwater from river Matla.

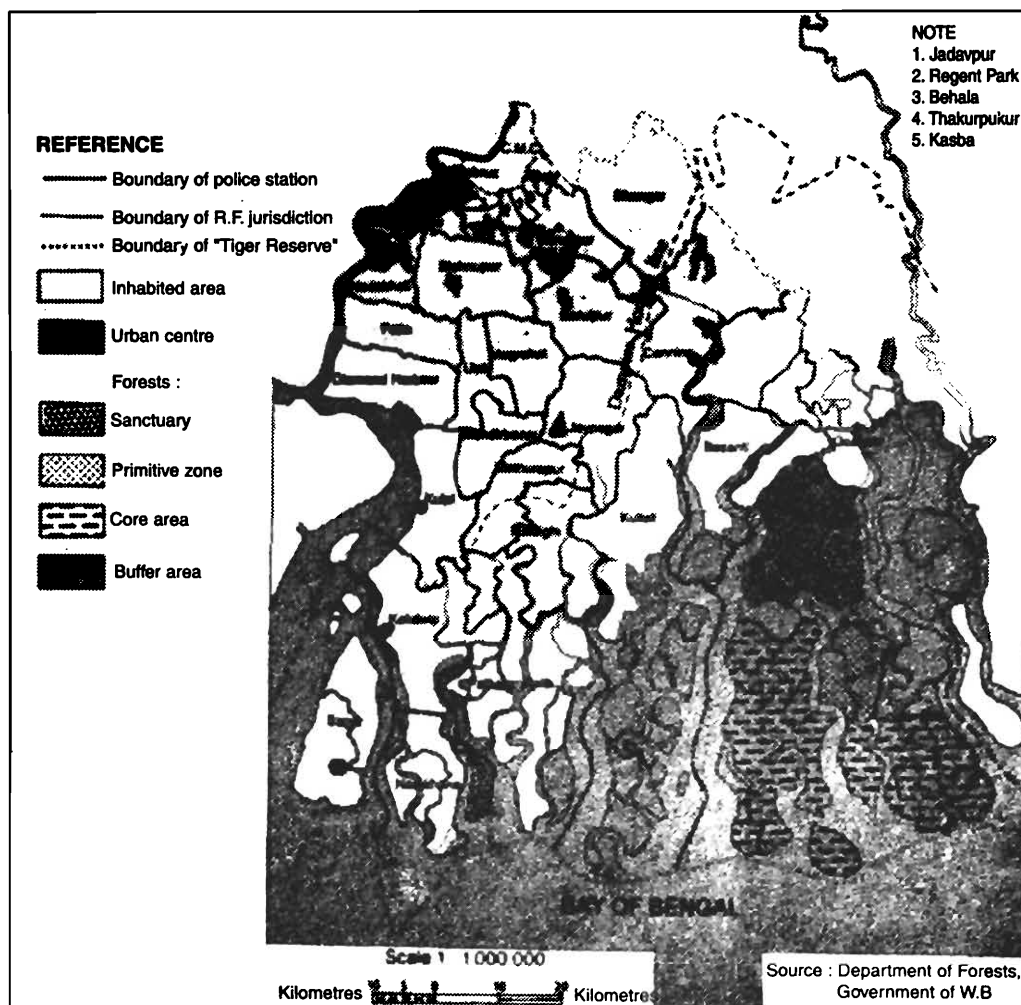


Fig. 1. Map of South 24 Parganas district of West Bengal showing the study stations

Kulpi bheri, Kulpi : This station is about 20 km south from Diamond Harbour, situated along the Hugli River and fed by estuarine water from the river for the purpose of paddy cum fish culture.

Sagar Island creek, Sagar Island : This is located in between the latitude of 21°31' to 21°53' N and 88°02' to 88°15' E longitudes and is dominated with mangrove vegetation. The mud flat of this creek gets inundated and exposed during tide.

Kakdwip mudflat, Kakdwip : This station is situated about 25 km away from the mouth of the Hugli estuary and about 50 km away from Diamond Harbour. The mudflat of this area is mixed with sand, while the bottom substratum at the adjacent jettyghat area is relatively sandy.

STUDY METHODS

Qualitative samplings were done seasonally from all the six wetlands (*viz.*, Matla char, Viswabank Bheri and Nikarighata Bheri, Canning; Kulpi bheri, Kulpi; Sagar Island creek, Sagar Island and Kakdwip mudflat, Kakdwip) along Hugli-Matla estuary, South 24-Parganas district, West Bengal, using sampler, sieve as well as by hand picking at low tide during April 2004–March 2006. Quantitative samplings comprising of six replicates of macrozoobenthic samples were collected fortnightly during low tide using box type sampler with 0.225 m² area (Paul and Nandi, 2003) in each of the sampling stations (*viz.*, Matla char, Viswabank Bheri and Nikarighata Bheri) at Canning throughout these two years. For data analysis, the frequency of occurrence of macrobenthic molluscan species was calculated using F index (Guille, 1970) :

$$F = p_a / P \times 100$$

where p_a = the number of stations where the species occurred and P = the total number of stations.

The macrobenthic molluscan species were classified as : constant species ($F > 50\%$), common ($10\% < F < 49\%$) and rare species ($F < 10\%$) based on the above formula. The density and dry weight biomass of macrozoobenthic

molluscs were estimated and expressed as the mean number of individuals/m² and gm/m² respectively. Biological data were also analyzed following Sorensen index (1948), and cluster analysis (Spellerberg, 1982) was made to show the pattern of similarity among the six study stations.

RESULTS

During the course of survey the ecological features of the six selected stations along the Hugli-Matla estuaries were ascertained and presented in Table 1. Both qualitative and quantitative samplings from these six study stations have revealed the presence of 35 molluscan macrozoobenthic species under 19 families as shown in Table 2. However, a thorough survey of the entire stretch undertaken one-time at Sagar Island revealed the presence of two more species *viz.*, *Onchidium tenerum* (Stoliczka) and *Onchidium tigrina* Stoliczka that occurred in soft mud banks and mudflats of mangrove vegetated lower littoral zone of Sagar Island. The population density of the collected macrobenthic molluscs along with estimated biomass from three selected stations at Canning are determined and presented in Table 3.

Ecological condition

It has been observed that out of the six selected brackishwater wetlands, two bheries (Viswabank Bheri and Nikarighata Bheri), one char (Matla char) and one creek are high saline, while one char (Kakdwip char) and one bheri (Kulpi Bheri) are medium saline.

Diversity of species

The present investigations have revealed that out of a total of 35 species of macrobenthic molluscs under 19 families (Table 2) the highest diversity of species was encountered at Ganga Sagar creek of Sagar Island (28 species, 80%), the lowest diversity of species was observed at Nikarighata bheri, Canning (9 species, 25.7%). The low diversity at Nikarighata bheri might be due to manmade habitat condition and frequent fisheries activity.

Table 1. Ecological characteristics of the wetlands surveyed from South 24 Parganas district of West Bengal

Characteristics	Canning			Kulpi Bheri	Sagar Island creek	Kakdwip char
	Matla char	Viswabank Bheri	Nikarighata Bheri			
Type of wetland	Natural	Man made	Man made	Man made	Natural	Natural
Ecological condition	High saline	High saline	High saline	Medium saline	High saline	Medium saline
General condition	Disturbed	Semi-disturbed	Disturbed	Disturbed	Un-Disturbed	Disturbed
State of utilization	Used for boat activities	Unmanaged fisheries	Managed fisheries activity	Paddy-cum-fish culture	Unutilized mudflat	Used as Jetty ghat
Soil condition	Silty	Silty	Silty	Silty	Muddy	Sandy
Vegetation cover	45%	20%	40%	70%	60%	10%
Vegetation type	Grass and mangrove	Aquatic weeds	Weed and mangrove	Weed and paddy	Grass and mangrove	Grass
Salinity (‰)	4–27.9	3–28.4	4–33.1	0–9.5	18–31.5	5–12.8
Total hardness	Very hard	Very hard	Very hard	Medium hard	Very hard	Very hard
Anthropogenic activity	High (Shell collection)	Low	High	Medium	Negligible	Very high (with oil spillage)
Dafaecation/ Waste disposal	Medium	Medium	Nil	Nil	Less	High

Table 2. Occurrence of macrozoobenthic molluscan species in the selected brackishwater wetlands of West Bengal

Sl. No.	Species	Matla char Bheri	Canning Viswa-bank Bheri	Nikari-ghata Bheri	Kulpi Bheri	Sagar Island creek	Kakdwip char
	GASTROPODA						
	Family NERITIDAE						
1.	<i>Neritina (Dostia) violacea</i> (Gmelin)	+	+	+	+	+	
2.	<i>Neritina (Vittina) smithi</i> Wood			-		+	
3.	<i>Nerita (Amphinerita) articulata</i> Gould					+	+
4.	<i>Theodaxus (Clithon) oualaniensis</i> Lesson			+			
	Family LITTORINIDAE						
5.	<i>Littoraria (Palustrina) melanostoma</i> (Gray)					+	+
6.	<i>Littoraria (Littorinopsis) scabra scabra</i> (Linnaeus)	+				+	+
7.	<i>Littoraria (Littoraria) undulata</i> Gray	+					
	Family STENOXYRIDAE						
8.	<i>Stenothyra deltae</i> (Benson)	+	+	+	+	+	+
9.	<i>Stenothyra blanfordiana</i> Nevill	+	+				+
10.	<i>Gangetia miliacea</i> (Nevill)	+	+	+	+	+	+
	Family ASSIMINEIDAE						
11.	<i>Assiminea beddomeana</i> Nevill	+	+	+	+	+	+

Table 2. Contd.

Sl. No.	Species	Matla char Bheri	Canning Viswa-bank Bheri	Nikari-ghata Bheri	Kulpi Bheri	Sagar Island creek	Kakdwip char
12.	<i>Assiminea brevicula</i> (Pfeiffer)	+	+	+	+	+	+
	Family THIARIDAE						
13.	<i>Thiara (Mainwaringia) paludomoides</i> Nevill	+			+		+
	Family POTAMIDIDAE						
14.	<i>Cerithidea (Cerithidea) obtusa</i> (Lamarck)					+	+
15.	<i>Cerithidea (Cerithideopsis) cingulata</i> (Gmelin)	+	+	+	+	+	+
16.	<i>Cerithidea (Cerithidea) alata</i> (Philippi)	+			+	+	+
17.	<i>Telescopium (T.) telescopium</i> (Linnaeus)	+	+	+	+	+	+
	Family NATICIDAE						
18.	<i>Natica tigrina</i> (Roeding)	+				+	
	Family RANELLIDAE						
19.	<i>Gyrineum natator</i> (Roeding)					+	
	Family MURICIDAE						
20.	<i>Thais blanfordi</i> (Nevill)	+				+	
21.	<i>Thais lacera</i> (Born)					+	
	Family NASSARIIDAE						
22.	<i>Nassarius stolatus</i> (Gmelin)	+				+	+
23.	<i>Nassarius foveolata</i> (Reeve)					+	
	Family SCAPHANDRIDAE						
24.	<i>Tornatina estriata</i> (Preston)		+				
	Family ELLOBIIDAE						
25.	<i>Auricula</i> sp.			+		+	+
26.	<i>Pythia plicata</i> (Ferussac)		+			+	+
	BIVALVIA						
	Family ARCIDAE						
27.	<i>Anadara granosa</i> (Linnaeus)	+				+	
	Family MYTILIDAE						
28.	<i>Modiolus striatulus</i> (Hanley)	+					
	Family TELLINIDAE						
29.	<i>Strigilla splendida</i> (Anton)					+	+
30.	<i>Macoma birmanica</i> (Philippi)	+				+	
	Family SEMELIDAE						
31.	<i>Theora opalina</i> (Hinds)	+				+	+
	Family DONACIDAE						
32.	<i>Donax incarnatus</i> Gmelin	+	+			+	
	Family CORBICULIDAE						
33.	<i>Polymesoda (Geloia) bengalensis</i> (Lamarck)	+					
	Family VENERIDAE						
34.	<i>Meretrix meretrix</i> (Linnaeus)	+	+			+	+
35.	<i>Pelecypora trigona</i> Reeve	+			+	+	+
	Total = 35 species	23	12	9	10	28	20

Note : Two gastropod species viz., *Onchidium tenerum* (Stoliczka) and *Onchidium tigrina* Stoliczka were also observed at Sagar Island creek outside the selected site.

Table 3. Seasonal abundance and biomass of macrozoobenthic mollusca in the wetlands of Canning region, West Bengal

Place	Premonsoon	Monsoon	Postmonsoon
Matla char			
1. Population density (no/m ²)	272.22 (±331.63)	507.47 (±633.43)	340.12 (±582.93)
2. Total biomass (gm/m ²)	185.16 (±260.32)	234.59 (±232.19)	124.71 (±174.99)
Viswabank bheri			
1. Population density (no/m ²)	1914.20 (±1773.13)	1001.85 (±589.47)	2014.81 (±1259.54)
2. Total biomass (gm/m ²)	333.90 (±183.16)	422.36 (±179.20)	241.30 (±107.80)
Nikarighata Bheri			
1. Population density (no/m ²)	1002.47 (±452.20)	812.34 (±304.69)	732.34 (±451.24)
2. Total biomass (gm/m ²)	447.16 (±469.08)	345.99 (±201.25)	256.32 (±138.25)

Frequency of occurrence

According to the frequency of occurrence (F value, Guille, 1970) 10 gastropod molluscan species *Assiminea beddomeana*, *A. brevicula*, *Neritina* (*Dostia*) *violacea*, *Stenothyra deltae*, *Gangetia miliacea*, *Cerithidea* (*Cerithideopsilla*) *cingulata*, *Cerithidea* (*Cerithidea*) *alata*, *Telescopium* (*T.*) *telescopium*, *Auricula* sp. and *Pythia plicata* and two bivalve species *Pelecypora trigona* and *Meretrix meretrix* are classified herein as constant species. Eight species of gastropods, such as, *Nerita* (*Amphinerita*) *articulata*, *Stenothyra blanfordiana*, *Littoraria* (*Littorinopsis*) *melanostoma*, *Littoraria* (*Littorinopsis*) *scabra scabra*, *Thiara* (*Mainwaringia*) *paludomoidea*, *Cerithidea* (*Cerithidea*) *obtusata*, *Nassarius stolatus* and *Thais blanfordi* and five species of bivalves, viz., *Anadara granosa*, *Strigilla splendida*, *Macoma birmanica*, *Theora opalina* and *Donax incarnatus* are identified as more or less common species. The remaining eight gastropods and two bivalves are considered as almost rare species in this region. The occurrence of *Tornatina estriata* (Preston) solely from the unmanaged Viswabank bheri, Canning and that too in the post-monsoon season only presumably related to specific non-vegetated soft silty-clay substratum as well as ecological condition and narrow niche/habitat preference of the species.

Seasonal abundance and biomass

Quantitative studies indicate that among the manmade wetlands the highest population

density of macrozoobenthic molluscs was in Viswabank bheri, Canning (2014.81 ind/ m²) with biomass of 241.30 gm/m² and at the Matla char, Canning (507.41 ind/m²) with biomass 234.59 ind/m² among the natural brackishwater habitats. The highest density in manmade Viswabank bheri may be due to habitat suitability as well as favourable cultural practices in this wetland. The highest estimated biomass of 447.16 gm/m² (1002.47 ind/m²) in premonsoon season was observed at Nikarighata bheri, Canning, while the lowest in the upper littoral zone of Matla riverbed (159.99 ind/m²) in post-monsoon season (Fig. 2). The average seasonal maximum population density of molluscan macrozoobenthos exceeds 1000 ind/m² in the bheries of Canning region whereas the station-wise population density was recorded minimum under natural habitat condition in the Matla char. At the upper littoral zone of Matla riverbed the population density and diversity of molluscan macrozoobenthos species were the lowest (159.99 ind/m² in postmonsoon season, representing five species) and in the lower littoral zone the population density of eight molluscan species was recorded highest (1127 ind/m²) in monsoon season. The variation in population density and biomass is related to size of the species as well as breeding season of the species concerned. The species *Telescopium* (*T.*) *telescopium* was scarce in quantitative samplings from the Matla char but the presence of large sized *Telescopium* (*T.*) *telescopium* was evident at this station. The

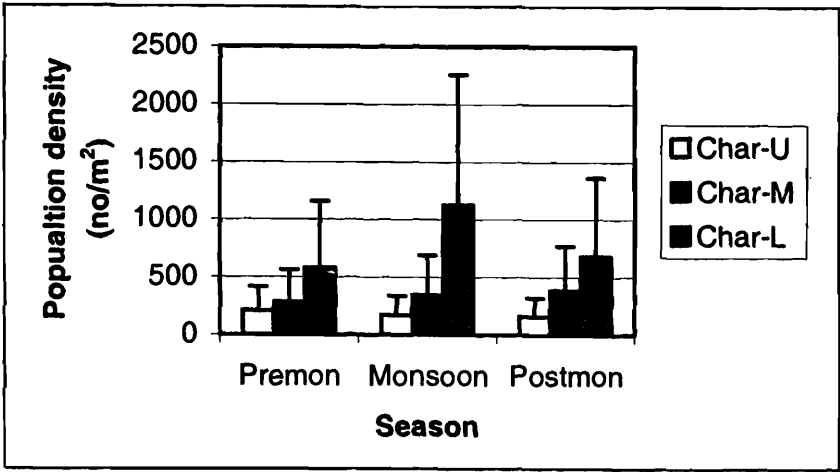


Fig. 2. Population density of macrozoobenthic mollusca in the upper, mid and lower littoral zones of Matla char, Canning

absolute dominance of *Cerithidea* (*Cerithideopsilla*) *cingulata* was observed in the bheries whereas *Cerithidea* (*Cerithideopsilla*) *cingulata* and *Cerithidea* (*Cerithidea*) *alata* were found throughout the year in the littoral zone at Matla char, Canning but *Cerithidea* (*Cerithidea*) *alata* was dominant in the lower littoral zone of Matla river, Canning. The juveniles of the bivalve species at the littoral zone of Matla char, Canning were dominant among the bivalves as reported earlier by Misra and Barua (1987). The highest population density at Matla char was observed in the monsoon season might be due to the highest density in the lower littoral zone. The Viswabank bheri showed most dense population in post monsoon season and in Nikarighata bheri in pre monsoon season may be associated with the intensity of piscicultural activities.

Cluster Analysis

Similarity indices have been used as a basis

for cluster analysis, showing affinities between samples and thus providing a baseline for monitoring programmes. Cluster (Dendrogram) analysis of the selected stations (Fig.3) showed two prominent clusters (A and B) and three intermediate clusters (C, D and E). Cluster 'A' denotes the highest cluster between Nikarighata bheri at Canning and Kulpi bheri at Kulpi from amongst the selected wetlands. Both these sites are manmade and used for fish culture activities. Similarly cluster 'B' is formed between Sagar Island creek and Kakdwip char showing the maximum similarity from amongst the natural wetlands in so far as the habitat, soil and substratum conditions are concerned. Cluster 'C' shows the similarity between cluster 'A' and Viswabank bheri, Canning, which is less managed in respect to fish culture. Cluster 'D' denotes the affinities between Cluster 'B' and Matla char, Canning, which is even though less disturbed exhibits habitat differences. The intermediate cluster 'E' shows least similarity.

	V	N	Ku	S	K
M	0.3055	0.25	0.26	0.3333	0.3256
V		0.3636	0.3333	0.2439	0.2727
N			0.4	0.2162	0.2414
Ku				0.2564	0.3226
S					0.375

Note : M = Matla char, Canning; V = Viswabank Bheri, Canning; N = Nikarighata Bheri, Canning; Ku = Kulpi Bheri, Kulpi; S = Sagar Island creek; K = Kakdwip char

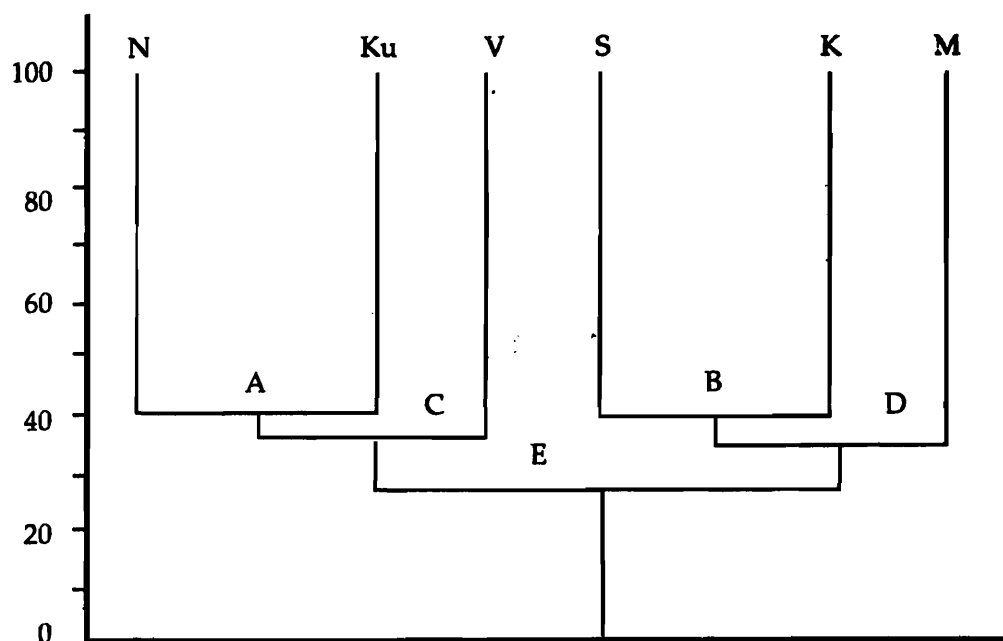


Fig. 3. Dendrogram showing percentage similarity values of the six selected sampling sites

DISCUSSION

The existing earlier reports on the composition and diversity of molluscan species in the estuarine wetlands of West Bengal (Choudhury *et al.*, 1980; Mandal and Misra, 1985; Nandi and Choudhury, 1985; Subba Rao *et al.*, 1983, 1987, 1995; Nandi and Das 2003 and Dey *et al.*, 2005) indicate a wide range of diversity of species varying from place to place. Mandal and Misra (1985) reported 16 molluscan macrobenthic species (9 gastropods and 7 bivalves) from mudflats of Matla riverbed at Canning. Misra and Barua (1987) recorded 21 species of macrobenthic mollusca (14 gastropods and 7 bivalves) also from Matla riverbed, Canning. The number of macrozoobenthic molluscan species found in the littoral zone of Matla char, Canning (23 species) was higher when compared to the earlier reports. The absences of gastropod species like *Haminea crocata* Pearse, and bivalves, *Pharella javonicus* (Lamarck) and *Laternula truncata* (Lamarck) have been encountered from Matla char, Canning, in the present study within the period of 20 years. This might be due to greater human-induced stresses and increasing environmental pollution from various sources. The gastropod *Telescopium* (T.) *telescopium* and bivalves

Pelecypora trigona and *Meretrix meretrix* are extensively exploited for harvesting their shells as source of calcium carbonate in the lime industry and in the poultry feed factory. The indiscriminate and unscientific exploitation as well as the gradual silting up of the estuary has resulted destruction of natural beds of these bivalve molluscs inhabiting littoral zone (Misra and Barua, 1987) and as a result the populations of these bivalve species were drastically reduced or absent from the littoral zones of Matla char, Canning during the course of present survey. The highest diversity representing 28 species was recorded at Ganga Sagar creek, Sagar Island. This may be due to naturalness and undisturbed mudflat with considerable mangrove vegetation cover. It is, however, mentioned that earlier Dey *et al.*, 2005 reported 31 species of molluscs from Sagar Island.

In so far as macrozoobenthic molluscan community in the brackishwater wetlands as a whole is concerned, *Cerithidea* (*Cerithideopsis*) *cingulata* was predominant, while *Telescopium* (T.) *telescopium* was abundant and *Stenothyra deltae* occurred as less abundant in the littoral zones of the selected natural wetlands surveyed. Misra and Barua (1987), on the contrary, observed that the lower littoral zone of Matla

char was dominated by *Meretrix meretrix* and *Natica tigrina*. The present study revealed that these species were distributed in patches on the Matla riverbed. It was also observed that *Assiminea beddomeana*, *A. brevicula*, *Telescopium* (T.) *telescopium*, *Cerithidea* (*Cerithideopsis*) *cingulata*, *Cerithidea* (*Cerithidea*) *alata*, *Stenothyra deltae*, *Macoma birmanica*, *Theora opalina* and *Strigilla splendida* prefer mud banks and mudflats as their ecological niches as reported earlier by Dey *et al.* (2005). Like-wise *Nassarius stolatus*, *Natica tigrina*, *Donax incarnates* and *Meretrix meretrix* were found to inhabit lower

littoral zones, dominated by sandy silts. It is mentioned that Choudhury *et al.* (1984) recorded dominance of molluscan species in the mangrove habitat (72.2%) than in the tidal creek (46.2%) of Prentice Island, Sundarbans.

The estimated biomass of macrobenthic molluscan species was apparently lower in the Matla char and Viswabank bheri, Canning than Nikarighata bheri, Canning. The presence of mollusc species of larger size such as *Telescopium* (T.) *telescopium* at Nikarighata bheri, Canning was responsible for the higher biomass at this station than the others.

LITERATURE CITED

- CHOUDHURY, A., DAS, A. BHATTACHARJEE, S. and BHUNIYA, A. B. 1980. Quantitative assessment of benthic fauna in the intertidal mudflats of Sagar Island. *Proc. Asian Symp. on Mangrove Environment, Research and Management*, Kuala Lumpur, Malaysia.
- CHOUDHURY, A., BHUNIA, A. B. and NANDI, S. 1984. Preliminary survey of macrobenthos of Prentice Island, Sundarbans, West Bengal. *Rec. zool. Surv. India*, 81(3 & 4) : 81–92.
- DEY, MITALI, JAMADAR, Y. A. and MITRA, A. 2005. Distribution of intertidal malacofauna at Sagar Island. *Rec. zool. Surv. India*, 105(Part 1-2) : 25–35.
- GUILLE, A. 1970. Benthic bionomy of continental shelf of the French catalane coast. II. Benthic communities of the macrofauna. *Vie Milieu*, 21(8) : 239–250.
- MANDAL, A. K., and MISRA, A. 1985. Mudflats of lower Bengal with special reference to macrobenthic fauna. The Mangroves : *Proc. Nat. Symp. Biol. Util. Cons. Mangroves*, 425–431.
- MISRA, A., and BARUA, S. 1987. The intertidal distribution of macro-fauna on the muddy shore of Matla river, Canning, West Bengal. *J. Indian Soc. Coastal agric. Res.*, 51 : 339–346.
- NANDI, N. C., and DAS, S. R. 2003. Diversity and population density of macrozoobenthos and zooplankton of South 24 Parganas district, West Bengal. *J. Aqua. Biol.*, 18(1) : 41–46.
- NANDI, S., and CHOUDHURY, A. 1983. Quantitative studies on the benthic macrofauna of Sagar Island, intertidal zones, Sundarbans, India. *Mahasagar, Bull. Nat. Inst. Oceanogr.*, 16 : 409–414.
- PATRA, K. C., BHUNIA, A. B. and MITRA, A. 1990. Ecology of macrobenthos in a tidal creek and adjoining mangroves in West Bengal, India. *Env. & Ecol.*, 8(2) : 539–547.
- PAUL, S., and NANDI, N. C. 2003. Studies on intertidal macrozoobenthos of Hugli river in and around Calcutta in relation to water and soil conditions. *Rec. zool. Surv. India. Occ. Paper No.*, 213 : 1–135.
- SPELLERBERG, I. F. 1982. *Monitoring Ecological Change*. Cambridge Univ. Press, Cambridge.
- SORENSEN, T. A. 1948. A method of establishing groups of equal aptitude in plant sociology based on similarity of species content, and its application to analysis of the vegetation on Danish commons. *K. dan. Vidensk. Selsk. Biol. Skp.*, 5 : 1–34.

- SUBBA RAO, N. V., DEY, A. and BARUA, S. 1983. Studies on the malacofauna of Muriganga estuary, Sunderbans, West Bengal. *Bull. zool. Surv. India*, **5(1)** : 47–56.
- SUBBA RAO, N. V., SURYA RAO, K. V. and MITRA, S. C. 1987. Malacological notes on Sagar Island. *Bull. zool. Surv. India*, **8(1-3)** : 149–158.
- SUBBA RAO, N. V., DEY, A. and BARUA, S. 1995. Molluscs. Estuarine Ecosystem Series. Pt. 2. *Hugli-Matla Estuary*. West Bengal, Z.S.I. Calcutta : 41– 91.
- STOLICZKA, F. 1869. The malacology of Lower Bengal and adjoining provinces. *J. Asiat. Soc. Beng.*, **38** : 86–111.

DIVERSITY OF MACROPHYTE-ASSOCIATED MACROINVERTEBRATES IN TWO WETLANDS OF SOUTHERN WEST BENGAL

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ABSTRACT

Two year studies were carried out on the occurrence, diversity and abundance of macrophyte associated macroinvertebrates and related physico-chemical parameters of water quality of two varying freshwater wetlands of southern West Bengal, one a sewage-fed bheri and the other an ox-bow lake. The macrophyte associated fauna of both the wetlands comprised mainly of gastropod mollusks, annelids, arachnids, crustaceans, larval stages of dipterans, ephemeropterans and odonates, both nymph and adult stages of hemiptera and adult stage of coleopteran insects. However, there were great variations in the faunal composition, diversity and density of the two wetlands. Altogether 39 species were recorded from the two wetlands (33 species in the ox-bow lake and 26 in the bheri). The density was considerably high in oxbow lake (annual mean of 3659/m²) than in the bheri (annual mean of 2046/m²). Gastropod mollusk was the dominant fauna with a relative composition of 61.2% in oxbow lake and 35.4% in the bheri. The rich diversity and abundance of macroinvertebrates in the oxbow lake may be attributed to diverse habitat and niches provided by diverse and dense macrophytes, whereas, due to high organic enrichment, sparse vegetation and intense grazing pressure in the bheri both density and diversity was reduced.

Keywords : Macrophytes and associated macroinvertebrates, Gastropods, Coleoptera, Hemiptera, diversity, density and seasonal variations.

INTRODUCTION

Aquatic vegetation, both floating and submerged, especially in the littoral region of the freshwater wetlands represents a complex habitat. Besides playing an important role in the energy dynamics of the ecosystem, they provide significant support, protection and food to the animal communities. It has been reported that the diversified aquatic plants support considerably rich biodiversity of various aquatic phytophilic macroinvertebrates by providing diverse microhabitats (Sozeka, 1975; Crowder and Cooper 1982; Hanson, 1990; Diehl, 1992; Mitra, 1997; Feldman, 2001 and Khan, 2002) and by affecting light penetration and dissolved oxygen in the water column (Caraco & Cole,

2002). Though there has been a large number of studies involving such communities in many parts of the world (Rosine, 1955; Harrod, 1964; Junk, 1976; Rooke, 1984; Kornijow, 1989; Bailey & Litterick, 1993; Muli, Mavuti and Ntiba, 2000 and Tessier *et al.*, 2004), in India the work on such lines is mainly confined to those done earlier by Michael (1968), Sarma *et al.* (1975) and more recently by Khan (2002) on two freshwater bodies of Calcutta, Bhuanik *et al.* (2004) on two floodplain wetlands of West Bengal and Pal and Nandi (2006) on two urban lakes of Kolkata.

The present paper reports the result of the detailed studies carried out on the species diversity, community structure and numerical

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density of macrophyte associated macro invertebrate communities of two varying freshwater wetlands.

MATERIALS AND METHODS

1) Description of the study area

East Kolkata Wetlands (No. 4 Bheri) : Located on the eastern fringes of the city of Kolkata between 22°25'-22°40'N latitude and 88°20'-88°35'E are many marshy wetlands known as East Kolkata Wetlands, covering a large area of around 250sq km, which have recently been described as wetlands of International Importance, according to the Ramsar Convention (1971), because of their immense ecological values and wise use (Fig. 1). The history of the region picture it as marshy Salt lakes teeming with fishes and birds. This region was part of the mature delta of river Ganga and the wetlands are the "inter distributary marshes in the delta." These salt-water marshes were between the river Hugli to the west and the Bidhyadhari River to the east, which opened into the Bay of Bengal through the river Matla. Here the streams, which were once active, became dead due to the shifting of the main river and siltation and consequent loss of headwaters. These streams lost their connection

with the river completely in course of time and were converted into low-lying areas of marshy land with vegetation. These marshy wetlands were then taken up by the local fishermen who began to practice intensive fish culture drawing water from the nearby sewage canals. The ever-expanding city of Kolkata with its increasing demands for drainage and waste disposal thus found a useful and easy outlet in the form of these fishery ponds, locally known as "Bheri", where sewage water began to be used for fisheries and agriculture. The wetlands act in two ways—providing a sink for pollution load and producing a good quality and quantity of fishes and vegetables. In general these bheries are managed by the fishermen's society, which indulges in regular fishing activities, cleaning these by manually removing the weeds leaving some weeds at only the sides to prevent illegal netting and theft of fishes. One such pond, "no. 4 bheri" of the Sukantonagar Fishermen Cooperative Society was selected for study. It is a large pond covering an area of about 72 acres, rectangular in shape and varying depth of around 1.2-1.5m. The periphery of the bheri is lined by abundant water hyacinth, *Eichhornia crassipes* (locally known as "kachuripana") and very little of other aquatic vegetation.

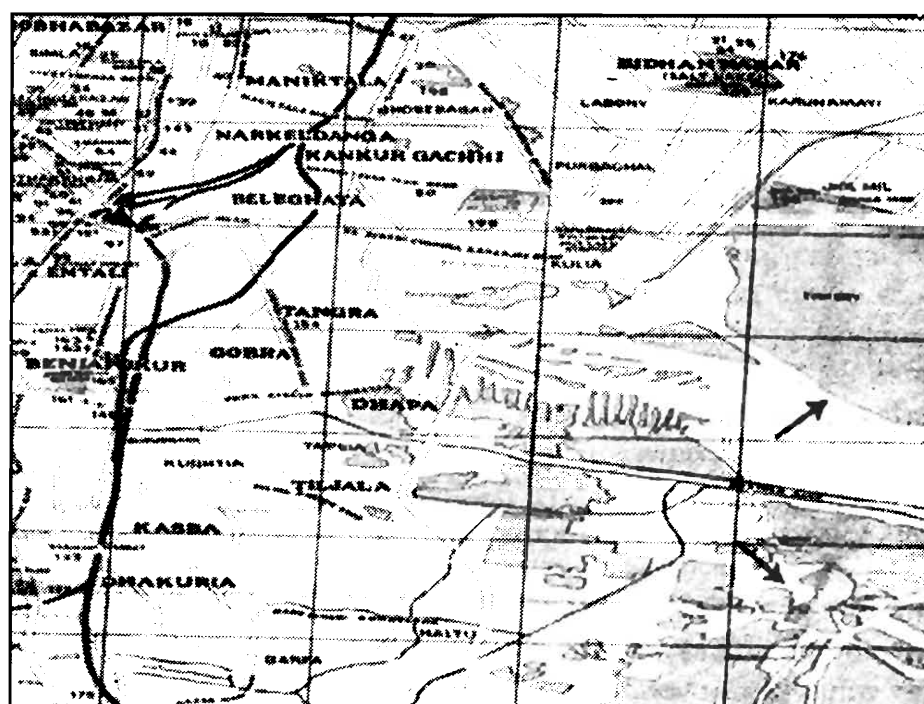


Fig 1. A view of a portion of East Kolkata Wetlands (arrows)

Gopalnagar bnour : Located at about 8 km west of the Bangaon subdivision (22°45'N) of North 24 Parganas district is a small town, Gopalnagar, where the river Icchamati has formed a floodplain wetland (Fig. 2). This is an open type (having connection with the source at one side) of oxbow lake (locally known as "Bnour") formed by the meandering river in its lower course. It has an area of about 120 acres and varying in depth between 2.4-3.6m during the different seasons depending on the influx. The ox bow lake is covered with dense and diverse aquatic vegetation in the littoral and pelagic zones belonging to the floating, submerged and emergent types. This Bnour is managed by the Barrackpore Fishermen's Cooperative Society at Beledanga in North 24 Parganas.

2) Collection of samples

Monthly investigations were carried out in both the wetlands during the period 2004-2006

covering all the 3 seasons—Premonsoon (PRM, March to June), Monsoon (MON, July to October) and Postmonsoon (POM, November to February). Sampling was done at three selected stations situated considerably apart from each other at each of the study sites. Macrophyte associated macroinvertebrates were collected with the help of a hand operated D-framed net of the size of 50 cm length and 25 cm breadth of the D. A net made of fine muslin cloth with approx. 200 mesh size was attached to the frame (Khan, 2002). The design and operation of the net was roughly based on that described by Junk (1977). Sampling was carried out from a boat at all the sampling sites. For collection of fauna the net was slowly pushed upside down to the bottom of littoral zone and quickly lifted after turning upwards the mouth of the net. (Khan, 2002). The vegetations projecting out from the net were cut off. The total area covered by the net was calculated for enumeration of the quantitative data.

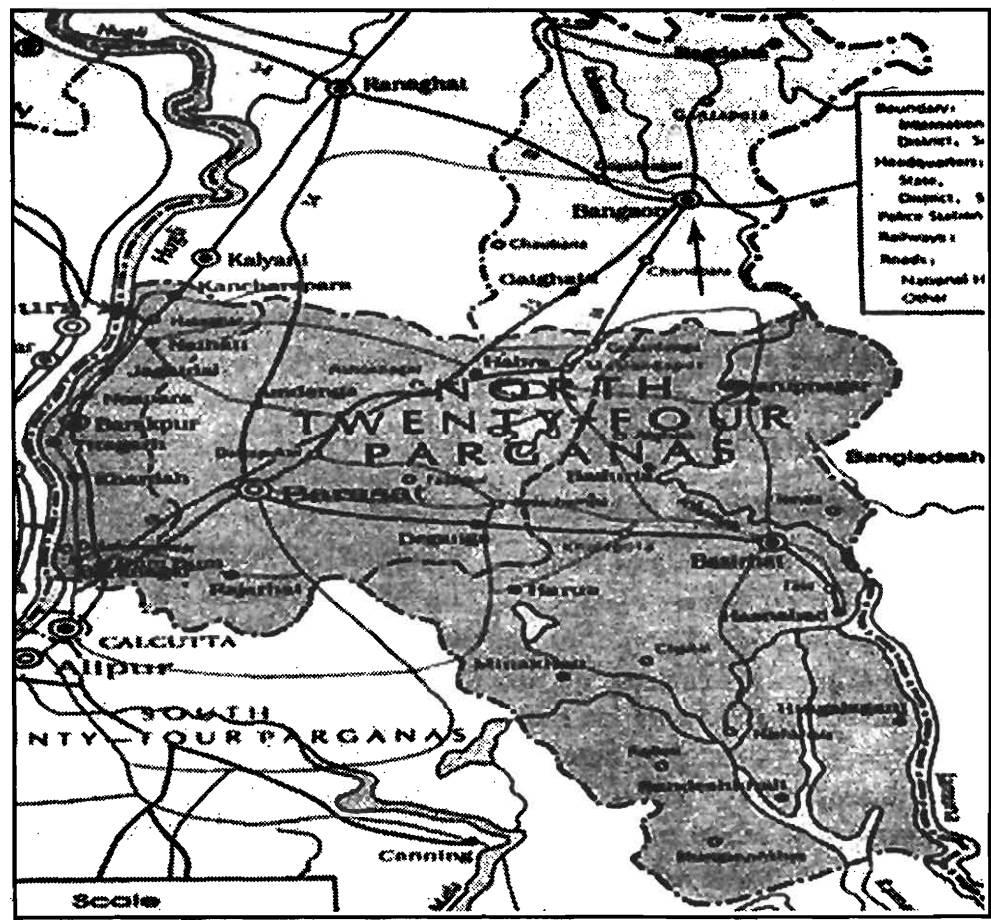


Fig. 2. A part of North 24 Parganas district showing the Bangaon region (arrow).

The macrophytic plants were first thoroughly washed several times in the net to remove all the attached fauna and then again the contents were washed on a sieve of 0.5mm to retain the smallest possible invertebrate fauna. The organisms were first narcotized by putting them in a killing bottle containing benzene vapor and then later preserved in 70% alcohol. The collected animals were sorted into different taxonomic groups and identified up to the lowest possible taxon under low powered dissecting binocular microscope under the guidance of the respective group experts at Zoological Survey of India. For relative composition and density measurements, quantitative samples were used.

Simultaneously, surface and subsurface samples were collected from the wetlands for analyzing the physico-chemical parameters of water quality such as dissolved oxygen, temperature, pH, alkalinity, transparency, conductivity, phosphate and nitrate. The chemical analysis was done following Standard Methods (APHA, 1998) : Winkler method for determination of dissolved oxygen, standard mercury thermometer (0°-50°C) for temperature, pen type pH meter (Eutech instruments) and pH paper (Qualigens) for measuring pH and Secchi Disk (black and white quadrants) of diameter 20 cm for transparency and Merck's field kit for total alkalinity-these were analysed in the field. Rest of the parameters were analysed in the laboratory.

RESULTS

a) Physico-chemical characteristics of water

The monthly data of various water quality parameters recorded during the two years for the two wetlands were pooled together to obtain a mean value as summarized in the Tables 1 and 2 below. Both the wetlands have an alkaline nature with pH ranging between 8.1-9.4 Secchi Disc transparency showed higher values in the ox-bow lake while the water in the bheri was turbid and had a certain green coloration. The conductivity values were higher in the sewage fed pond presumably due to the

high ionic content resulting from the presence of large concentration of nutrients (Muli, Mavuti and Ntiba, 2000). The dissolved oxygen content was higher in the ox-bow lake than in the sewage fed pond, where almost anoxic conditions prevailed. The phosphate and nitrate concentrations in the bheri were much higher than those in the ox-bow lake.

b) Biological characteristics

i) Macrophytes—

There were a large number of diverse types of aquatic vegetation in the ox-bow lake belonging to three main categories, namely floating, submerged and emergent types. Altogether 16 taxa of Macrophytes were recorded throughout the oxbow lake during the study period as listed in the Table 3. During winter and summer, the spread of the vegetation varied between 60-70% and 80-90% respectively. However, during monsoon, there was a considerable reduction in area coverage (30%-40%). Considering the area of coverage, the winter was recorded as most favourable season for the growth of the macrophytes with submerged group of vegetation found to be most dominant followed by free floating ones. Rooted and free-submerged group like *Ceratophyllum* sp., *Hydrilla* sp., *Potamogeton* sp. and *Vallisneria* sp. were the major contributors throughout the year in the bhour. Rooted floating macrophytes were represented by *Limnophila* sp. and *Nymphaea* sp. The marginal areas were infested with mainly *Eichhornia* sp. followed by *Pistia* sp., *Lemna* sp. and *Typha* sp. But the scenario in the sewage fed pond was entirely different where the vegetation was confined to mainly monospecific strands of *Eichhornia crassipes* and a few limited number of species of *Lemna* sp. and *Pistia* sp. as shown in the Table 3.

ii) Macroinvertebrates –

Qualitative studies reveal the presence of altogether 39 commonly occurring species of macrophyte associated macroinvertebrate fauna belonging to almost all the major groups, from both the wetlands (see Table 4) during the two

Table 1. Pooled monthly data of the physico-chemical characteristics of water quality for two years (2004-2006) in the ox-bow lake

Parameters/Seasons	March	April	May	June	July	August	September	October	January	February
Air Temperature (°C)	35.4	32.7	36.6	38.4	37.3	39	31.8	40.5	26	33.25
Water Temperature (°C)	30.5	32.8	34.5	36.8	33.9	37.5	34.5	39	23.8	31.5
Secchi Disc Transparency (cm.)	144.5	105.5	84.1	182	79.5	225	93	135	255.5	167
Total Dissolved Solids (mg/l)	0.369	0.139	0.129	0.274	NA	0.265	NA	0.299	0.378	0.371
Conductivity (mhos/cm)	0.542	0.198	0.184	0.322	NA	0.378	NA	0.428	0.54	0.529
pH	8.9	8.5	9.2	9.3	9.4	8.3	8.9	8.1	8.2	8.9
Dissolved oxygen (mg/l)	9.9	10.1	6.3	10.9	8.2	2.2	8.1	4	11.35	12.6
Total Alkalinity (mmol/l)	4	4.1	3.8	4.7	3.7	3.3	5.1	3.1	4.7	7.6
Total Hardness (mg/l)	150.21	184.26	244.56	191.99	209.63	134	324.421	120	304.458	153.313
Nitrate (mg/l)	0.002	0.004	BDL	0.044	NA	0.002	NA	0.129	BDL	0.098
Nitrite (mg/l)	0.04	0.05	BDL	0.03	BDL	0.01	BDL	0.02	BDL	0.03
Total Phosphate (mg/l)	0.158	0.25	0.25	0.342	0.25	0.296	0.25	1.228	0.183	0.992
Chloride (mg/l)	28.1	24	14	22.5	8	24.14	24	17.04	114.5	24.75

BDL = below detection level; NA = not available.

Note : Data for the months of November and December could not be recorded due to fishing and cleaning activities in the bhour

Table 2. Pooled monthly data of the physico-chemical characteristics of water quality for two years (2004-2006) in the sewage-fed pond

Parameters / Seasons	March	April	May	June	July	August	September	October	December	January	February
Air Temperature (°C)	29.9	31.7	34.5	34.7	27.3	30.8	34	32	27.5	26.3	30.3
Water Temperature (°C)	29.8	31.3	32.9	34.6	28.3	32.8	34.3	32.5	28.7	25	29.5
Secchi Disc Transparency (cm.)	8.3	10	10.5	11.8	27.3	12.8	NA	16	10	12.3	9.8
Total Dissolved Solids (mg/l)	0.0813	0.0767	0.9249	0.3862	0.2837	0.535	0.658	0.0691	0.0693	0.4317	0.107
Conductivity (mmhos/cm)	0.1162	0.1095	1.433	0.6276	0.4778	0.8585	0.94	0.0987	0.099	0.6167	0.1529
pH	8.9	9	8.9	9.1	8.7	9.6	8.3	9.3	8.8	8.7	9.2
Dissolved oxygen (mg/l)	7.7	2.9	4.3	4.6	4.3	12.1	3.3	10.7	7.9	2.9	4.9
Total Alkalinity (mmol/l)	4.1	3.95	3.6	3.5	4.9	4.2	2.2	1.15	4.6	1	4.2
Total Hardness (mg/l)	339.39	224.6	370	194.6	399.3	344.4	NA	270.768	1168.49	277	257.043
Nitrate (mg/l)	10	10	10	BDL	0.378	BDL	10	10	BDL	10	10
Nitrite (mg/l)	BDL	BDL	BDL	BDL	0.1	BDL	0.2	0.5	0.15	0.05	0.05
Total Phosphate (mg/l)	0.25	0.25	0.25	0.5	1.758	1.5	0.5	0.25	0.25	0.25	0.25
Chloride (mg/l)	224	208	242	226	196	186	NA	144	180	178	184

BDL = below detection level; NA = not available.

Note : Data for the month of November could not be recorded due to fishing activities

Table 3. List of macrophyte taxa recorded from the Ox-bow Lake and Sewage fed fishery pond

Sites Plant species	Ox-bow lake (Gopalnagar Bnour)	Sewage fed pond (4 No. Bheri)
Rooted floating		
<i>Limnophila</i> sp.	+	–
<i>Nymphaea</i> sp.	+	–
Free-floating		
<i>Pistia</i> sp.	+	+
<i>Lemna</i> sp.	+	+
<i>Spirodella</i> sp.	+	–
<i>Trapa</i> sp.	+	–
<i>Eichhornia</i> sp.	+	–
<i>Azolla</i> sp.	+	–
Rooted submerged		
<i>Chara</i> sp.	+	–
<i>Hydrilla</i> sp.	+	–
<i>Vallisneria</i> sp.	+	–
<i>Potamogeton</i> sp.	+	–
Free-submerged		
<i>Ceratophyllum</i> sp.	+	–
Emergent erect		
<i>Scirpus</i> sp.	+	–
<i>Typha</i> sp.	+	–
Emergent prostate		
<i>Ipomoea</i> sp.	+	–

year period. These were represented by 11 species each of Gastropod Mollusks and Coleoptera, 7 species of Hemiptera, 4 species of Annelids and 3 species each of Arachnida and Crustacea. Mollusca and Coleoptera had maximum represented species followed by Hemiptera and then Annelids. The number of species unique to each wetland was 11 sp in case of Bnour and 7 sp in case of bheri. The common fauna belonged to mainly 1 species each of Hirudinea and Crustacea, 3 species each of Arachnida and Coleoptera, 6 species of Hemiptera and 9 species of Mollusca (Table 4).

Wetland wise, the faunal diversity was higher in the bnour where 33 species were recorded, but it was comparatively lower in the bheri where 26 species were noticed. Gastropod Mollusks dominated the phytofaunal community in both the wetlands with 11 species in the Bnour and 9 species in the bheri. The

decapod and ostracod crustaceans were obtained only in the Bnour. The hexapod fauna were comprised of a large number of species constituting the orders Coleoptera and Hemiptera of which both adult and nymphal forms were found while quite a few numbers of only the nymphs of Ephemeroptera, Odonata and Diptera were present. While 8 species of Coleoptera and 3 species of Hemiptera were recorded in the sewage-fed pond, the number was 7 each of coleoptera and hemiptera in the ox-bow lake. The arachnofauna was equally represented in both the wetlands with 3 species being present. A few number of oligochaetes such as *Tubifex* sp. and *Limnodrilus* sp. occurred in the sewage –fed pond but their number was considerably reduced in the ox-bow lake. Hirudinea was consisted of 3 species in bheri and 2 species in Bnour. Since the immature forms of Dipterans belonging mainly to the

Table 4. Qualitative abundance of the macrophyte associated macroinvertebrate fauna of the two wetlands during different seasons. [PRM= Premonsoon, MON = Monsoon, POM = Post monsoon; " + " = Presence " - " = Absence].

MACROINVERTEBRATE GROUPS	OXBOW LAKE (GOPALNAGAR BNOUR)			SEWAGE-FED FISHERY POND (4NO. BHERI)		
	PRM	MON	POM	PRM	MON	POM
ANNELIDA : OLIGOCHAETA (2 taxa)						
<i>Tubifex sp.</i>	+		+	+	+	+
<i>Limnodrilus sp.</i>			+	+	+	+
ANNELIDA: HIRUDINEA (4 taxa)	2 species			3 species		
<i>Barbronia weberi</i> (Blanchard)						+
<i>Glassophonia weberi</i> (Blanchard)	+	+	+	-	-	-
<i>Helobdella nociva</i> Harding				+		
<i>Herpobdelloidea lateroculata</i> , Kaburaki	+		+	+		
ARTHROPODA: CRUSTACEA (4 taxa)	3 species					
<i>Stenocypris major</i> (Baird)	+	+	+			
<i>Macrobrachium lamarrei</i> (H.M.Edwards)	+	+	+			
<i>Macrobrachium dyanum</i> (Henderson)	+	+	+			
<i>Caridina sp.</i>	+	+	+			
Conchostraca	+	+	+			+
Juvenile crabs	+	+	+	+		
ARTHROPODA: ARACHNIDA (8 taxa)	3 species			3 species		
<i>Pardosa sumatrana</i> (Thorell)	+			+		+
<i>Tetragnatha andamanensis</i> (Tikader)		+			+	
<i>Zygoballus narmadaensis</i> Tikader		+		+		
<i>Hippasa sp.</i>						+
<i>Larinia sp.</i>	+	+	+			
<i>Lycosa sp.</i>		+		+		
<i>Neoscona sp.</i>				+		
<i>Pardosa sp.</i>	+				+	
<i>Theridion sp.</i>				+		
<i>Tetragntha sp.</i>				+		
<i>Lycosid spiderlings</i>	+	+	+	+		
INSECTA : HEMIPTERA (7 taxa)	7 species			3 species		
<i>Anisops bouvieri</i> Kirkaldy	+	+	+	+		
<i>Diplonychus rusticum</i> (Fabricius)	+	+	+	+	+	
<i>Diplonychus annulatum</i> (Fabricius)	+	+	+		+	
<i>Laccotrephes greseus</i> (Guerin)	+	+	+			
<i>Mesovelina vittigera</i> Horvath	+	+	+			
<i>Micronecta scutellaris</i> (Stal)	+	+	+			
<i>Plea litturata</i> (Fieber)	+	+	+			
<i>Anisops nymphs</i>	+	+	+	+		
<i>Diplonychus nymphs</i>	+	+	+	+	+	+

Table 4. Contd.

MACROINVERTEBRATE GROUPS	OXBOW LAKE (GOPALNAGAR BNOUR)			SEWAGE-FED FISHERY POND (4NO. BHERI)		
	PRM	MON	POM	PRM	MON	POM
INSECTA : COLEOPTERA (11 taxa)	7 species			8 species		
<i>Amphiops simplex</i>	+	+	+	-		
<i>Berosus indicus</i> Motschulsky				+	+	+
<i>Canthydrus morsbacchi</i> (Wehnkee)	+	+	+			
<i>Canthydrus laetabilis</i> (Walker)	+	+	+	+	+	+
<i>Canthydrus luctuosus</i> (Aube)				+	+	+
<i>Helochaeres anchoralis</i> Sharp	+	+	+	+	+	+
<i>Hydrocoptus subvittulus</i> Motschulsky	+	+	+	+		+
<i>Hydrovatus acuminatus</i> Motschulsky	+	+	+	+	+	+
<i>Laccophilus anticus</i> Sharp	+	+	+			
<i>Regimbertia attenuata</i> (Fabricius)				+	+	+
<i>Spercheus gibbus</i> Champion				+	+	+
INSECTA: DIPTERA (1 taxa)						
<i>Chironomus</i> sp.	+	+	+			
<i>Chironomid larvae</i>	+	+	+	+	+	+
INSECTA						
Ephemeroptera nymphs	+	+	+	+	+	+
Odonata nymphs	+	+	+	+	+	+
MOLLUSCA: GASTROPODA (11 taxa)	11 species			9 species		
<i>Bellamya bengalensis</i> (Lamarck)	+	+	+	+		+
<i>Digoniostoma cerameopoma</i> (Benson)	+	+	+	+		
<i>Giarulus convexiusculus</i> (Hutton)	+	+	+	+	+	+
<i>Gabbia orcula</i> Frauenfeld	+	+	+	+	+	+
<i>Indoplanorbis exustus</i> (Deshayes)	+	+	+	+	+	+
<i>Lymnaea</i> (P.) <i>luteola</i> Lamarck	+	+	+	+		+
<i>Lymnaea</i> (P.) <i>acuminata</i> Lamarck	+	+	+		+	
<i>L. (P.) biacuminata</i> Annandale & Rao	+	+	+			
<i>Pila globosa</i> (Swainson)		+	+			
<i>Thiara</i> (T.) <i>lineata</i> (Gray)	+	+	+	+	+	
<i>Thiara</i> (T.) <i>tuberculata</i> (Muller)	+	+	+	+	+	+
TOTAL SPECIES	33			26		
GRAND TOTAL OF SPECIES	39					

family Chironomidae, could not be identified, these were not reckoned for computation of species diversity.

c) Relative composition and Density

The relative composition of the Mollusks was highest during all the seasons in both the wetlands, being 61.2% in Ox-bow Lake and

35.48% in sewage-fed pond biannually (Fig. 3 and Fig. 4). Their contribution was almost substantial throughout the year with very narrow seasonal fluctuations. This was followed by Coleoptera, which had a contribution of 19.1% in bheri and 11.1% in bnour. Next in abundance were Hemiptera. The mean density over the biannual season was highest in case of

gastropods in both the wetlands and lowest in case of ostracods and odonates in the Ox-bow Lake and sewage -fed pond respectively (Fig. 5). The population density was highest during postmonsoon in both the wetlands.

d) Diversity Index

The faunal diversity in the two wetlands was clearly visible from comparison of the values of various diversity indices applied. There were marked differences in the values obtained. While the Simpson diversity index had a mean value of 0.119 in ox bow lake and 0.064 in sewage fed pond, the values of Shannon-Weiner diversity index (H) was always above 3 (with a mean of 3.27) in ox-bow lake and around 1 (with a mean of 1.65) in sewage fed pond.

DISCUSSION

It is well-known that higher density of invertebrates inhabits vegetated areas relative to the nonvegetated areas. This is attributed to the fact that vegetation adds colonizable surface area to the lake (Brown & Lodge, 1993). It is evident from the present studies also that since there was dense growth of diverse aquatic macrophytes in the ox-bow lake, larger number of fauna were obtained here than in the bheri where there was less growth of vegetation. While some workers (Laal, 1989 and Harod, 1962) have reported that the mass of finely divided roots of water hyacinth with luxurious growth of root hairs provide a large surface area and protection to the associate fauna from predation; these macroinvertebrates form good

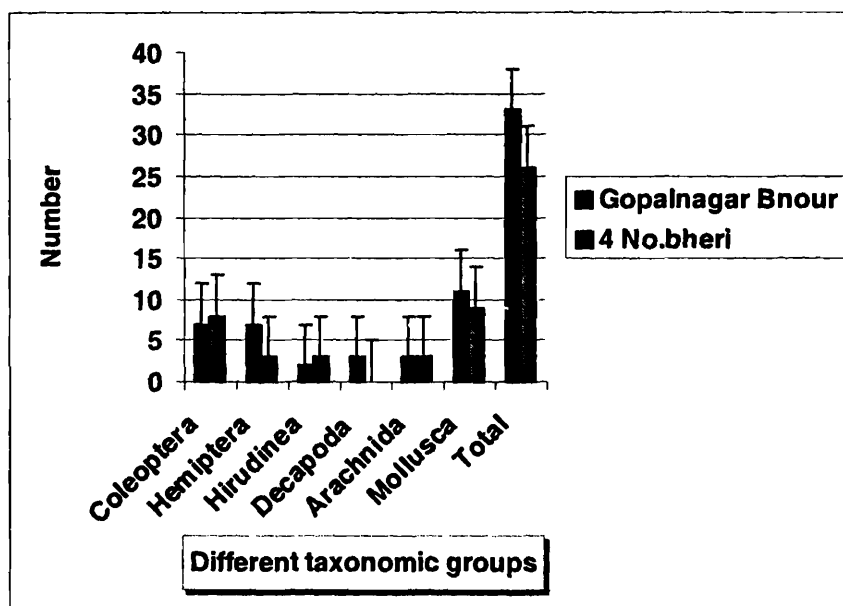


Fig. 3. Number of taxa of each group in the two wetlands

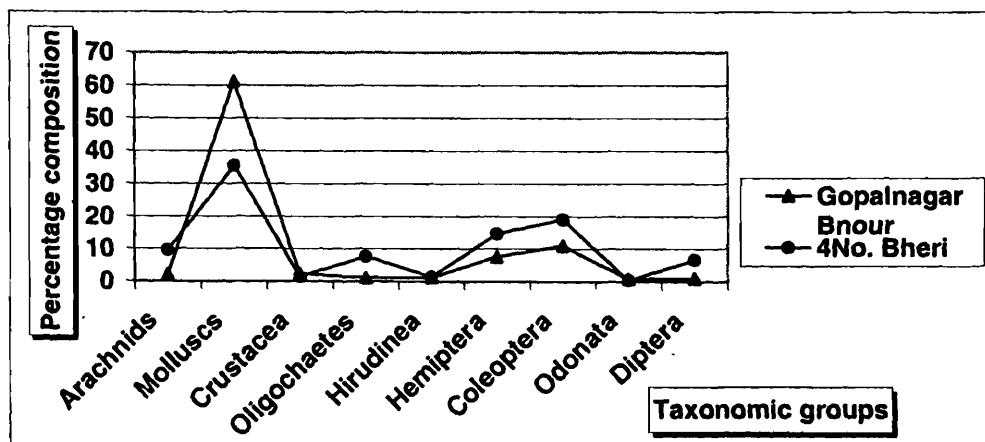


Fig. 4. Relative abundance of the macro invertebrates in the two wetlands

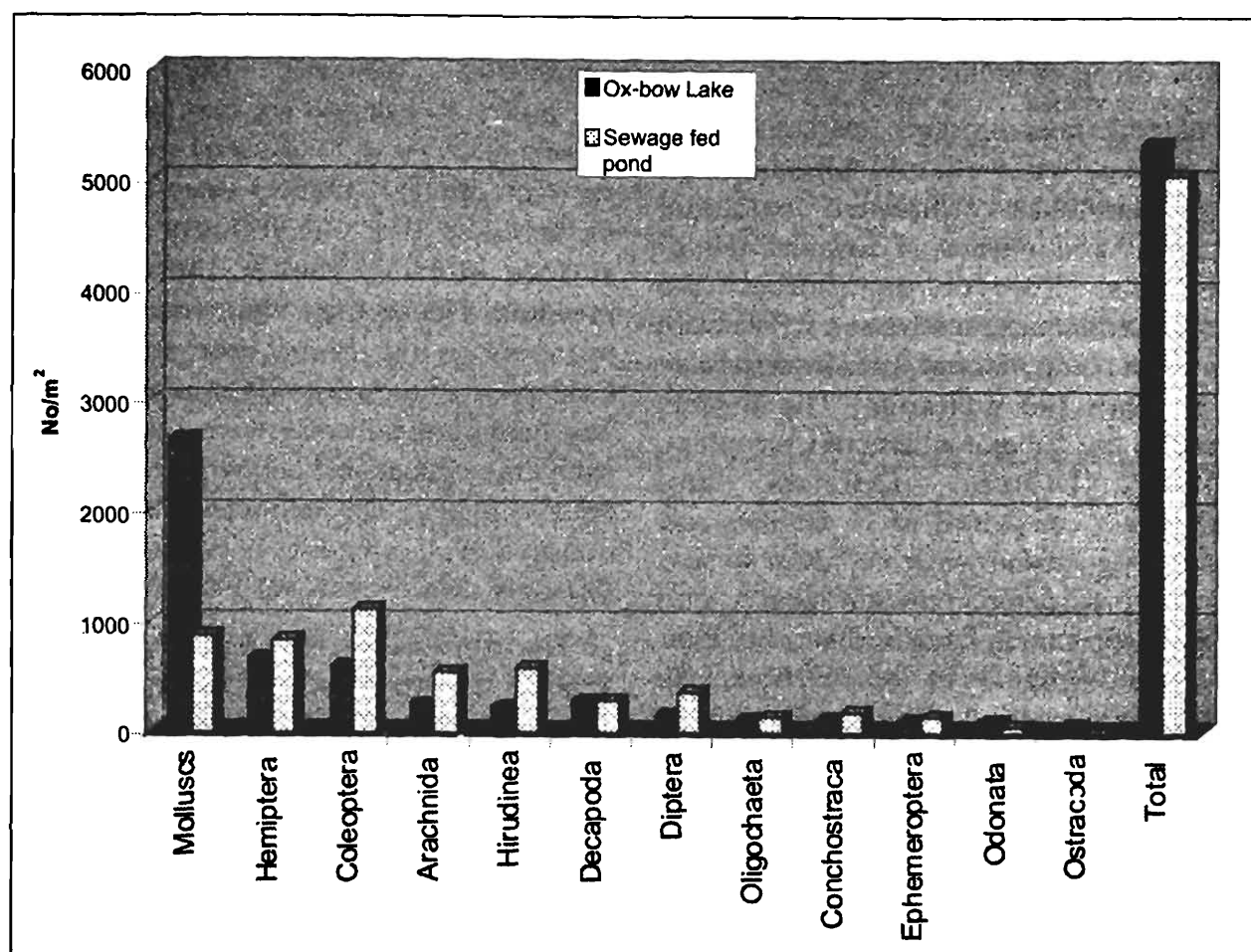


Fig. 5. Mean Density of different macro invertebrate groups in the two wetlands

food items of fish. Hence the growth of *Eichhornia* sp. indirectly encourages increase in fish production (Terry, 1992). But in the investigated wetlands, the studies revealed quite significant differences in the diversity of macrophyte associated macro invertebrates. The ox-bow lakes representing intermediate conditions between lotic and lentic ecosystems, with considerable variations at micro-ecological levels, serve as unique habitats for the colonization of rich and diverse faunal communities (Pieczynska & Ozimek, 1976). In this study it has been found that the rich diversity of macrophytic community consisting of 16 commonly occurring taxa provided diverse niches for the establishment of stable communities of faunal assemblage in the ox-bow lake. The lower diversity in the bheri is due to the profuse growth of water hyacinth, which covered the entire pond while other types of vegetation could not grow. The diversity is reduced, since only species that

tolerate low dissolved oxygen, high conductivity, high nutrient content and toxic gases emanating from the fringe can exist. Analysis of the water quality parameters showed that the dissolved oxygen concentration in the sewage fed pond was low where on some occasions even anoxic conditions prevailed (with the value reaching below 4mg/l) than in the ox-bow lake. The conductivity values were high in sewage fed pond. This may be attributed to the high ionic content resulting from the presence of large concentrations of nutrients (Willoughby *et al.*, 1993). The phosphate, nitrate and nitrite levels also point towards the eutrophic condition in the pond. Water in the ox-bow lake was found to be cleaner. The water temperature in the wetlands closely followed the atmospheric temperature. Both the freshwater wetlands were found to be alkaline in nature with pH values ranging from 8.3-9.3 in the bheri and 8.1-9.4 in the Bnour. The high alkalinity may be presumably due to

the presence of salts generated through the death and decay of biotic components.

Out of the 39 taxa recorded during the study period in the two wetlands together, the gastropod mollusks contributed maximum quantitatively and in terms of diversity in both the wetlands. However, qualitatively the aquatic and semiaquatic insects as a whole were the dominant component of macroinvertebrate fauna in both the wetlands. The insects belonging to the 5 major orders of Coleoptera, Hemiptera, Diptera, Odonata and Ephemeroptera comprised of 11 families and 19 species. Oligochaetes such as *Tubifex* sp. and *Limnodrilus* sp. occurred in the sewage fed pond during postmonsoon in large numbers but their number was negligible in the ox-bow lake during the same period. Their availability in greater numbers in the fishery pond than in the bhour may be attributed to the inflow of nutrient-rich sewage (Mukherji, Pal and Nandi, 1998). Moreover, these two species are biological indicators of pollution. Their comparatively less numbers in the ox-bow lake is an indication of less pollution. Again, the presence of chironomids is good indicator of greater degree of eutrophy (Barbhuyan & Khan, 1992) in the sewage fed pond than in the ox-bow lake. The presence of Ephemeropterans in greater numbers in the ox-bow lake indicates clean water conditions (Hellawell, 1989). In general, the macroinvertebrate density was found to be highest in post monsoon and lowest in monsoon. This is due to the moderate temperature and increased primary productivity in winter. During monsoons, because of the influx of water from the river in Ox-bow Lake and accumulation of rainwater in the sewage-fed pond the speed of water is increased and the aquatic vegetation is dislodged and scattered. Thus the faunal species are unable to colonize the vegetation as the substratum gets loosened. Again, due to intense grazing pressure and high organic enrichment in the bheri both diversity and density are reduced. Analysis of habitat preference by macrofauna to particular type of vegetation

revealed the fact that gastropod mollusks show preference towards the submerged Macrophytes. *Lymnaea* sp. was found attached loosely to *Chara* sp., *Vallisneria* sp. and *Ipomoea* sp. Coleopteran insects seemed to prefer *Eichhornia* sp. due to their bushy roots and leaf surface offering shelter for feeding and breeding. Hence they were found in greater numbers in the bheri than in the bhour. Coleoptera and Arachnida inhabited *Pistia* sp. The hemipteran insects were recorded in the submerged roots and below leaf sheath of the aquatic plants. The ephemeropteran nymphs occurred in all categories of macrophytic plants (Bhattacharya and Gupta, 1991; Pal *et al.* 1998).

The application of diversity indices to analyze the macro invertebrate communities reveals the fact that the ox-bow lake supports comparatively richer diversity of fauna than the sewage-fed pond. A value of Shannon-Wiener index ($\bar{H}$) above 3 indicates cleaner water conditions in the ox-bow lake. The value of Simpson diversity index reflects diversified resources available for diverse components of the aquatic faunal community in the ox-bow lake than in the sewage-fed pond.

The nature of interactions and relationship between the biotic and abiotic factors of two wetland ecosystems is not simple. The occurrence of aquatic faunal resources is dependent on several physiographical factors, analytical procedures and spatio-temporal factors.

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LITERATURE CITED

- APHA, AWWA, WEF, WPCF. 1998. *Standard Methods for the Examination of water, sewage and industrial wastes*. 20th Edn. American Public Health Association, Washington, USA.
- BARBHUYAN, S.I. and KHAN, M.A. 1992. Studies on the structure and function of benthic ecosystem in a eutrophic body of water-temporal and spatial distribution of benthos. *J. Freshwater Biol.*, 4(40) : 239-247.
- BHAUMIK, M., MITTAL, I.C., DAS, P., and PARIA, T. 2004. Macrophytes and Macrophyte Associated Fauna in a floodplain wetland system of West Bengal having both open and close characteristics. *Env. and Ecol.*, 22(Spl-2) : 371-378.
- BHATTACHARYA, D.K., and GUPTA, B., 1991. Freshwater wetland inhabiting insects of West Bengal. *Env. & Ecol.* 9(4) : 995-998.
- BAILEY, R.G. and LITTERICK, M.R. 1993. The macroinvertebrate fauna of water hyacinth fringes in the Sudd swamps (River Nile, Southern Sudan). *Hydrobiologia*, 250 : 97-103.
- CARACO, N.F. and COLE, J.J. 2002. Contrasting impacts of a native and alien macrophyte on dissolved oxygen in a large river. *Ecol. Appl.*, 12 : 1496-1509.
- CROWDER, L.B. and COOPER, W.E. 1982. Habitat structural complexity and the interaction between bluegills and their prey. *Ecology*, 63 : 1802-1813.
- DIEHL, S. 1992. Fish predation and Benthic community structure: the role of omnivory and habitat complexity. *Ecology*, 73 : 1646-1661.
- FELDMAN, R.S. 2001. Taxonomic and size structures of phytophilous macro invertebrate communities in Vallisneria and Trapa beds of the Hudson River, New York. *Hydrobiologia*, 452 : 233-245.
- HARROD, J.J. 1964. The distribution of invertebrates on submerged aquatic plants in a chalk stream. *J. Animal Ecol.* 33 : 335-348.
- HANSON, J.M. 1990. Macro invertebrate size distributions of two contrasting freshwater macrophyte communities. *Freshwat. Biol.*, 24 : 481-491.
- HELLAWELL, J.M. 1989. Biological indicators of freshwater pollution and environmental management. Elsevier Applied Science, London, New York.
- JUNK, W.J. 1977. The invertebrate fauna of floating vegetation of Bong Barapet, a reservoir in Central Thailand. *Hydrobiologia*, 53 : 229-238.
- KHAN, R.A. 2002. Diversity of freshwater macroinvertebrate communities associated with Macrophytes. *Rec. zool. Surv. India*, 100(Part 1-2) : 211-228, 2002.
- KHAN, R.A. 2002. The Ecology and Faunal Diversity of two floodplain ox-bow lakes of South-Eastern West Bengal. *Rec. Zool. Surv. India, Occ. Paper No.*, 195 : 1-57.
- LAAL, A.K. 1989. Association of macroinvertebrates with Macrophytes in Tropical ponds. *Journal of Inland Fishery Society of India*, 21(1) : 20-25.
- MITRA, K. 1997. Macrophytes and weed associated fauna—a major link in the food chain of floodplain lakes. In : *Fisheries enhancement for small Reservoirs and Floodplain lakes in India*(Sugunan V.V. and Sinha M. Ed.). Central Inland Capture Fisheries Research Institute Bull. 75 : 103-108.
- MULI, J.R., MAVUTI, K.M., and NTIBA J.M. 2000. Macroinvertebrate fauna of water hyacinth in the Kenyan waters of Lake Victoria. *Internat. J. Ecol. Env. Sc.*, 26 : 281-302.

- MUKHERJI, M., PAL, S. AND NANDI, N.C. 2000. The Macroinvertebrate Diversity of some urban wetlands of Calcutta. In : *Diversity and Environment* Proc. Nat. Seminar on Environ. Biol. (Aditya, A.K. and Haldar, P. Eds) Daya Publishing House, Delhi : 136-143.
- PAL, S., DEY, S.R., BHATTACHARYA, D.K., DAS, S.K. and NANDI, N.C. 2000. Macrophyte preference and insect diversity of freshwater wetlands in southeastern Bengal. In : *Diversity and Environment*. Proc. Nat. Seminar on Environ. Biol. (Aditya, A.K. and Haldar, P. Eds.) Daya Publishing House, Delhi : 165-169.
- PAL, S. and NANDI, N.C. 2006. Phytofaunal community of two freshwater lakes. *Rec. Zool. Surv. India, Occ. Paper No.*, 248 : 1-143.
- ROSINE, W.N. 1955 The distribution of invertebrates on submerged aquatic plant surfaces in Muskee Lake. *Ecology*, 36 : 377-381.
- SOSZKA, G.J. 1975. The invertebrates on submerged Macrophytes in the three Masurian lakes. *Ekol. Pol.*, 23 : 371-391.
- SARMA, A.L.N., RAO, D.G. and DURANI, F.K. 1983. The phytal macrofauna of Dal Lake (Srinagar, Kashmir) *J. Environ. Biol.*, 4 : 117-176.
- TESSIER, C., CATTANEO, A., PINEL-ALLOUL, B. and GALANTI, G. 2004. Biomass, composition and size structure of invertebrate communities associated to different types of aquatic vegetation during summer in Lago di Candia (Italy). *J. Limnol.*, 63(2) : 190-198.

STUDY OF MARINE PLANKTONIC DIVERSITY IN DIGHA COAST, BAY OF BENGAL

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ABSTRACT

Marine planktonic population shows great diversity in terms of species richness. Total 52 plankton species have been identified among 12 groups namely—diatoms, dinoflagellates, green algae, copepoda, tintinnids, radiolaria, foraminifera, decapoda, urochorda, chaetognatha, rotifera and nauplii from the collected samples. The log-normal rank abundance graph shows the most dominant and most rare groups of collected plankton species. Among them diatom (phytoplankton) and copepod (zooplankton) are found to be the most dominant plankton group and observing the abundance pattern throughout the total study period and it seems to be that copepod may be the predator of diatom group.

Keywords : plankton, diversity index, abundance, prey-predator relationship, dominant group.

INTRODUCTION

Planktons are the basis of the food chain and food web related dynamics in most of the natural aquatic ecosystem. The coastal regions of India harbour a lot of diverse biota, the interlinking food chains of which are based on the planktons. Also at the functional ecological level, the planktonic blooms are both beneficial and harmful for the marine biota. Possibly this diversity of planktons adds to the stability of the marine community, apart from generating a rich source of energy for the higher trophic levels. Studies on the abundance and diversity of planktons may help to understand the food webs and subsequent links among the organisms inhabiting aquatic ecosystems like coastal and open oceans. The phytoplankton form the foundation stone of world fishery. The distribution and abundance of the commercially important fish and shellfish and their larvae are dependent on some species of the phytoplankton besides serving as their main

food source. Among the species of diatoms, *Fragilaria oceanica* and *Hemidiscus hardmanii* have been recorded to indicate the abundance of the clupeid fish, Hilsa in the Hooghly estuary and oil sardine, *Sardinella longiceps* in the west coast of India. Similarly the colonial diatom *Fragilaria antarctica* is known to indicate the abundance of the Antarctic Krill, *Euphausia superba*. Apart from the contribution of oxygen and removal of carbon-di-oxide in the atmosphere, there are various other substances and gases which are recycled by phytoplankton through a number of bio-geochemical cycles e.g. phosphorus, nitrogen, sulphur compounds etc. The production of organic matter is of utmost importance because it initiates the whole marine food chain that terminates in the larger fishes and sea mammals. Ecological studies on the estuaries and coastal seas in Indian sub-continent have been initiated in the early fifties. Since then, the contribution related to bioecology of planktons and other fish and

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crustacean landing is although substantial from Arabian sea along the west coast of India, such reports from Bay of Bengal of east coast, particularly north east coast is still in a state of infancy. In view of this and in continuation with the studies on the plankton in the coastal region of West Bengal, a survey was carried out during the period of May 2004 to May 2005 on the planktons to measure their diversity as well as temporal abundance.

MATERIALS AND METHODS

The study area (Fig. 1) extends from Talsari (Orissa, India) to Digha Mohana (West Bengal, India). Geographically the area is situated between 21°37' Northern latitude and 87°25' Eastern longitude to 21°42' Northern latitude and 87°31' Eastern longitude.

The collection of plankters was done by sampling the water from the seven stations between Talsari and Digha every two weeks interval at a depth of 0-2 meters with the help of a horizontal plankton tow (20mm mesh size and 30cm. diameter). The collected materials were kept in a mixture of 4% formaldehyde and sea-water and were brought to the laboratory for counting and identification. Following identification the number of plankters (species and abundance) was counted

with the help of a Sedgewick-Rafter counting chamber under a microscope ($\times 10 \times 10$). Identification of individual plankton species was done following Tomas (1997).

Total seven stations were selected and from each station water samples were collected to study the physico-chemical properties viz. water temperature, pH, dissolved oxygen, and salinity. Thermometer of standard type calibrated into centigrade scale (accuracy, 0.01° C) has been used to measure the surface water temperature. pH of water was estimated on board with the help of Lovibond comparator using BDH (England) colour disc and relevant indicator. The dissolved oxygen content of the sample water was estimated by standard modified Winkler's method as given by Stickland and Parsons (1969). Salinity was measured by using Salinity Refractometer (Erma, Japan).

After identification and counting, the samples were placed in freshly prepared formaldehyde and preserved in the laboratory. The data obtained on species variety and their relative numbers were subjected to statistical analysis following Zar *et al.* (1999) for measuring the diversity indices and correlation between plankton density and water quality parameters.

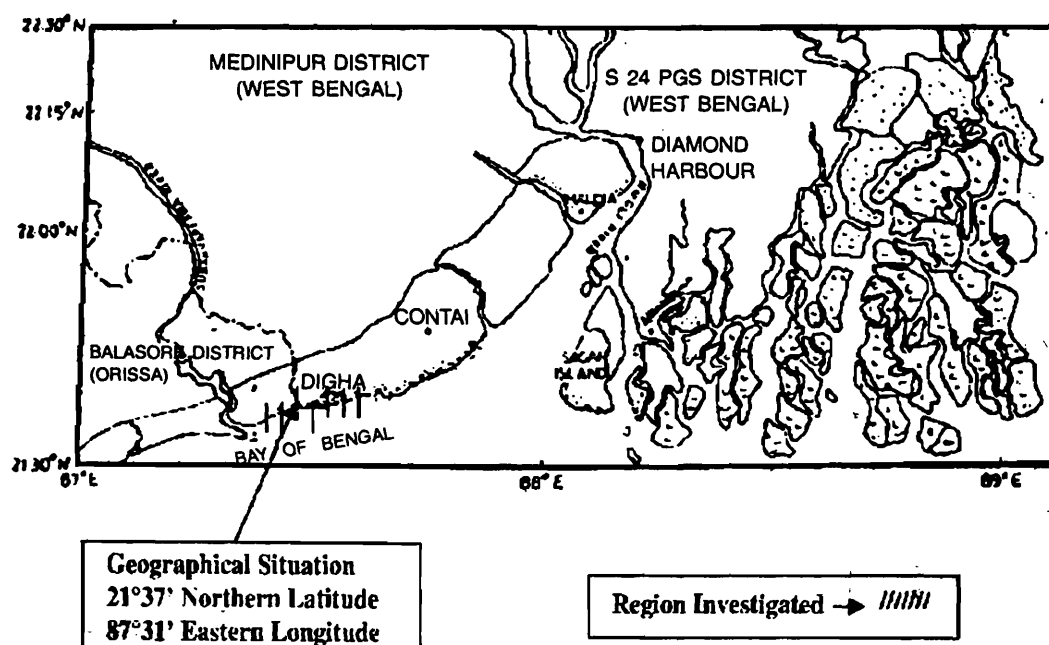


Fig. 1. Map of Coastal Region of West Bengal and part of Orissa, India (Source : CIFRI, Barrackpore, India)

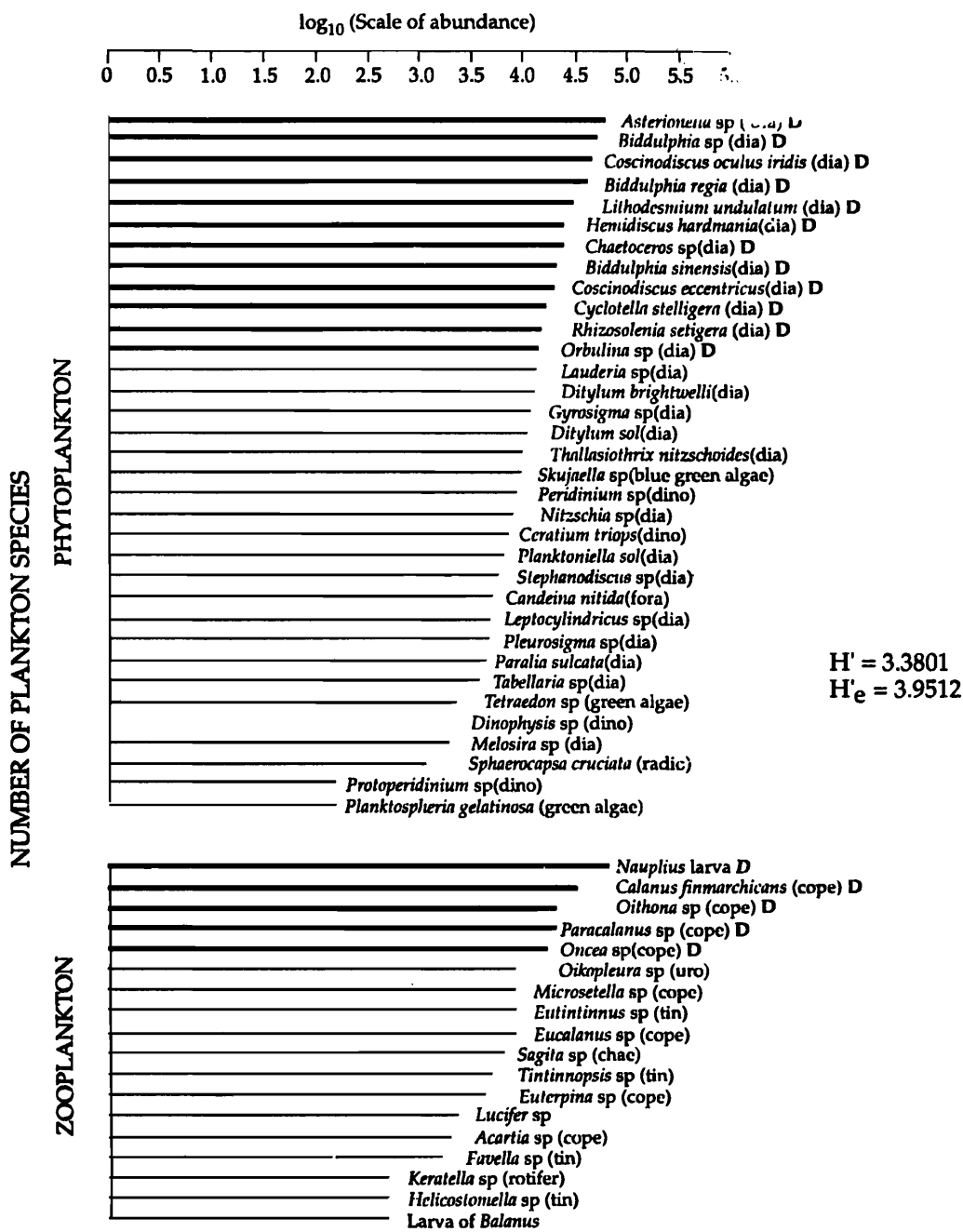


Fig. 2. Plankton species diversity and abundance in the Digha-Talsari coast. [dia—diatoms, dino—dinoflagellates, fora—forameniferans, radio—radiolarians, cope—copepods, uro—urochorda, tin—tintinnids] D indicates dominant species; Bold lines indicate the dominant plankton species

OBSERVATION AND DISCUSSION

A total of 52 plankton species were identified with variation in their relative abundance. Among them 24 species were Diatoms, 4 were Dinoflagellates, 2 Foraminiferans, one Radiolarian, two green Alga, eight Copepods, four Tintinnids, one Chaetognatha, one Urochorda and a group of Nauplii larvae. Depending on the relative abundance of planktons the log-normal rank abundance graph (Fig. 3) has been drawn which shows

that a maximum 19 plankton species belong to log 3.6 to log 4 in abundance value and 12 dominant (9 phytoplankton and 3 zooplankton) species among the 52 were noted, based on the cut of value of log 4.131 (Fig. 2). Amongst the phytoplankton species-, *Asterionella* sp, *Biddulphia* sp, *Biddulphia sinensis*, *Biddulphia regia*, *Cyclotella stelligera*, *Coscinodiscus oculus iridis*, *Coscinodiscus* sp, *Lauderia* sp, *Lithodesmium undulatum*, *Hemidiscus hardmanii*, *Rhizosolenia setigera*, were dominant (Diatom group) and *Calanus finmarchicus*, *Oithona* sp, *Paracalanus*

Rank	Log value	No of individuals
1	2-2.5	2
2	2.6-3	4
3	3.1-3.5	10
4	3.6-4	19
5	4.1-4.5	12
6	4.5-5	5

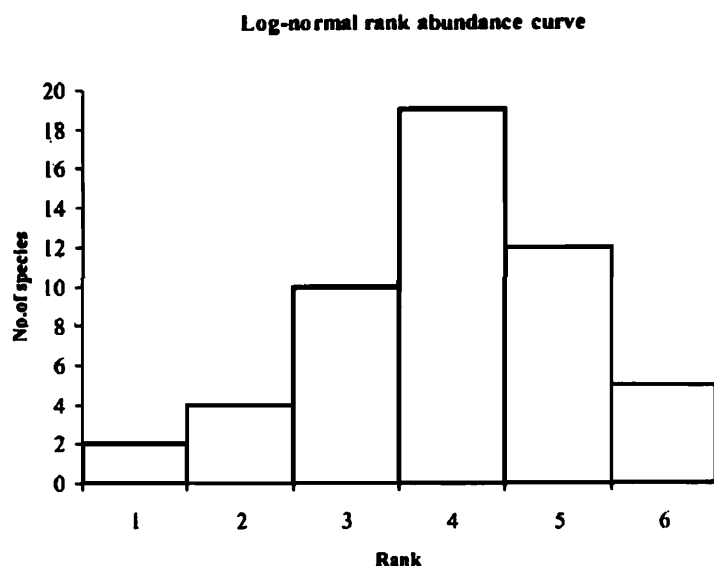


Fig. 3. Rank-abundance Graph for plankton species

sp, *Oncea* sp (Calanoid copepod) and the Nauplius larvae (of unidentified crustacean species) were dominant amongst the zooplankton species. To estimate the diversity of the collected sample, we have calculated the two important diversity indices –Shannon-Weiner index and Species evenness index. The Shannon-Weiner index (H') and Species evenness index (H'_e) based on this data are 3.3801 and 3.9512 respectively.

The present study summarizes the abundance of different phytoplankton and zooplankton in the Digha-Talsari offshore of Bay of Bengal. Taxonomically the copepods are found to be the most dominant one among zooplankton and diatoms amongst phytoplankton. Besides these we also found two hydrological parameter i.e. water temperature and salinity playing an active or passive regulatory role on the seasonal abundance of diatom and copepod population. During the study period we have also found some harmful phytoplankton-viz., *Nitzschia* sp, *Chaetoceros* spp. *Skujella thiebautii* among Diatoms and *Peridinium* sp and *Dinophysis* sp among dinoflagellates. The toxin producing phytoplankton and their blooms impart an adverse effect on the standing crop of higher trophic level. Though termination of planktonic blooms by the toxin producing plankton regulates the overall planktonic abundance by decreasing the zooplankton grazing pressure has been proposed (Chattopadhyay *et al.*, 2002).

But in several such situations in recent years it has been found that the abundance of phytoplankton itself is dependent on the nutrients available in water. The toxin producing planktons seem to be dependent on several nutrients for their blooming. Thus the role of environmental variables on abundance of phytoplankton needs to be addressed to understand the interactions of phytoplankton-zooplankton systems and diversity noted here.

The abundance of the diatoms and copepod can form the base for the food chain link to the secondary carnivores like the marine fishes, and other plankton feeding organisms of economic importance. Though the prey-predator relationship amongst the plankters themselves could not be studied individually but observing the abundance pattern, the copepods seem to be dependent on the diatoms (fig. 4) and may be responsible for regulating the population of less abundant species. This has been observed in the few studies carried out on the planktons of various regions. The environmental fluctuations have been found to play a key role in the oscillatory succession of the planktonic abundance in terms of the major taxa noticed would reveal about the probable interaction governing such variation in abundance.

ACKNOWLEDGEMENT

This work was supported by Indian Statistical Institute. Kolkata.

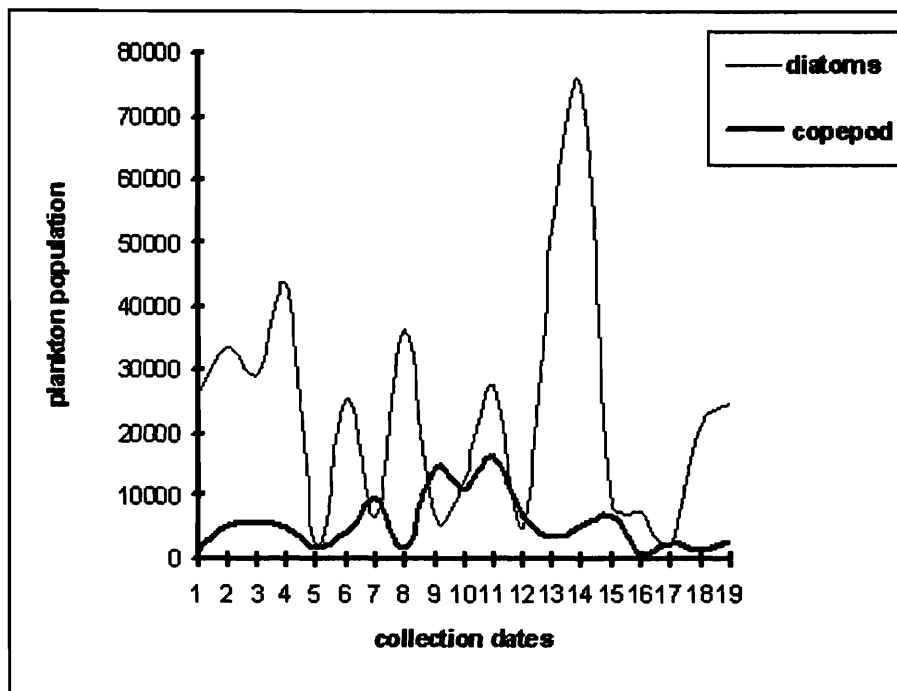


Fig. 4. Relationship between two dominant plankton species diatom (phytoplankton) and copepod (zooplankton)

LITERATURE CITED

- BLAXTER, J.H.S. and SOUTHWARD, A.J. 1997. *Advances in Marine Biology*, Academic Press, London, UK.
- CHATTOPADHYAY, J., SARKAR, R. and MANDAL, S. 2002. Toxin producing plankton may act as Biological indicator for planktonic blooms-Field study and mathematical modeling. *J. Theor. Biol.*, **215** : 333-344
- DAVIS, C.C. 1955. *The marine and freshwater plankton.*, Michigan State Univ. Press. p. 562.
- DHARANI, G., ABDUL NAZAR, A. K., KANAGU, P., VENKATESAWARAN, P., KUMAR, T.S. and RAVINDRAN, M. 2004. On the recurrence of *Noctiluca scintillans* bloom in Mannie Bay, Port Blair : Impact on water quality and bioactivity of extracts. *Curr. Sci.* **87**(7) : 990-994.
- HAWSER, S.P. and CODD, G.A. 1992. The toxicity of *Trichodesmium* blooms from Caribbean waters. In : "*Marine pelagic Cyanobacteria : Trichodesmium and other Diazotrophs*" Kluwer, Dordrecht, The Netherlands.
- JAMES, M.R. and HALL, J.A. 1995. Planktonic ciliated protozoa : their distribution and relationship to environmental variables in a marine coastal ecosystem. *J. Plankton. Res.*, **17** : 659-683
- KOCHSIEK, K.A., WILHM, J. L. and MORISON, R. 1971. Species Diversity of Net Zooplankton and Physiochemical Conditions in Keystone Reservoir, Oklahoma. *Ecology*, **52** : 1119-1125
- MITRA, A., BANERJEE, K. and GANGOPADHYAY, A., *Introduction to Marine Plankton* : 1-101.
- NEWELL, G. E. and NEWELL, R. C. 1979. *Marine plankton, A Practical guide*, 5th Edn.
- RAO, T.S.S., NAIR, V.R. and MADHUPRATAP, M., 1981. *Proc. Symp. Ecol. Anim, Popul. Zool. Surv. India*, **1**, 15-39.

- RATHOD, V., 2005. Distribution, abundance and vertical migration pattern of krill *Euphausia superba* Dana at fishing area 58 of the Indian Ocean sector of Southern Ocean, *Curr. Sci.*, **89** : 681-686
- RITSCHARD, R.L., 1992. Marine algae as a carbon di-oxide sink, *Water Air Soil Pollut.* **64** : 289-303.
- SARKAR, R.R. and CHATTOPADHYAY, J., 2003. Occurrence of planktonic blooms under environmental fluctuations & its possible control mechanism—mathematical model and & experimental observations. *Journal of Theoretical Biology*, **224**, 501-506.
- SRIVASTAVA. K. and PRAKASH. S. 2003. Spatio-temporal variation of phytoplankton in river Mahanadi. *J. Inland Fish Soc. India.*, **35**(1) : 53-57.
- STICKLAND, J.D.H. and PARSONS, T.R. 1969. *A practical handbook of sea water analysis*, Bull. 167., Fisheries Research Board of Canada.
- TAYLOR, F.J.R, TAYLOR, N.J. and WALSBY, J.R. 1985. *International review der Gesamten Hydrobiology*, **70** : 773-795.
- TOMAS, C.R. 1997. *Identifying marine diatoms and dinoflagellates*. A.P. San Diego. C.A., : 858.
- ZAR, H.J., BROWER, E. and VANHOLD. C.N., 1999. *Field and laboratory methods for General ecology*, 4th Ed., : 1-273.

THE GENUS *DROSOPHILA* (DIPTERA : DROSOPHILIDAE) IN FOUR DISTRICTS OF WEST BENGAL, INDIA

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ABSTRACT

The composition and abundance of *Drosophila* species, found in four districts of West Bengal are described. A well standardized sampling procedure applied on four different areas resulted in 684 samples. All males collected were identified by analyses of the genitalia. The progenies obtained from single gravid females were mainly used for the analysis of species identification and this being the only data set used in present investigation. Twenty five species were detected amongst the 7,389 males analyzed. From them 76% could be identified as described species. On an average identified species were almost 7 times more abundant than unidentified ones and this difference was significant. One unidentified species is undescribed. The results illustrate the large richness of *Drosophila* species in the W. Bengal state, India. It also indicates that more than 24% of the species in the region remain to be described.

Keywords : Diversity, *Drosophila*, new species

INTRODUCTION

The dipteran family Drosophilidae includes over 3000 described species that are distributed all over the world (Throckmorton, 1975; Wheeler, 1986). Observations and experiments over nearly a century have revealed an astounding breadth of morphological, ecological and behavioral diversity of *Drosophila* species. Most genera of Drosophilidae display high degrees of sexual dimorphism, including hypercephaly (Grimaldi and Fenster, 1989), extensive foreleg and mouth part modification (Carson *et al.*, 1970), and wing pattern diversity. The bulk of ecological and behavioral data suggested that the variety of ecological niches, occupied by Drosophilidae may be the causative factors for their morphological diversity (Markow and O'Grady, 2005). Though most species of the family breed in decaying fruits, plant and fungal matter (Carson, 1971; Heed, 1968, 1971; Grimaldi and Nguyen, 1999)

some are predatory, feeding other insect larvae and even frog and spider embryos (Ashburner, 1989). The wealth of interspecific diversity in this family has therefore long been attracted to the attention of good number of both taxonomists and ecologist.

Eberhard (1985) analyzed group of animals where either primary or secondary external male genitalia are used to distinguish species. He suggested that the morphological traits directly involved in copulation, excluding internal reproductive organ (e.g. testes and accessory glands) act as a driving force for interspecific divergence. Accordingly, several taxonomist used *Drosophila* male genitalia, especially the aedeagus morphology as the criteria to recognize a species. Eberhard and Cordero (1995) and Civetta and Singh (1998) however indicated that higher divergence of reproductive traits is certainly not restricted to

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genital organs. Some other structures are also involved (Remsen and O'Grady, 2002). Therefore, geneticists have carried out tests of reproductive isolation in the laboratory and on the field with application of genetic markers. In many cases, when sibling species are detected on the basis of genetic markers or reproductive isolation, differentiation of the male genitalia is observed. Indeed, differentiation of male genitalia, especially the aedeagus, is used as a gross quality for a species most frequently applied to this taxon (Gupta and Panigrahy, 1987; Gupta and Sundaran, 1990; Kumar and Gupta, 1990; Powell, 1997; De and Gupta, 1994; Singh and Dash, 1998, Joshi *et al.*, 2005).

The *Drosophila* fauna of the oriental region is highly diverse (Singh and Gupta, 1977; Gupta, 1985; 1993, Singh and Negi, 1989; Singh and Dash, 1998; Singh *et al.*, 2004; Upadhyay and Singh, 2006). More than 150 species of Drosophilidae are so far known from India (Gupta 1985; 1993; Gupta and Panigrahy, 1987; Gupta and Sundaran, 1990; Kumar and Gupta, 1990; Singh and Dash, 1998; Joshi *et al.*, 2005). Unfortunately, the composition of *Drosophila* species diversity in West Bengal has never been worked out in detail. Thus, a vast area of great ecological interest in West Bengal, awaits exploration.

We have, therefore, made an attempt to study the composition and abundance of the *Drosophila* species found in the four districts namely-Hooghly, Howrah, Medinipur (in the manuscript we described Purba and Paschim Medinipur as Medinipur, see Fig. 1) and Kolkata of the West Bengal, India from 2005-2007. Our data reveal that 25 species belonging to 10 genera are distributed in four district of West Bengal. *Sopophora* group represented maximum number of species. *Replita* and other group of *Drosophila* are also abundant in the West Bengal. Multistate character study of species under each sub-genus was carried out. The list is an inventory of the *Drosophila* species group of in the four district of West Bengal, India.

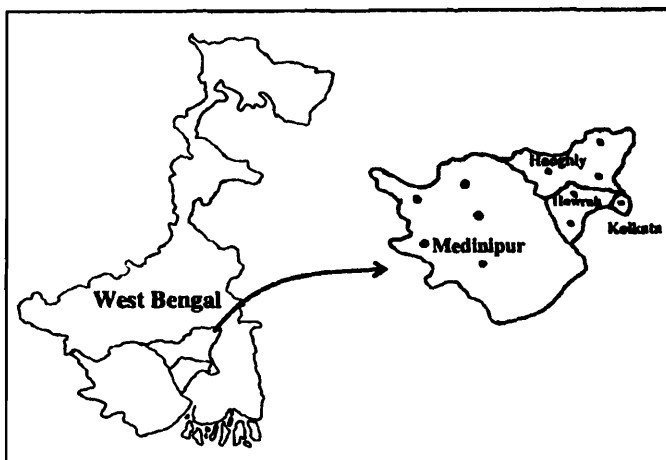


Fig. 1. Maps of West Bengal region showing collection sites.

MATERIALS AND METHODS

Samples were collected from four different districts of West Bengal from Jan 2005 to Jan 2007. Figure 1 shows the collection localities of the *Drosophila* sp. These localities not only differ in their microclimatic conditions but also in ecological conditions. Collections were largely made by using both trap-bait and net-sweeping methods. A variety of fermenting fruits such as banana, pine apple and orange were used as baits in order to obtain a wide spectrum of species. Several males and females of unidentified species were collected over rotten flowers and fruits in urban park in Kolkata. Other species were collected from bushes. The collected flies were brought to the laboratory for analyses.

In the laboratory, the flies were etherized, categorized and species were identified. The individual females that could not be identified at the first instance were isolated and allowed to breed in separate vials containing standard laboratory food medium. The progeny obtained from such single gravid females were used for species identification. All cultures were maintained on standard *Drosophila* medium at $24^{\circ}\pm 1^{\circ}\text{C}$. The unculturable specimens are preserved in 70% ethanol and stored in the laboratory.

RESULTS

A total of 7,389 *Drosophila* males were examined. Twenty five species were found : 14

from Kolkata, 6 from Hooghly, 11 from Howrah and 15 from Medinipur (i.e. from Purba and Paschim Medinipur). Nineteen of these were found to be as described species, based on figures of the male genitalia. The identified species are listed in Table-1. Data in Table 1 also show the total number of males/females per species along with their locality, as well as the references used for identification. Curiously, we observed that the invasive species *Zaprionus indianus*, Gupta is common in Kolkata and Howrah district. Figure-2 shows the distribution pattern of the 25 species in the four districts of West Bengal. As it appears from the figure, the recorded and unrecorded flies were higher in Medinipur (60%) and Kolkata (55%) areas.

Besides 19 known species, we also observed the occurrence of six unidentified species, which has never been registered before in India (Table -1). One new species is cultured in our laboratory (see Table-1) and named as *D. mukherjee*. The identification of the species were based on a comparison with the drawing of the aedeagus and of a holotype provided by Gupta (1993) and others.

Fig. 3 shows the morphology of the adult flies of the new species. The body color of the flies is black. The mean body length of male is 2.51 mm and female is 2.99 mm. This species closely resembles *Repleta* group. However, they are distinctly different from other *Drosophila* of the group in having arista branches, and

Table-1. Data showing the total number of male flies of each species and the collection sites. The references following the name of the each species correspond to the used references in identifications. In the numbers underlined the figure used represented a specimen from the type series.

Genus	Subgenus	species	No. of male <i>Drosophila</i> analysed from sample culture				
			Medinipore	Howrah	Hooghly	Kolkata	Total
<i>Drosophila</i>	<i>Sopophora</i>	<i>melanogaster</i> Meigen, 1830	57	155	173	222	607
"	"	<i>ananassae</i> Doleschall, 1858	821	972	753	1045	3591
"	"	<i>biplectinata</i> Duda, 1923	142	-	-	271	413
"	"	<i>kikkawai</i> , Burla, 1954	34	42	24	47	147
"	"	<i>takahashi</i> Sturtevant, 1927	6	5	-	-	11
"	"	<i>raychaudhuri</i> Gupta, 1969	21	9	-	17	47
"	"	<i>rajasekari</i> , Reddy & Krishnamurty, 1968	7	-	-	6	13
"	"	<i>seguyi</i> , Smart, 1945	11	-	-	6	17
"	"	<i>brunetti</i> , Raychaudhuri & Mukherjee, 1941	-	-	-	21	21
"	"	<i>malerkotliana</i> , Prasad & Paika, 1964	87	18	-	51	156
"	"	<i>trunkata</i> , Okada, 1964	27	-	-	-	27
"	<i>Dorsilopa</i>	<i>buskii</i> , Coquillett, 1901	7	-	-	15	22
"	<i>Hirtodrosophila</i>	<i>pentavittata</i> , Gupta & Raychaudhuri, 1970	-	3	-	9	12

Table-1. Contd.

Genus	Subgenus	species	No. of male <i>Drosophila</i> analysed from sample culture				
			Medinipore	Howrah	Hooghly	Kolkata	Total
"	<i>Scaptodrosophila</i>	<i>bambuphila</i> , Gupta, 1971	3	4	5	5	17
	<i>Drosophila</i>	<i>repleta</i> , Wollaston, 1958	13	4	—	12	29
	"	<i>immigrans</i> , Sturtevant, 1921	10	—	6	—	16
	"	<i>nasuta</i> , Lamb, 1914	—	4	8	—	12
	"	<i>orissaensis</i> , Gupta, 1972	20	—	—	—	20
	<i>Zaprionus</i>	<i>Zaprionus indianus</i> , Gupta, 1970	—	674	—	892	1566
			A. Total no. of recorded male fly 6,744				
Unidentified							
<i>Drosophila</i> sp. I			uc	—	—	—	—
D. sp. II			uc	—	—	—	—
D. sp. III			—	uc	—	—	—
D. sp. IV			—	—	—	uc	—
D. sp. V			—	—	—	uc	—
D. sp. VI (<i>D. mukherjee</i>)			—	—	—	645	645
			B. Total no. of unrecorded male fly 645				
			Total No. of Male fly analysed (A + B) 7,389				

uv = Unculturable

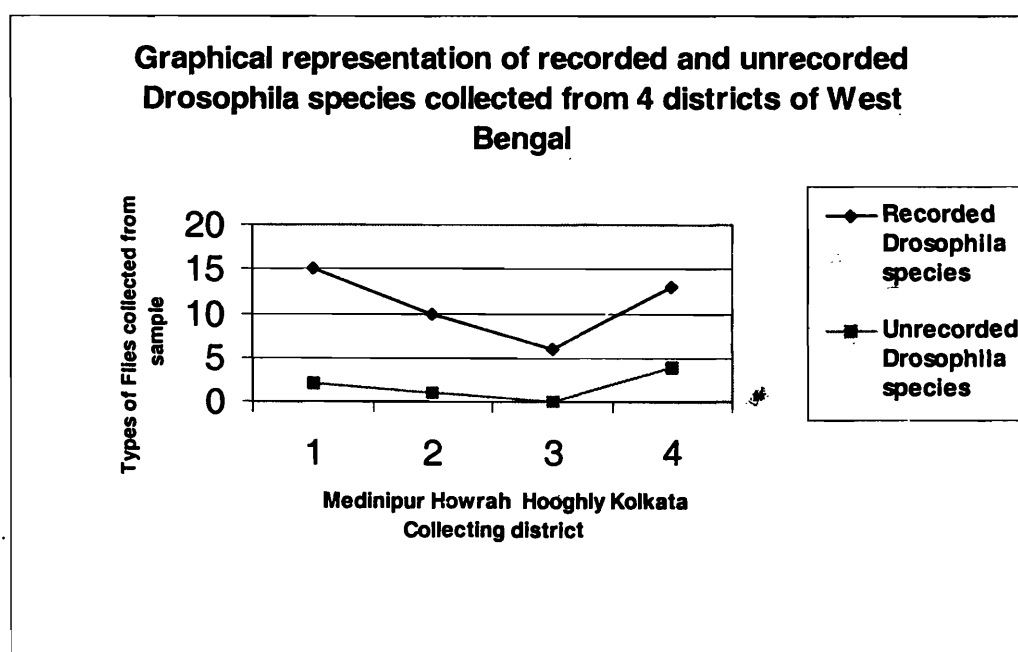
Fig. 2. Graphical representation of recorded and unrecorded *Drosophila* species collected from four districts of West Bengal.



Fig. 3. a-b. Photographs showing the morphology of the collected new species from Kolkata district of West Bengal, India. Figure 3a showing the dorsal view and (3b) ventral view of male and female of species. Note the black body color of the fly.

anterior gonapophysis and posterior lobe of male genital appendages. The detail description of the two species will be published elsewhere.

DISCUSSION

The data presented in this paper describe the spatial distribution of some *Drosophila* species in the four districts of West Bengal, India. It may be noted here that as the restriction of the use of only one type of bait, one kind of trap, and the inclusion of all sampling points to a homogenous area (except for the gradient studies) could have limited the chance to capture different species, we have used several collecting methods for the present investigation. Our results clearly show that samples obtained by employing all collecting methods may provide more accurate data in species inventories of *Drosophila*, with the additional advantage that it is possible to quantify sampling efforts.

Large proportion of an inventory usually consists of rare species, and many species are detected on the basis of only a few individual.

In contrast, the higher number of species found in our inventory probably reflected the sensitivity of our identification method. Thus, the proportion of species detected with higher values in the four districts. The chance of detecting a species also diminishes as the list of species already detected increases, because of the increasing probability of its resembling a species detected in other parts of India. It has been reported that some species were not detected in the previous inventory of the same region (Gupta 1985, 1993). We believe that such species may have been overlooked because they were very similar to more abundant species already present in the list. Gupta and his co-workers (Gupta and Panigrahy 1987; Gupta, 1993; Gupta and Sundaran 1990, 1995; Singh *et al.*, 2004) also suggested that the low occurrence of *Drosophila* species in previous inventories in near by areas reflects its frequent inclusion in an unidentified group. Maximum sensitivity is therefore essential for the method used to detect species in an inventory project. Our results also indicate that the concentration of the identification effort on the male genitalia provides better results than when this criterion is applied only when doubts appear during identification based on external morphology, as is usually done.

In brief, we have identified 19 described species (76% of the total) from the four districts of West Bengal, India. In reality, the proportion of identified species were 60% in Medinipur, 40% in Howrah, 30% Hooghly and 52% from Kolkata.

Some of our unidentified species have probably already been described. Five species have not been recognized because of the lack of detailed representation of aedeagus in the literature and they are probably a minority. One new species of this group is maintained in our laboratory. This species is undescribed and include unillustrated genitalia. It is therefore reasonable to suggest that majority of unidentified species are in fact undescribed.

In summary, our data reveal that the combined use of standerized collecting procedures and a technique with a high and

consistent sensitivity for species identification allows us to quantify biological diversity in West Bengal, India. This approach highlights the great diversity of *Drosophila* species in different districts of West Bengal, India. Moreover, it indicates that least about 25% of the species in this region remain to be described. *Drosophila* genus is an exception between the mega diversified taxa of small forest dwelling invertebrates, by having received a significant taxonomic attention. Thus, our conclusions illustrate the actual state of knowledge about four districts of West Bengal biota, from which the proportion of

described species is estimated to be more. Moreover, it shows that *Drosophila* genus still needs intensive taxonomic effort as the most of our taxa.

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LITERATURE CITED

- ASHBURNER, M. 1989. *Drosophila* : A laboratory Handbook. Cold Spring. Harbor Laboratory Press, New York.
- CARSON, H. L., 1971. The ecology of *Drosophila* breeding sites, Harold L. Lyon Arboretum Lecture Number Two, University of Hawaii : 1-27.
- CARSON, H. L., HARDY, D. E., SPIETH, H. T., and STONE, W. S. 1970. The evolutionary biology of the Hawaiian Drosophilidae. In (Hecht, M. R. and Steere, W. C. Eds.), Essays in Evolution and genetics in Honor of Theodosius Dobzhansky. Appleton-century-Crofts, New York, : 437-543.
- CIVETTA, A. and SINGH, R. S. 1998. Sex and speciation : genetic architecture and evolutionary potential of sexual versus non-sexual traits in the sibling species of the *Drosophila melanogaster* complex. *Evolution*, 52 : 1080-1092.
- DE, A. and GUPTA, J. P. 1994. The genus *Hypselothyrea* from India (Diptera : Drosophilidae). *Proc. Zool. Soc. Calcutta*, 47 : 53-56.
- EBERHARD, W. G. 1985. Sexual Selection and Animal Genitalia. Harvard University Press. Cambridge.
- EBERHARD, W. G. and CORDERO, C. 1995. Sexual selection by cryptic female choice on male seminal products—a new bridge between sexual selection and reproductive physiology. *Trends Ecol. Evol.*, 10 : 493-496.
- GRIMALDI, D and FENSTER, G. 1989. Evolution of extreme sexual dimorphisms : structural and behavioral convergence among broad headed male Drosophilidae (Diptera). *Am. Mus. Nov.* 2939 : 1-25.
- GRIMALDI, D. and NGUYEN, T. 1999. Monograph on the spittlebug flies, genus *Cladochaeta* (Diptera : Drosophilidae : Cladochaetini). *Bull. Am. Mus. Nat. Hist.*, 241 : 1-326.
- GUPTA, J.P. 1985. Further additions to the list of drosophilid species from India. *D.I.S.*, 61 : 86-88.
- GUPTA, J. 1993. A consolidated list of the Indian species of Drosophilidae. *D.I.S.*, 72 : 87.
- GUPTA, J. P. and PANIGRAHY, K. K. 1987. Some further additions to the list of Indian fauna of Drosophilidae. *Proc. Zool. Soc. Calcutta*, 36 : 57-66.

- GUPTA, J. P. and SUNDARAN. 1990 Further record of two new and one known species of *Drosophila* (Diptera : Insecta) from Karnataka, India. *Proc. Zool. Soc. Calcutta*, **43** : 31-35.
- HEED, W. B. 1968. In : Ecology of the Hawaiian Drosophilidae, Vol. 6818. Univ. Texas Publ. pp. 387-419.
- HEED, W. B. 1971. Host plant specificity and speciation in the Hawaiian *Drosophila*. *Taxon* **20** : 115-121.
- JOSHI, M., FARTYAL, R. S. and SINGH, B. K. 2005. A report on two new and two unrecorded species of *Drosophila* from Mukteshwar, Kumaon India (Diptera : Drosophilidae) *Entom*, **30** : 75-84.
- KUMAR, A. and GUPTA, J. P. 1990 Four new species of Drosophilidae (Diptera : Insecta) from Sikkim, India. *Proc. Zool. Soc. Calcutta*, **43** : 25-30.
- MARKOW, T. A. and O'GRADY, P. M. 2005 Evolutionary Genetics of reproductive behaviour in *Drosophila* : Connecting the dots. *Ann. Rev. Genet*, **39** : 263-291.
- POWELL, J. R. 1997. Progress and Prospects in Evolutionary Biology : The *Drosophila* Model. Oxford University Press, New York.
- REMSEN, J. and O'GRADY, P. 2002. Phylogeny of Drosophilinae (Diptera : Drosophilidae) with comments on combined analysis and character support. *Mol. Phylo. and Evolu.*, **24** : 249-264.
- SINGH, B. K. and GUPTA, J. P. 1977. Two new and two unrecorded species of the genus *Drosophila* fallen (Diptera : Drosophilidae) from Shillong, Meghalaya, India. *Proc. Zool. Soc. Calcutta*, **30** : 31-38.
- SINGH, B. K. and NEGI, N. S. 1989. Drosophilidae of Garhwal region with the description of one new species. *Proc. Zool. Soc. Calcutta*, **40** : 19-26.
- SINGH, B. K. and DASH, S. 1998. Drosophilidae of Kumaun Region, India with the discription of four new species (Insecta : Diptera) *Proc. Zool. Soc. Calcutta*, **51** : 45-56.
- SINGH, B. K., DASH, S. and FARTAL, R. S. 2004. Revision of the species of the subgenus *Drosophila* (*Drosophila*) of the Kumaon region, India, with the description of eight new species (Insecta. Diptera, Drosophilidae) *Senckenbergiana Biol.*, **83** : 163-176.
- THROCKMORTON, L. H. 1975. The Phylogeny, Ecology and Geography of *Drosophila*. In King R. C. Ed.) *Handbook of Genetics*. Vol. 3. Plenum Press, New York, : 421-469.
- UPADHYAY, K. and SINGH, B. K. 2006 One new species and two new records of the subgenus *Dro-sophila* (Insecta : Diptera : Drosophilidae) from Kuimaon region, Uttaranchal, India. *Proc. Zool. Soc. Calcutta*, **59** : 195-202.
- Wheller, M. R. 1986. Additions to the catalog of the world's Drosophilidae. In ("M. Ashburner, J. N. Thompson and H. L. Carson eds.), the Genetics and Biology of *Drosophila*, Vol 3e. Academic press, London, : 1-105.

ZOOPLANKTON DIVERSITY OF FRESHWATER WETLANDS IN THE LATERITIC TRACTS OF SOUTH-WEST BENGAL, INDIA

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ABSTRACT

The environment of South-West Bengal is characterized by having hilly lateritic tracts endowed with rapidly depleting forest coverage, high temperature profile, low rainfall and turbid water bodies. An attempt has been made in the present paper to study species composition, density and distribution pattern of zooplankton from different wetlands along a stretch of about 150 kms. covering two districts of South-West Bengal viz. West Midnapore and Bankura. Altogether 7 wetlands having different morphometry and ecological conditions were selected for recording the zooplankton diversity in relation to the prevailing major ecological parameters. These wetlands can broadly be classified into four categories viz. an eco-restored forest-covered wetland at Gurguripal ecopark, two natural wetlands having different species composition of macrophytes and as well as different quantum of non-point pollution stress, one natural wetland devoid of any macrophyte and encircled by forest, one large culturable fish pond at the border of Midnapore and Garhbeta subdivision, one artificial impoundment at the foothill of Susunia hills receiving mining discharge and an important vast dam of Kangsabati river at Mukutmonipur of Bankura district. A total of 52 zooplankton have been recorded, of which Rotifera, Copepoda, Cladocera, Protozoa, Nematoda and Ostracoda harboured 28, 10, 9, 3, 1 and 1 species respectively along with unidentified larval stages. It has been found that Rotifer zooplankton showed their maximum abundance in all 7 different wetlands followed by Copepoda, Cladocera, Protozoa, Nematoda and Ostracoda. A total of 17 macrophytic vegetations have been found to occur in 7 wetlands, only Sarenga wetland was devoid of any macrophyte. Considerable variations in physicochemical parameters have been observed among all those wetlands, of which variations in dissolved oxygen (DO), turbidity (TDS), conductivity and alkalinity were more pronounced. All environmental parameters in relation to the assessed diversity revealed that there appeared no well marked effectiveness of any single environmental factor controlling the distribution of zooplankton. The different ecological parameters exhibited their effectiveness on some zooplankton forms but not on all. On the other hand, it was also noticed that there existed a distinct community interaction in different water bodies which was reflected by the significant positive correlations between different groups. Similarity indices revealed minimum relationship among different water bodies. The differential and spatial distributional pattern has been explained in respect to ecological, biotic and abiotic gradients.

Keywords : Zooplankton, lateritic tract, southern-West Bengal, ecological gradients, wetlands

INTRODUCTION

Biodiversity has become a password in the world nowadays. Biodiversity is not just the assemblage of flora and fauna but is also their genetic and habitat diversity. Exploring diversity of aquatic organisms is considered as an important tool in today's world not only for giving an impression about the productivity of

aquatic systems but also for acting as an important indicator of environmental changes. But the freshwater aquatic ecosystems are considered very much threatened especially in developing countries like India (Salam and Mahmood, 1988) because of several reasons such as—large scale abstraction of water for irrigation purpose, massive deforestation coupled with higher rate of erosion leading to

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the dumping of the eroded products into bed of several freshwater wetlands and thereby reducing the volume and depth of water body, discharge of human wastes as well as agricultural wastes to those unmanaged water bodies converting them into a eutrophicated one, multifarious human uses like bathing, washings, etc. (Pradhan *et al.*, 2006a).

An attempt has been made in this paper to explore diversity of zooplankton, an important biotic component of any aquatic system, from different contrasting wetlands located along a stretch of about 150 kms. covering two districts of South West Bengal viz. West Midnapore and Bankura. This paper also includes the study of species composition, density and distribution pattern of zooplankton, physicochemical parameters and morphometry of those wetlands.

Study sites

Altogether 7 wetlands having different morphometry and ecological conditions were

selected (Fig. 1) as sampling zones for recording the zooplankton diversity in relation to the prevailing major ecological parameters. These wetlands can be broadly classified into four categories on the basis of nature of human use viz. ecorestored, natural, man managed and artificial wetlands :

- A. an ecorestored forest-covered wetland at Gurguripal ecopark, located almost 9 kms. away (on Jhargram Road) from Midnapore town (22.25°N, 87.65°E), selected as study site I;
- B. two natural wetlands having different species composition of macrophytes as well as different quanta of non-point pollution stress located at Barwa, near Keranichoti, selected as study site II and Sundra, selected as study site III respectively; one natural wetland devoid of any macrophyte and encircled by forest, located at Sarenga, selected as study site V;
- C. one large man-managed pond primarily

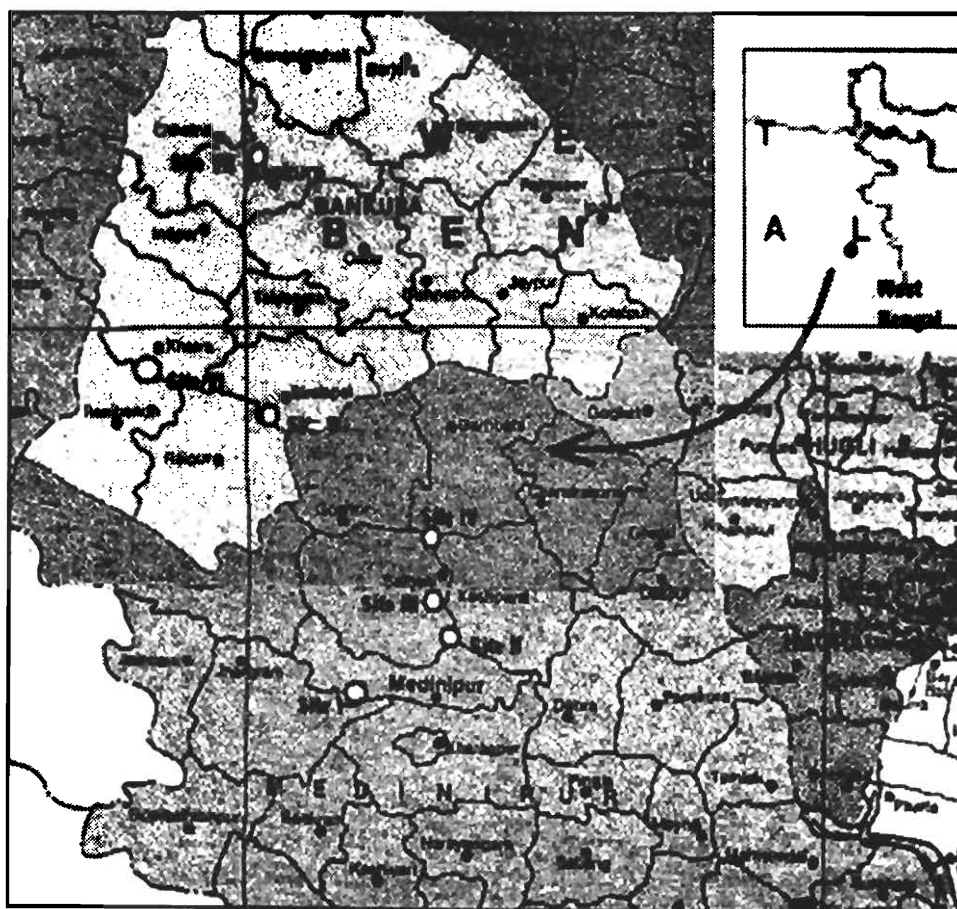


Fig 1. Map of Midnapore and Bankura districts showing the location of different study sites.

used for fish culture at Salboni, the border of Midnapore and Garhbeta subdivision, selected as study site IV;

- D. one artificial impoundment at the foothill of Susunia hills, Bankura, selected as study site VII, receiving mining discharge and having sparse macrophytes; and an important vast reservoir created by the dam on Kangsabati river at Mukutmonipur of Bankura district (23.25°N, 87.07°E), selected as study site VI.

Each study site included 4 sampling sites at different sides of each of the respective wetlands from where water samples were collected and averaged for further study.

MATERIALS AND METHODS

The Zooplankton (and phytoplankton) samples were collected at monthly intervals for 5 consecutive months starting from October 2006 till February 2007, preferably between 7 a.m. to 10 a.m. Collections were made from surface waters (limnetic part) of the water bodies at each sampling site with a plastic bucket (of 10 litres capacity), using a plankton net having 54 μ m mesh size. A total of 100 litres of water was filtered from each sampling site and poured into small clean plastic vials. 5% buffered formaldehyde was added at the rate of 4 drops per 15 ml to the samples for preservation (Schaden, 1985). The zooplankton were identified to the greatest possible taxonomic level (order/genus/species) following Michael and Sharma (1988); Sharma (1992); Battish (1992) and Pontin (1978). Quantitative study of zooplankton was done under a compound microscope and a trinocular phase contrast microscope (model no. Zeiss 1000 1098) with the help of Sedgewick Rafter counting cell and the values were expressed in numbers per litre.

Simultaneously physicochemical parameters of water of the selected study sites were analysed during the above mentioned period with the aid of indigenously designed water analyzer (Water quality checker TOW A 22 A, Japan). Further volumes of water were carried

in bottles for qualitative analysis through Standard methods (A.P.H.A. 1995). In some cases, some of the qualitative analyses was performed by certain apparatus viz. water temperature was measured with mercury glass thermometer in centigrades, pH with griph pH meter, available nitrogen with TOA-ion meter (IM-40s), phosphorus with a systronics-20 spectrophotometer, conductivity with conductivity meter (Systronics type 304), etc.

RESULTS AND DISCUSSION

Seven different wetlands located in different agroclimatic zones within a stretch of 150 kms. covering 2 districts of South-West Bengal display different morphology as outlined in Table 7. Out of those 7 wetlands, study site VI is unique in its expanse by having the largest area and greatest depth. The study sites I and V possess similar depth but their areas are varying as the former has a moderate area whereas the latter has the second largest water area. Study site VII ranks minimum from the point of both area and depth.

Species composition

The planktonic species identified so far and enumerated in the wetland ecosystems of South-West Bengal are listed in Table 1. It has been found that Rotifera showed their maximum abundance in all 7 different wetlands followed by Copepoda, Cladocera, Protozoa and some miscellaneous groups like Ostracoda and Nematoda. A total of 52 invertebrate Zooplankton have been recorded from the selected study sites, out of which Rotifera were represented by 28 species that belonged to 12 genera and 10 families namely Brachionidae, Lecanidae, Notommatidae, Trichocercidae, Asplanchnidae, Synchaetidae, Euchlanidae, Colurellidae, Filinidae and Philodinidae, according to Sharma and Michael (1980). The second most abundant group was that of micro crustacean zooplankton as class Copepoda, which comprised of 3 genera of order Cyclopoida, 6 genera of order Calanoida; and as Cladocera which was represented by 4 families namely Moinidae, Macrothricidae,

Chydoridae and Sididae with 6 genera and few unidentified larval stages of Crustacea i.e. nauplii. The presence of other phyla viz. Protozoa, Nematoda and Ostracoda which harboured 3, 1 and 1 species respectively were also marked at some of the study sites.

The only zooplankton omnipresent in the seven study sites were the different stages of nauplii which are yet unidentified as they are supposed to develop into either of the adult Crustacean groups as mentioned in Table 1. Among all the investigated areas, study site I was found to be most diverse with regard to species composition (highest species richness = 36) by possessing 22 species of Rotifera, 6 species of Cladocera, 2 species of Calanoida, 3 species of Cyclopoida and 1 species each of Protozoa, Nematoda and Ostracoda. Study site VI showed the second highest diversity (26) with a composition of 14 rotiferan species, 2 Cyclopoids, 1 Calanoid, 5 Cladocerans, 3 Protozoans and 1 Nematoda. Study site V harboured the third highest diversity (15) with a composition of 9 rotiferan, 1 Cyclopoid, 1 Calanoid, 2 Cladocerans and 2 Protozoans species. Study sites III and IV exhibited moderate plankton diversity having total number of species of 10 and 15 respectively, whereas study sites II and VII were poorly diverse having total number of species of 5 and 3 respectively. Notably, study site II, being located on roadside at the middle of a village, is largely interfered by local people for domestic purpose. Within a short span, this wetland which was full of water and was covered with macrophytes turned into an almost dried pond whose water was perhaps drained out for irrigation purpose, leading to loss of habitat for planktons. On the other hand, study site VII, as mentioned earlier, is an artificial impoundment built over barren land that was meant for temporary storage of rainwater streaming downhill and at the same time it happens to receive mining discharge from its surrounding, which has made it polluted and perhaps inappropriate for zooplankton inhabitation. This fact further strengthens the role of zooplankton especially Rotifera in biomonitoring (Sharma 2001). Although

Rotifera are the dominant group inhabiting these freshwater wetlands, only in study site III the crustacean planktons outnumbered non-crustacean ones. This finding is in agreement with the earlier findings and has certain adaptive significance (Balkhi *et al.* 1984; Kumar 1994 and Bath 1997). According to Syal (1991), copepods and cladocerans are tolerant groups of a wetland ecosystem and favour more stable environment (Allan, 1976; Schmid-Araya *et al.* 1992) and this indicates the stability of study site III. Occurrence of nematodes at study sites I and VI indicate the partial use of those wetlands for human or animal excretion. Also a small number of ostracods, which are an integral part of any freshwater community, were found only at study site 1.

Table 2 lists the number of individuals that were counted in each group of zooplankton. Such quantification has been elaborated as relative abundance of 6 major groups, viz. rotifera, copepoda, cladocera, protozoa, nauplii and miscellaneous species, separately at seven study sites with the help of charts in Figure 2. Worth mentioning in this study is that the larval forms-nauplii should have been considered as a part of crustacean groups, but due to their notable percentage of existence within the planktonic community, they have been simply pooled out as another countable group. Here rotifers seem to be the most abundant groups at all study sites except the reverse case in study sites II and VII, wherein nauplius population are found to exceed the rest of groups. All major groups were present, although in varying percentages, at study sites I and VI, whereas study site VII had the minimum variety of zooplankton. Study sites I, III, V and VI possessed the least percentage of protozoa and all other groups were dominated by rotifers. The miscellaneous groups were absent in study sites II, III, IV, V and VII but they were present in a higher percentage at study site VI as compared to rest of the sites. Study site IV showed the least percentage of cladocera and nauplii.

Macrophytes play a vital role in the physicochemical nature of wetlands and phytoplanktonic and zooplanktonic abundance

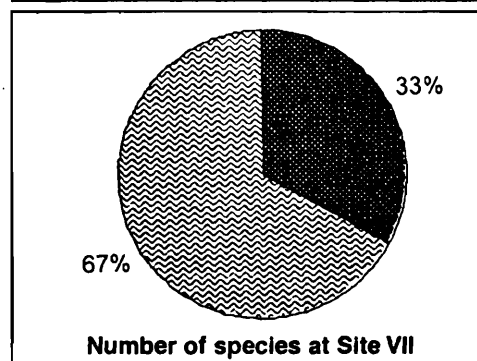
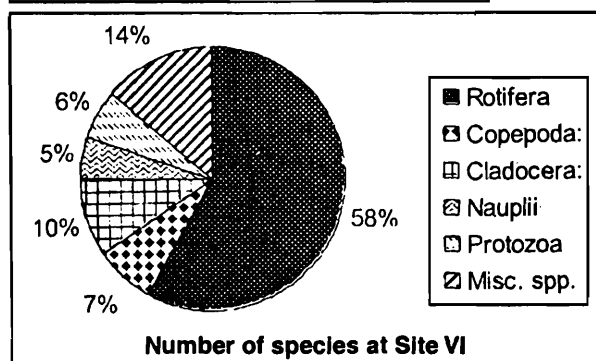
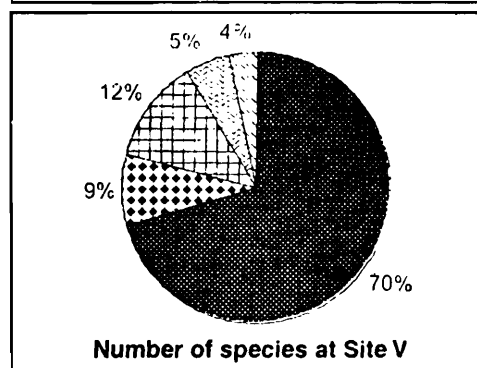
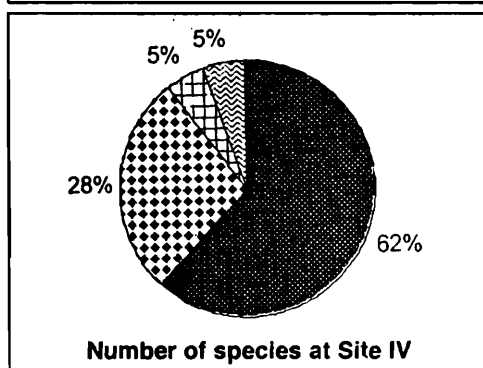
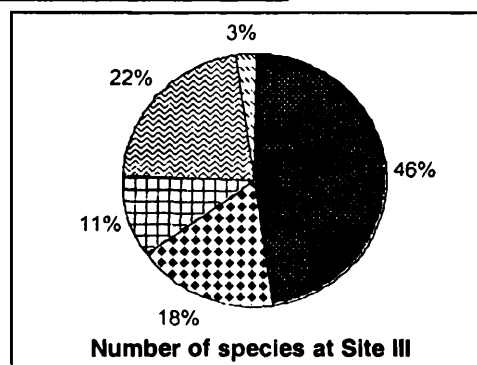
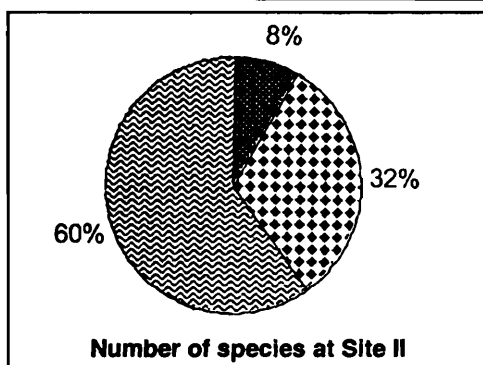
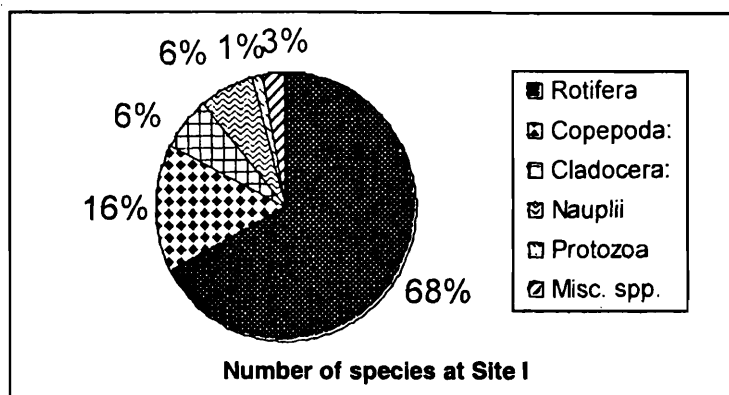
Table 1. Occurrence of Zooplankton species at 7 study sites of South-West Bengal during 2006-2007

Group	Family	Sr. no.	Species	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
Rotifera	Brachionidae	1.	<i>Brachionus calyciflorus</i>	+			+		+	
		2.	<i>Brachionus angularis</i>	+	+		+			+
		3.	<i>Brachionus caudatus</i>	+			+			
		4.	<i>Brachionus quadridentatus</i>	+				+		
		5.	<i>Brachionus forficula</i>	+				+	+	
		6.	<i>Brachionus rubens</i>				+			
		7.	<i>Brachionus diversicomis</i>	+			+	+		
		8.	<i>Keratella cochlearis</i>	+				+		
	Synchaetidae	9.	<i>Keratella tropica</i>			+	+	+	+	
		10.	<i>Keratella tecta</i>	-					+	
		11.	<i>Polyarthra</i> sp.	+		+		+	+	
		12.	<i>Lecane (Monostyla) bulla</i>						+	
	Lecanidae	13.	<i>Lecane (M.) quadridentata</i>	+						
		4.	<i>Lecane (M.)</i> sp." (Battish,1992)						+	
		15.	<i>Lecane lunaris lunaris</i>	+						
	Trichocercidae	16.	<i>Trichocerca</i> sp.	+				+	+	
	Asplanchnidae	17.	<i>Asplanchna priodonta</i>	+			+		+	
	Notommatidae	18.	<i>Cephalodella</i> sp.	+						
		19.	<i>Scaridium</i> sp.	+					+	
	Euchlanidae	20.	<i>Euchlanis</i> sp.	+					+	
	Colurellidae	21.	<i>Squatinella</i> sp.	+						
	Filinidae	22.	<i>Filinia</i> sp.	+				+	+	
	Philodinidae	23.	<i>Philodina</i> sp.	+		+				
		24.	Unidentified sp. 1	+						
		25.	Unidentified sp. 2						+	
	Unknown	26.	Unidentified sp. 3	+						
		27.	Unidentified sp. 4	+						
		28.	Unidentified sp. 5	+				+	+	
Estimated number of Rotiferan species				22	1	3	7	9	14	1

Group	Family	Sr. no.	Species	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
Copepoda	Cyclopoida	29.	<i>Mesocyclops sp.</i>	+		+			+	
		30.	<i>Paracyclops sp.</i>	+	+		+		+	
		31.	<i>Eucyclops sp.</i>	+		+				
		32.	Unidentified sp.		+		+	+		+
		33.	<i>Paradiaptomus sp.</i>		+					
	Calanoida	34.	<i>Neodiaptomus schmackeri</i>		+	+		+	+	
		35.	<i>Phyl/odiaptomus sp.</i>				+			
		36.	<i>Al/odiaptomus sp.</i>				+			
		37.	<i>Heliodiaptomus sp.</i>	+						
		38.	<i>Senecel/a calanoides</i>	+						
Estimated number of Cope pod species				5	4	3	4	2	3	1
Cladocera	Moinidae	39.	<i>Moina brachiata</i>	+			+	+	+	
		40.	<i>Moina flagel/ata</i>	+						
		41.	<i>Macrothrix sp.</i>					+		
	Chydoridae	42.	<i>Chydorus barroisi</i>	+						
		43.	<i>Chydorus hermanni</i>	+		+				
		44.	<i>Chydorus eurynotus br.</i>	+					+	
		45.	<i>Alona sp.</i>	+					+	
	Sididae	46.	<i>Leydigia sp.</i>						+	
47.		<i>Diaphanosoma senegal</i>			+			+		
Estimated number of Cladoceran species				6	0	2	1	2	5	0
	Protozoa	48.	<i>Arcel/a sp.</i>					+	+	
		49.	<i>Actinophrys sp</i>						+	
		50.	Unidentified sp.	+		+		+	+	
Estimated number of Protozoan species				1	0	1	0	2	3	0
	Nauplius		Unidentified larval stages	+	+	+	+	+	+	+
	Nematoda	51.	Unidentified sp.	+		+			+	
	Ostracoda	52.	Unidentified sp.							
Estimated number of miscellaneous species										0
Total number of Zooplankton species										3

Table 2. Quantification of major groups of Zooplankton (in nos./lt.) at 7 study areas

Zooplankton groups	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
Rotifera	94	2	54	36	40	47	1
Copepoda	22	8	20	16	5	6	0
Cladocera	9	0	12	3	7	8	0
Nauplii	9	15	25	3	3	4	2
Protozoa	2	0	3	0	2	5	0
Misc. spp. (Nematoda, Ostracoda)	4	0	6	0	0	11	0



* The zooplankton groups found to be absent (i.e. 0%) in a particular area have been excluded from the respective charts

Fig 2. Relative abundance of zooplankton at 7 study area

Table 3. Different physicochemical parameters at 7 study sites.

Parameters	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
Temp. (°C)	18.5	20.5	20	19	18.1	19	17.8
pH 7.82	6.99	7.43	7.69	8.25	9.4	9.1	
Alkalinity (mg/l)	105	112	110	65	95	90	96
Conductivity (mho/cm)	122	165	172	118	238	136	212
TDS (mg/l)	135	148	170	180	190	165	183
TSS (mg/l)	70	67	65	55	70	52	50
DO (mg/l)	5.48	4.95	4.84	4.92	5.32	5.06	4.3
BOD (mg/l)	1.98	2.21	2.32	2.32	2.02	2.02	1.89
COD (mg/l)	41	39	37	38	32	42	39
Total Kjeldahl Nitrogen (mg/l)	2.02	2.38	2.41	2.46	2.14	2.82	2.11
Total Phosphate phosphorus (mg/l)	0.174	0.169	0.176	0.176	0.148	0.162	0.155
Total Coliform (MPN/100ml)	540	1600	1600	920	920	540	350
Faecal Coliform (MPN/100ml)	220	540	540	350	540	170	220

(Pahari *et al.* 2000). A total of 17 macrophytic vegetations have been found to occur in 7 wetlands, out of which study site III had a maximum coverage of plants on its water surface. Study site I had maximum variety of macrophytes. Study sites IV and VI had sparse macrophytic inhabitation. Only the wetland at study site V was devoid of any macrophyte (Table 8).

The presence of phytoplankton was also observed in varying quantities at the different sites, of which study sites I, III, IV and VI had higher density of phytoplankton than the rest. The important phytoplanktonic algae represented by the family Chlorophyceae including Chlorococcales; Diatoms; *Volvox sp.*, *Spirogyra sp.*, *Pediastrum sp.* and few unidentified ones were also noted but not emphasized in the present study.

Physicochemical Characteristics

The physicochemical properties of water (Table 3) revealed considerable variations in all of these wetlands especially dissolved oxygen (DO), total dissolved solids (TDS), conductivity and alkalinity.

Interrelationships between zooplankton and physicochemical parameters with the help of correlation data

Table 4 displays correlation coefficients among various zooplanktonic groups. There

existed significant positive correlation between Rotifera and Copepoda ($r = 0.750$) and Cladocera ($r = 0.823$) which corroborates the findings of Sharma (2001) and Pradhan *et al.* (2006 b). Cladocera and Copepoda also showed significant positive correlation between themselves ($r = 0.601$). Worth mentioning is the significant correlation of Nauplii with Copepoda ($r = 0.547$) and Cladocera ($r = 0.433$) rather than any other groups strengthening the fact that nauplii are the larval stages of these microcrustaceans only and have no developmental relationship with Rotifera or metazoan parasites.

In addition, the temperatures recorded in our study has been pooled as a representation of winter and adjoining months which is not enough for drawing relations between temperature variations and zooplanktonic species resulting over various seasons. Thus emphasis is more on spatial comparison. Table 5 displays correlation coefficients between physicochemical parameters and zooplankton. From this table, the single effect of temperature seen to be exerted on any biotic variable of our study area is on density of nauplii ($r = 0.773$), which is also in corroboration with Hofmann's (1977) opinion that temperature has significant direct influence on embryonic development of an organism. By studying pH of various study sites, it seems that study sites VI and VII have the highest pH which might infer the alkaline

Table 4. Correlation coefficient between major groups of Zooplankton present in 7 study sites

Zooplankton groups	Rotifera	Copepoda	Cladocera	Nauplii	Protozoa	Misc. spp.
Rotifera	1					
Copepoda	0.591**	1				
Cladocera	0.928**	0.536**	1			
Nauplii	0.222	0.662**	0.453*	1		
Protozoa	0.748**	0.108	0.804**	0.1484	1	
Misc. spp.	0.619**	0.174	0.668*	0.214	0.927**	1

* Correlation is significant at 0.01 level (2-tailed)

** Correlation is significant at 0.05 level (2-tailed)

Table 5. Correlation coefficient between zooplankton and physicochemical parameters of 7 study sites

Parameters	Rotifera	Major Zooplankton groups			Protozoa	Misc. spp.
		Copepoda	Cladocera	Nauplii		
Temp.	-0.131	0.359	0.064	0.773**	0.033	0.171
pH -0.055	-0.596**	-0.009	-0.651 **	0.428	0.408	
Alkalinity	0.040	0.073	0.214	0.663**	0.145	0.124
Conductivity	-0.461 *	-0.637**	-0.165	-0.097	-0.150	-0.404
TDS	-0.421 *	-0.511 *	-0.143	-0.3 78	-0.100	-0.271
TSS 0.416	0.458*	0.375	0.460*	-0.004	-0.202	
DO 0.734**	0.479*	0.531 **	0.014	0.383	0.207	
BOD	-0.023	0.533**	0.142	0.590**	-0.124	-0.049
COD	0.155	0.160	-0.068	-0.003	0.205	0.527**
Total Nitrogen	-0.110	-0.079	0.129	0.074	0.530**	0.648**
Total Phosphate	0.380	0.845**	0.244	0.569**	-0.052	0.190
Total Colifonn	-0.182	0.318	0.1 09	0.804**	-0.117	-0.131
Faecal Coliform	-0.237	0.106	0.058	0.563**	-0.225	-0.402

* Correlation is significant at 0.01 level (2-tailed)

** Correlation is significant at 0.05 level (2-tailed)

nature of the wetlands at Bankura, whereas the rest of them moreorless had pH approaching neutrality. The pH factor also lacked positive correlation with any of the biotic or abiotic parameters which is again in accordance with Hoffmann (1977) stating that although pH varies in space and time, little is known about its influence on population dynamics of rotifers. pH showed significant negative correlation with larval forms and copepods ($r = -0.651$ and 0.596 respectively) as well as with TSS, BOD, Phosphorus, total and faecal coliform count ($r = -0.672$, -0.714 , -0.605 , -0.811 and -0.713 respectively). This implies that nauplii developing into copepods prefer relatively low pH for their proliferation and not higher pH

i.e. alkaline waters. Alkalinity was only found to have significant positive correlation on larval stages like nauplii ($r = 0.663$). Another strong negative correlation observed was between copepod density and conductivity ($r = -0.637$) but the reason is not very clear, whereas negative significant correlation at 1% level is exerted by conductivity and TDS on rotifer density ($r = -0.461$ and -0.421); also between TDS and copepod density ($r = -0.511$). Thus it may be deduced that both rotifers and copepod prefer waters having low TDS i.e. they might have a liking towards transparent waters.

Since dissolved oxygen is an important determinant of the occurrence and abundance of rotifer communities (Dhanapathi, 2000), the

Table 6. Sorensen's Similarity indices between 7 study sites

Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	
Site I	X						
Site II	0.11	X					
Site III	0.15	0.17	X				
Site IV	0.16	0.70*	0.25	X			
Site V	0.18	0.15	0.21	0.35	X		
Site VI	0.12	0.08	0.16	0.06	0.20	X	
Site VII	0.07	0.40	0.18	0.22	0.17	0.00	X

Sorensen's quotient of Similarity value <0.5 => Dissimilar
>0.5 => Similar*

Table 7. The morphometry of the 7 studied wetlands.

Study site	Area	Depth
I	890 m. × 400 m.	10ft.
II	300 m. × 250 m.	6 ft.
III	150 m. X 750 m.	8 ft.
IV	280 m. × 220 m.	5 ft.
V	1500 m. × 500 ill.	9 ft.
VI	12000 m. × 6000 m.	100 ft.
VII	200 m. × 40 m.	4.5 ft.

Table 8. Occurrence of Macrophytes in 7 study sites

Name of Macrophyte	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
<i>Ludwigia parviflora</i>	+	-	-	-	-	-	-
<i>Scirpus articulatus</i>	+	+	-	-	-	-	-
<i>Oryza sativa</i>	+	-	+	-	-	-	-
<i>Brachiaria sp.</i>	+	-	-	-	-	-	-
<i>Juncus sp.</i>	+	-	+	-	-	-	-
<i>Nymphaea cristatum</i>	+	-	-	-	-	-	-
<i>Melastoma malabaricum</i>	+	-	-	-	-	-	-
<i>Cyperus sp.</i>	+	+	-	-	+	+	-
<i>Barleria sp.</i>	+	-	-	-	-	-	-
<i>Hydrilla sp.</i>	-	+	-	-	-	+	-
<i>Nymphaea nouchali</i>	-	-	+	-	-	-	-
<i>Eichhornia sp.</i>	+	+	-	-	-	-	-
<i>Utricularia sp.</i>	+	-	-	-	-	-	-
<i>Commelina bengalensis</i>	-	-	+	-	-	-	-
<i>Polygonum sp.</i>	-	-	+	-	-	-	-
<i>Alternanthera sp.</i>	-	-	+	-	-	-	-
<i>Tenhydra sp.</i>	-	-	+	-	-	-	-
Total no. of species	10	4	6	1	0	2	1

present study also revealed strong positive correlation of DO equally with rotifers, copepods and cladocerans ($r = 0.734, 0.479$ and 0.531). Simultaneously, BOD manifested strong

positive correlation with nauplii and copepod density ($r = 0.590$ and 0.533 respectively) but an inverse relationship with rotifers which was not statistically significant. Both COD and total

nitrogen exhibited significant correlation on the miscellaneous group ($r = 0.527$ and 0.648 respectively). The only zooplanktonic group showing least relation with any physicochemical parameter was that of the protozoans as they were observed to possess significant positive correlation with total nitrogen ($r = 0.530$). Significant positive correlation coefficient ($r = 0.845$) was found to exist between phosphorus and copepod density, and this might be an indication that the copepods prefer to live in water having high phosphorus content. Finally, worth mentioning is the significant impact of temperature on total and faecal coliform bacteria ($r = 0.866$ and 0.580), otherwise there exists no interference of these bacteria with the presence of zooplanktonic communities in the studied wetlands.

Similarity indices

Sorensen's index of Similarity given in table 6 with respect to various biotic components and abiotic parameters clearly indicate the contrasting nature of our 7 selected study sites as dissimilarities existed among those sites except study site II and IV which showed moderate similarity (S.S.I. value = 0.7). This implies that both these study sites have a similar size and depth and both of them suffer from anthropogenic interference influencing their abiotic attributes. This fact also strengthens the contrasting nature of the selected wetlands.

CONCLUSION

All environmental parameters in relation to the assessed diversity state that there appeared no well marked effectiveness of any single environmental factor controlling the distribution of zooplankton. The different ecological parameters revealed their effectiveness on some zooplankton forms but not on all. On the other hand, it was also noticed that there existed a distinct community interaction in different water bodies which was related by the significant positive correlation between different groups. All the zooplankton groups tended to occur as associated community rather than as isolated groups.

Similarity indices revealed minimum relationship among different water bodies except few moderate relationships. The differential, temporal and spatial distributional pattern of zooplankton population has been explained in respect to ecological, biotic and abiotic gradients prevalent in south-west Bengal.

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LITERATURE CITED

- ALLAN, J.D. 1976. Life history pattern in zooplankton. *The Am. Naturalist*, 110 : 165-180.
- APHA. 1995. American Water Works Association and Water environmental Federation. *Standard Methods for the examination of water and wastewater*. 19th ed. Washington DC. 2000
- BALKHI, M.H., YOUSUF, A.R. and QUADRI, M.Y. 1984. Rotifera of Anchar lake during summer and winter. *Geobios New Reports*, 3 : 163-165
- BATH, K.S. 1997. *Limnological studies on the Harike wetland ecosystem*. Doctoral thesis, Punjab Univ., Patiala, India.
- BATTISH, S.K. 1992. *Freshwater zooplankton of India*. Oxford and IBH publishing Co., New Delhi.
- DHANAPATHI, M.V.S.S.S. 2000. *Taxonomic notes on the rotifers from India (from 1889-2000)*. Pub., Indian Association of Aquatic Biologists (IAAB), Hyderabad, A.P., : 178.

- HOFMANN, W. 1977. The influence of abiotic factors on population dynamics in planktonic rotifers. *Arch. Hydrobiol. Beih., Ergebn. Limnol.*, 8 : 77-83.
- KUMAR, A. 1994. Periodicity and abundance of Rotifers in relation to certain physicochemical characteristics of two ecologically different wetlands of Santal Pargana, Bihar, India. *J Ecol.*, 21 : 54-59
- MICHAEL, R G. and SHARMA, B.K. 1988. *Indian Cla do cerna (Crustacea : Branchiopoda, Cladocera)*. Fauna of Indian and adjacent countries series. Publ. Zoological Survey of India, India.
- PAHARI, P.R, DUTTA, T.K. and BHATTACHARYA, T. 2000. Macrophytic and planktonic components of two contrasting wetlands in Midnapore district. *Environment & Ecology*, 18(1) : 196-201
- PONTIN, RM. 1978. *A key to the freshwater planktonic and semi-planktonic rotifera of the British Isles*. Freshwater Biological Association, Scientific publication no. 38
- PRADHAN, P. and CHAKRABORTY, S.K. 2006. Diversity of Zooplanktonic rotifers of river Shilabati, West Midnapore district, West Bengal, India. *Aquacult*, 7(1) : 1-19
- PRADHAN, P., GIRI, S. and CHAKRABORTY, S.K. 2006. Ecological gradients determining the density and diversity of Rotifera in a freshwater river system of South West Bengal, India. *J Aqua. Biol.*, 21(1) : 19-28.
- SALAM, A. and MAHMOOD, J.A. 1988. Studies on physico-chemical parameters of river system in Chitral, Pakistan. *P. J. Zool. Abstract*, Series No. 18.
- SCHMID-ARAYA J.M. and ZUNIGA, L.R. 1992. Zooplankton community structure in two Chilean reservoirs. *Archiv. Fur. Hydrobiologie*, 123 : 305-335.
- SHARMA, B.K. 1992. Freshwater rotifers (Rotifera : Eurotatoria). In : *Fauna of West Bengal, State fauna series, Zool. Surv. India*, Calcutta, 3(13) : 1-121.
- SHARMA, B.K. 2001. *Biomonitoring and role of Rotifera*. In : *Water quality assessment, biomonitoring and zooplankton diversity* (Ed. B. K. Sharma, Department of Zoology, NEHU, Shillong) : 83-95.
- SHARMA, B.K. and MICHAEL, R.G. 1980. Synopsis of taxonomic studies on Indian Rotatoria. *Hydrobiologia*, 73 : 229-236.
- SYAL, J. 1991. *Analytical studies on aquatic ecosystem of river Satluj in and around Nangal (Punjab)*. M. Phil. Thesis, Punjab Univ. Patiala, India.

COMMUNITY STRUCTURE OF MACROBENTHIC MOLLUSCS OF THREE CONTRASTING INTERTIDAL BELTS OF MIDNAPORE COAST, WEST BENGAL, INDIA

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ABSTRACT

Thirteen species of intertidal macrobenthic molluscan species were recorded from different tidal levels (Low Tide level, Mid Tide Level and High Tide Level) of three intertidal belts viz. Junput, Sankarpur and Talsari of Midnapore coast, West Bengal. Community analysis like dominance, richness, diversity, evenness, similarity index and relative abundance were made. Among thirteen species, *Cerithidea cingulata* was the most abundant species throughout the year. The species diversity and species richness index were recorded maximum during monsoon season; while the evenness index and index of dominance were found to be higher during premonsoon. Maximum similarity was found in between low tide level and mid tide level in all study sites as revealed by similarity indices.

Keywords : Benthic molluscs, Intertidal belts, Midnapore coast, Community analysis.

INTRODUCTION

The intertidal belt of Midnapore district supports a galaxy of macrobenthic fauna of which molluscs constitute an important component (Khalua *et al.*, 2003). The coastal belt of Midnapore district represents 27% (60 Km) of West Bengal coastal tract—extending along the Hooghly estuary from New Digha (at the confluence of river Subarnarekha with Hooghly estuary) to the extreme South-West point of Midnapore District and then curving around Junput, Rosulpur, Khejuri and Haldia on the east to further North-East upto Tamluk or even Kolaghat on the bank of Rupnarayan. Several works have so far been carried out on macrobenthic molluscan faunal abundance, their ecology and population dynamics in different parts of India (Radhakrishna and Janakiram, 1975; Untawale and Parulekar, 1976; Ansari *et al.*, 1986; Das and Dev Roy, 1989; Mondal and Nandi, 1989; Subbha Rao *et al.*, 1995; Sunil Kumar, 1995; Surya Rao and Maitra,

1998; Lerberg *et al.*, 2000; Rajan and Murugan, 2001; Khan, 2003).

Although published documents are available on littoral molluscs from Sundarban mangrove ecosystem (Subba Rao *et al.*, 1987, 1992, 1995; Mondal and Nandi, 1989; Chakraborty and Chouhury, 1993; Eleftheriou, 2000); almost no such attempts have so far been made from the coastal tract of Midnapore, West Bengal, excepting the occasional report by Subba Rao (1977); Subba Rao *et al.*, (1992) and Bharati Goswami (1992). In the present paper, studies on the seasonal community organization of the macrobenthic molluscs from three tidal zones of respective three contrasting intertidal belts of the Midnapore coastal tract have been undertaken.

MATERIALS AND METHODS

The present study was carried out at three contrasting intertidal belts of Junput,

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Sankarpur, and Talsari (longitudinal extension 87°20' E to 88°5'E and latitudinal extension 21°30' N to 22°2' N). All three study sites possess different characteristics with regard to the textural composition of their intertidal zones. The study site-I (Junput) showed muddy substratum, while Sankarpur was with sandy and intertidal belt of Talsari was a blend of mud and sand. Different macrobenthic molluscs were collected at monthly intervals (July 2000 to June 2002) from the intertidal mudflats of Junput (S I), intertidal sandflats of Sankarpur (SII) and intertidal muddy-sandy zones of Talsari (SIII) during low tide (Fig. 1). Quadrats

having 0.5/m² area were established for the quantification of the molluscs. Random samplings were made at different spots at consistent positions along the transects traversing the intertidal zone of each study site. Three transects were established in tidal zones viz. Low Tide Level (LTL), Mid Tide Level (MTL) and High Tide Level (HTL) on a particular study site, each including five samples. The fauna inhabiting the soil were unearthed with the help of a shovel and sorted out by a sieve with a mesh size of 0.5 mm. The species were ranked in order of abundance. The most numerically abundant species was ranked

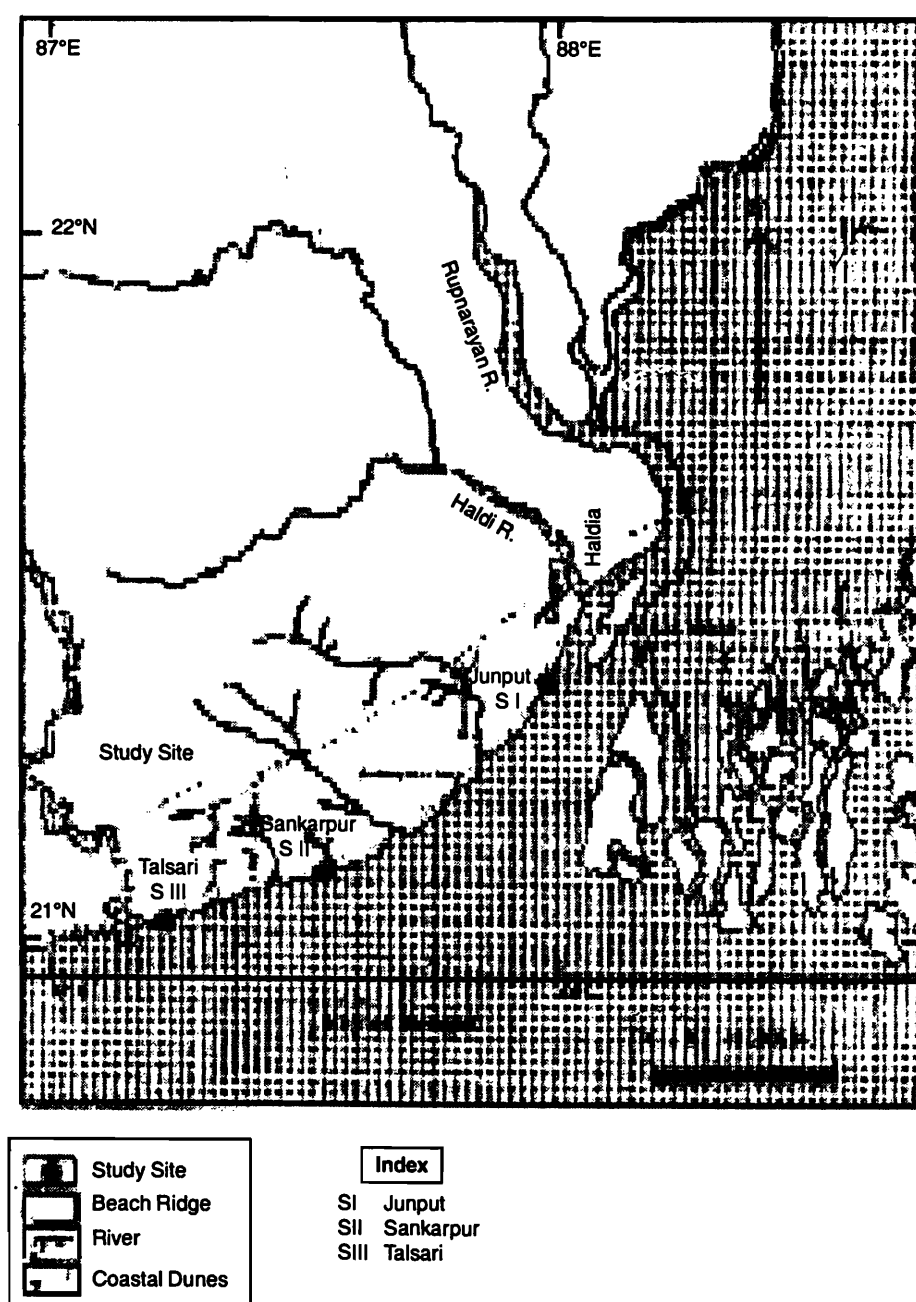


Fig. 1. Map of coastal tract of Midnapore District showing the location of different study sites

as one (Shaw *et al.*, 1983). Relative abundance (Tamura, 1967), index of dominance (Simpson, 1949), species richness index (Menhinick, 1964), species diversity index (Shannon and Wiener, 1963) and species evenness index (Pielou, 1966) were computed. Similarity indices of different tidal levels of different study sites were found out (Sorensen, 1984).

RESULTS AND DISCUSSION

The present study revealed the occurrence of thirteen macrobenthic molluscan species

from three selected study sites during July 2000 to June 2002 (Table-1) It was found that *Cerithidea cingulata* was the dominant species and exhibited higher abundance in study site I (64.92) followed by study site II (54.22) and study site III (49.49) and thereby enjoyed the first rank in all three study sites. This has been considered as more sensitive and simpler method of detecting the dominants in an assemblage of organisms (Shaw *et al.*, 1983).

Table 1. Occurrence and distribution of molluscan species along with their relative abundance and rank in selected study sites of Midnapore coast.

Sl. No.	Species	Junput (SI)		Sankarpur (SII)		Talsari (SIID)	
	Class GASTROPODA	Relative abundance	Rank	Relative abundance	Rank	Relative abundance	Rank
	Order MESOGASTROPODA Family ASSIMINEIDAE						
1.	<i>Assiminea brevicul</i> (Pfeiffer)	11.28	3			5.09	4
	Family LITTORINIDAE						
2.	<i>Littorina (Littoraria) melanostoma</i> Gray			5.60	4	3.76	6
	Family POTAMIDAE						
3.	<i>Telescopium telescopium</i> (Linnaeus)	19.36	2	2.98	2	20.06	2
4.	<i>Cerithidea (Cerithideopsis) cingulata</i> (Gmelin)	64.92	1	54.22	1	49.49	1
5.	<i>Cerithidea obtusa</i> (Lamarck)	1.46	5	5.36	5	3.26	8
	Family NATICIDAE						
6.	<i>Natica tigrina</i> (Roding)					2.03	9
7.	<i>Nassarius foveolatus</i> (Mss. Dunker Reeve)					8.04	3
	Family OLIVIDAE						
8.	<i>Amalda ampla</i> (Gmelin)					0.4	11
	Order SOLEOLIFERA Family ONCHIDIIDAE						
9.	<i>Onchidium tigrinum</i> Stoliczka	2.56	4			0.50	10
	Class BIVALVIA Order AROCOIDA Family AROCOIDA						
10.	<i>Anadara granosa</i> (Linnaeus)	0.41	6	3.89	6	3.36	7
11.	<i>Modiolus striatulus</i> (Hanley)					0.10	12
	Order VENEROIDA Family Donacidae						
12.	<i>Donax (Latona) incarnates</i> Gmelin			5.73	3		
	Family VENERIDAE						
13.	<i>Meretrix meretrix</i> (Linnaeus)			2.19	7	3.87	5

Species diversity index

Species diversity index ($\bar{H}$) is a measurement of relationship between number of individuals and number of species. Species diversity tends to be low in physically controlled ecosystems and high in biologically controlled ecosystems (Odum, 1977). The present study revealed that the species diversity index was highest in study site-III, followed by study site-I and study site-II. Monsoon registered the maximum species diversity index in all three tidal levels among all three study sites. This may help to reduce oscillations and hence increase stability in that season (Margalef, 1968). The measures of diversity are frequently seen as indicators of well being of ecological system. According to Wilhm and Doris (1968); the value of diversity index less than one was considered as an indicator of higher pollution. The present study exhibited that out of three study sites the diversity scores at study site-II were least and varied from 0.14-0.60 (Table -3); such scores in study site-I were moderate and ranged from 0.24-0.48 (Table-2); while in study site-III, it was maximum and varied from 0.11-0.79 (Table 4). Thus it can be stated that all three intertidal belts were under stress of pollution. In the present study, the comparatively higher $\bar{H}$ in LTL than MTL and HTL were supposed to be due to occurrence of more dominant species in LTL than MTL and HTL.

Species dominance index

In an intra-community assemblage, species or species groups normally controlling the energy flow and strongly affecting the prevailing environment of all other species in a community are known as ecological dominants (Chakraborty and Chowdhury, 1994). A dominant species in a community may exert a powerful control over the occurrence of other species. The degree to which dominance concentrates in any species or species groups can be expressed by an appropriate index of dominance (Odum, 1977; Krebs, 1985). Among the three study sites, the dominance index was maximum in study site-I followed by study site-III and study site-II at LTL. At MTL, this index was maximum in study site-III, followed by

study site II and study site-I. At HTL, this index was maximum and equal in study sites-I, II and III (Table 2, 3 and 4). It was found that during premonsoon, the communities at all three study sites were dominated by fewer species. The index of dominance value is always higher where the community is dominated by fewer number of species and lower when the dominancy is shared by large number of species (Whittaker, 1965). The present study endorses the above statement to show the minimum dominance value during monsoon and maximum in premonsoon.

Species richness index

Species richness index is expressed simply by the ratio between total species and total individuals. It is known to increase with increased complexity in a community and decrease where simplification occurs within a community (Bhattacharya and Bhattacharya, 1983). The value of richness index does not show any seasonal trend in any three study sites. It was maximum at study site-I (1.58), followed by study site-III (1.4) and study site-II (1.16) respectively (Table-2, 4 and 3). But it should be noted that the highest value of species richness was recorded from HTL than MTL and LTL respectively probably due to the occurrence of smaller number of individuals in HTL and less dominant species in HTL.

Species evenness index

Species populations or individual species organisms do not exist in nature by themselves only; instead they form a part of an assemblage of species population living together in a definite habitat enjoying the impact of certain ecological parameters of the locality (Krebs, 1985). The quantified seasonal changes in community structure were demonstrably associated with net population change of species. Dynamic events like recruitment and mortality, occurring at the population level were thus related to the seasonal changes in structure as observed at the community level (Holland and Polgar, 1976). Species evenness index is the expression of abundance, i.e. how equally the species are abundant. High evenness occurs, when species are equal or

Table 2. Seasonal variation of different community indices at Junput (S I) during monsoon 2000 to pre monsoon 2002.

Community Indices	2000 2001									2001 2002								
	Monsoon			Post monsoon			Pre monsoon			Monsoon			Post monsoon			Pre monsoon		
	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL
Dominance	0.43 index	0.44	0.62	0.68	0.46	0.48	0.51	0.51	1	0.50	0.32	0.68	0.57	0.40	0.44	0.48	0.47	0.63
Diversity	0.36 index	0.46	0.30	0.25	0.45	0.34	0.48	0.40	0.24	0.41	0.46	0.26	0.39	0.47	0.40	0.38	0.39	0.24
Richness	0.48 index	0.49	0.76	0.34	0.64	0.65	0.50	0.54	1.58	0.39	0.54	1.02	0.57	0.47	0.90	0.38	0.51	1
Evenness index	0.25	0.28	0.14	0.12	0.35	0.16	0.29	0.24	0.18	0.24	0.32	0.13	0.27	0.29	0.19	0.18	0.19	0.49

Table 3. Seasonal variation of different community indices at Sankarpur (S II) during monsoon 2000 to pre monsoon 2002.

Community Indices				2000-2001												2001 2002		
	Monsoon			Post monsoon			Pre monsoon			Monsoon			Post monsoon			Pre monsoon		
	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL
Dominance	0.35 index	0.35	0.65	0.47	0.36	0.60	0.35	0.62	1	0.41	0.27	0.54	0.40	0.46	0.78	0.38	0.55	1
Diversity	0.54 index	0.52	0.31	0.43	0.49	0.31	0.46	0.24	0.14	0.49	0.60	0.34	0.47	0.47	0.14	0.44	0.32	0.14
Richness	0.46 index	0.45	1.03	0.59	0.58	1.16	0.44	0.50	0.50	0.51	0.54	0.95	0.44	0.73	0.70	0.41	0.63	0.50
Evenness	0.78 index	0.86	0.45	0.61	0.81	0.65	0.97	0.81	0.17	0.71	0.86	0.73	0.79	0.67	0.54	0.93	0.67	0

Table 4. Seasonal variation of different community indices at Talsari (S III) during monsoon 2000 to pre monsoon 2002.

				2000-2001												2001 2002		
Community Indices	Monsoon			Post monsoon			Pre monsoon			Monsoon			Post monsoon			Pre monsoon		
	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL
Dominance index	0.36	0.20	0.34	0.41	0.86	1	0.50	0.57	0.50	0.21	0.28	0.39	0.49	0.64	1	0.50	0.53	0.12
Diversity index	0.73	0.79	0.53	0.50	0.11	0.13	0.34	0.27	0.30	0.79	0.67	0.49	0.41	0.28	0.19	0.35	0.36	0.21
Richness index	0.63	0.72	0.85	0.55	0.38	1	0.42	0.55	1.4	0.73	0.73	0.87	0.55	0.46	0.50	0.44	0.84	0.13
Evenness index	0.81	0.71	0.32	0.35	0.03	0.14	0.16	0.08	0.09	0.79	0.56	0.30	0.29	0.14	0.12	0.17	0.17	0.15

Table 5. Similarity index among different tidal levels of three study sites.

		S_1			S_2			S_3		
		LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL
S_1	LTL	X	90.91	66.67	60.00	66.67	66.67	26.67	37.5	28.57
	MTL	X	X	80.00	66.67	61.54	54.55	61.54	57.14	50.00
	HTL	X	X	X	44.44	54.55	75.00	44.44	60.00	100.00
S_2	LTL	X	X	X	X	83.33	44.44	53.33	35.29	28.57
	MTL	X	X	X	X	X	72.73	46.15	53.33	66.67
	HTL	X	X	X	X	X	X	44.44	72.73	100
S_3	LTL	X	X	X	X	X	X	X	66.67	28.57
	MTL	X	X	X	X	X	X	X	X	66.67
	HTL	X	X	X	X	X	X	X	X	X

virtually equal in abundance. In the present study, evenness index did not display any seasonality although the values were tended to be higher during premonsoon in all three study sites. It was found that high evenness occurred in study site-II (Table-3).

Similarity Index

The index of similarity envisages the measurement of degree of similarity between the communities of two habitats. In the present study, degree of similarity varied from 44.44% to 75% (in between study site-I and study site-II) and 26.67% to 100% (in between study site-I and study site-III) while it showed 28.56% to 100% (in between study sites-II and III). The higher similarity appeared to be due to the occurrence of muddy substratum in both the study sites. The index of similarity in the present communication revealed the highest affinity in between study site-I and II and in between study site-II and III which were supposed to be due to their similarity in environmental features and species composition

through different months, seasons and years during the study period. It was also observed that the similarity index in between LTL and MTL varied from 66.67% to 90.19% in different study sites. This value in between LTL and HTL ranged from 28.57% to 66%. In between MTL and HTL, it fluctuated from 66.67% to 80% in three study sites (Table 5). The maximum similarity found in between LTL and MTL, probably due to more or less similar textural components of the substratum and as per as the other physico-chemical parameters concerned that also revealed similar type of changes.

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LITERATURE CITED

- ANSARI, Z.A., INGOLE, S., BANERJEE, G. and PARULECAR, A.H. 1986. Spatial and temporal changes in benthic macro fauna from Mandovi and Zuari estuaries of Goa, West coast of India. *Indian Journal of Marine Science*, 15 : 223-229.
- BHARATI-GOSWAMI, B.C. 1992. Marine fauna of Digha Coast of West Bengal, India. *J. Marine Biological Association, India*, 34(1&2) : 115-137.
- BHATTACHARYA, T. and BHATTACHARYA, J. 1983. Community structure of soil Oribatida as influenced by industrial water. *Entom.*, 8(4) : 337-347.
- CHAKARBORTY, S.K. and CHOUDHURY, A. 1993. Community organization of macrobenthic molluscs of Sagar Island, Sundarbans, India. *Ind. Biol.* Vol xxv no. 1 : 33-36.
- CHAKARBORTY, S.K. and CHOUDHURY, A. 1994. Community structure of Macrobenthic polychaetes of Intertidal Region of Sagar Island, Hooghly Estuary, Sundarbans, India. *Trop. Ecol.*, 35(1) : 97-104.
- DAS, A.K. and DEV ROY, M.K. 1989. A general account of the mangrove fauna of Andaman and Nicobar Island. *Fauna of conservation areas* : In : *The Proceedings of Zoological Survey of India*. 4 : 173.
- ELEFTHERIOU, A. 2000. Marine benthos dynamics : environmental and fisheries impacts. *J. Marine Science*, 57 : 1299-1302.
- HOLLAND, A.F. and POLGAR, T. T. 1976. Seasonal changes in the structure of an intertidal community. *Mar. Biol.*, 37 : 341-346.
- KHALUA, R.K., CHAKRAVARTY, G., CHAKRABORTY, S.K. 2003. Annotated list of molluscs from the coastal tract of Midnapore District, West Bengal, India. *J. Marine Biological Association*, 45(2) : 245-249.

- KHAN, R.A. 2003. Population dynamics and biology of aquatic gastropod, *Gyraulus convexiusculus* (Hutton) in a small pond. *Rec. zool. Surv. India*, 101(Part 3-4) : 25-37.
- KREBS, C. L. 1985. Ecology : the experimental analysis of distribution and abundance. Third edition, Harper and Row Publishers, Inc. New York.
- LERBERG, S.B., FREDERICK HOLLAND, A. and SANGER, D.M. 2000. Responses of tidal creek Macrobenthic communities to the effects of watershed development. *Estu.*, 23(23) : 838-853.
- MONDAL, A.K. and NANDI, N.C. 1989. Fauna of Sundarbans mangrove Ecosystem, West Bengal, India. *Fauna of Conservation Areas*. : In : *The Proceedings of Zool. Surv. India*, 3 : 116.
- MARGALEF, R. 1968. Perspective in ecological theory. *University of Chicago Press, Chicago*, 111.
- MENHINICK, E. F. 1964. A comparison of some species diversity indices applied to samples of field insect. *Ecol.*, 45 : 859-861.
- ODUM, E.P. 1977. Fundamentals of Ecology. W.B. Saunders Co., Philadelphia and London.
- PIELOU, E .G. 1966. The measurment of diversity in different types of biological collections. *J. Theor. Biol.*, 13 : 131-144.
- RADHAKRISHNA, Y. and JANAKIRAM, R. 1975. The mangrove mollusca of Godavari and Krishna estuaries. In : (ed. R. Natarajan) Recent Reasearches in Estuarine Biology. Hindusthan Publication Crop., 177-184.
- RAJAN, M.K. and N. MARUGAN. 2001. Diversity of molluscan fauna of Arjuna river in relation to pollution, Sivakasi, Tamilnadu. *J. Aquat. Biol.*, 16(2) : 5-9.
- SORENSEN, T. 1984. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation of Danish commons. *Biol. Skr.* (eds. K. danske vidensk. Selsk. N. S.) 5 : 1-34.
- SHANNON, C. E. and WEAVER, W. 1963. *The mathematical theory of communication*. Urbana University of Illonois Press, 117.
- SHAW, K.M.; LAMBSHED, P.T.O. and PLATT, H.M. 1983. Detection of Pollution induced disturbance in marine benthic assemblages with special reference to Namatodes. *Mar. Ecol.*, 11 : 195-222.
- SIMPSON, E.H. 1949. Measurement of Diversity. *Nature*, 163 : 688.
- SUBBA RAO, N.V. 1977. Molluscs of Digha coast, West Bengal. 1 Gastropoda Newsl. *Zool. Surv. India*, 3(4) : 145-148.
- SUBBA RAO, N.V.; DEY, A. and BARUA, S. 1992. Estuarine and marine molluscs. *Fauna of West Bengal, State Fauna Series*, 3(Part 9) : 129-268. *Zool. Surv. India*.
- SUBBA RAO, N.V., SURYA RAO, K.V. and MAITRA, S.C. 1987. Malacological notes on Sagar Island. *Bull. zool. Surv. India*, 8(1-3) : 149-158.
- SUBBA RAO, N.V., SURYA RAO, K.V. and MANNA, R.N. 1995. Mollusca Wetland. *Fanna of Chilka Lake, Ecosystem Series*, 1 : 391-468. *Zool. Surv. India*.
- SUNIL KUMAR, R. 1995. Macrobenthos in the mangrove ecosystem of Cochin backwaters, Kerala (south west coast of India). *J. Marine Science*, 24 : 56-61.
- SURYA RAO, K.V. and MAITRA, S. 1998. *Mollusca Estuarine Ecosystem Series*, 3, Mahanadi Estuary : *Zool. Surv. Inaia*, 161-197.
- TAMURA, J. 1967. Some ecological observations on Collembola in Sappose, Northern Japan. *J. Fac. Sci. Hokkaido Univ. Zer. VI. Zool.*, 16(2) : 238-252.
- UNTAWALE, G. and PARULEKAR, A.H. 1976. Some observation on the ecology of estuarine mangroves of Goa, Mahasagar. *Bul. Nat. Inst. Oceanogra*, 13(3) : 215-223.
- WHITTAKER, R.H. 1965. Dominance and diversity in land plant communities. *Science* 147:250-260.
- WILHM, J. L. and DORRIS, T.C. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. *Ame. Mid. Nat.*, 76 : 427-449.

DIVERSITY OF RHOPALOCERA IN HASTINAPUR WILDLIFE SANCTUARY, UTTAR PRADESH, INDIA

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ABSTRACT

Thirty-six species of butterflies referable to twenty-eight genera and seven families i.e., Papilionidae, Pieridae, Danaidae, Satyridae, Nymphalidae, Lycaenidae and Hesperidae, are reported for the first time from Hastinapur Wildlife Sanctuary, Uttar Pradesh, India. First six families belong to superfamily Papilionoidea and last to the superfamily Hesperoidea.

Keywords : Rhopalocera, Papilionoidea, Wildlife, Sanctuary

INTRODUCTION

Hastinapur Wildlife Sanctuary lies along the banks of the Ganga in Western Uttar Pradesh. The sanctuary was established mainly to accord protection to Swamp Deer *Cervus duvauceli duvauceli*, the state animal of Uttar Pradesh, and to conserve the fast vanishing, unique biome, locally known as Gangetic Khadar. It is unique in that it contains a variety of landforms and habitat types such as wetland, marshes, dry sand beds and gently sloping ravines known as Khola. Till a few decades ago (before 1980s), the Gangetic Khadar had extensive tracts of tall wet and dry grass, and khola had luxuriant forests. However, today much of the natural vegetation has been lost due to industries, human settlements and cultivation. Thus, the so-called sanctuary is highly disturbed protected area. The sanctuary is located between 78° 08' 47'' E longitudes and 29° 32' 28'' N latitudes. The temperature varies from 0°-48° C and the rainfall is more than 1000 mm. The sanctuary supports 180 species of birds and the vegetation of the sanctuary can be classified into tall wet grasslands, dry short grasslands, scrub and plantations (Nawab, 2000).

The butterfly fauna of Uttar Pradesh has been previously studied by Marshall and de Niceville

(1882), de Niceville (1886, 1890), Bingham (1905, 1907), Evans (1932), Talbot (1939, 1947) and Wynter-Blyth (1957). A perusal of literature reveals that nothing is known about the insect fauna of the Hastinapur Wildlife Sanctuary. The present work is an attempt to provide a comprehensive account of Rhopalocera found in the Sanctuary. The article deals with an account of thirty-six species, twenty-eight genera and seven families i.e., Papilionidae, Pieridae, Danaidae, Satyridae, Nymphalidae, Lycaenidae and Hesperidae, of which first six belong to superfamily Papilionoidea and last to the superfamily Hesperoidea. All the species dealt with this account are reported for the first time from this sanctuary.

SYSTEMATIC ACCOUNT

Phylum ARTHROPODA

Class INSECTA

Order LEPIDOPTERA

Suborder RHOPALOCERA

Family 1. PAPILIONIDAE

Genus 1. *Papilio* Linnaeus, 1758

1. *Papilio demoleus demoleus* Linnaeus

1758. *Papilio demoleus* Linnaeus, *Syst. Nat.* (ed. 10) : 464.

1939. *Papilio demoleus demoleus* Linnaeus : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 189.

Common name : The Lime Butterfly.

Material examined : 2♂, Hastinapur Range, 10.ix.2005, Coll. N. Sharma; 2♂, 1♀, 13.ix.2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Bihar; Delhi; Orissa; Madhya Pradesh; throughout India (Wynter-Blyth, 1957).

Elsewhere : Pakistan, Sri Lanka and North Myanmar.

2. *Papilio polytes romulus* Cramer

1775. *Papilio romulus* Cramer, *Pap. Exot.*, 1 : 67.

1939. *Papilio polytes romulus* : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 178.

Common name : Common Mormon.

Material examined : 2♂, 10.ix.2005, 1♂, 1♀, 11.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Andaman and Nicobar; Delhi; Bihar; Tamil Nadu; Sikkim; Assam; Manipur; Meghalaya; Tripura; Nagaland; Lakshadweep; West Bengal; North-West Himalayas.

Elsewhere : Sri Lanka; Bangladesh; Myanmar.

Genus 2. *Graphium* Scopoli, 1777

3. *Graphium doson axion* C & R Felder

1864. *Papilio axion* C & R Felder, *Verh.zool.-bot. Ges. Wien.*, 14 : 305.

1939. *Graphium doson axion* : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 223.

Common name : The Common Jay.

Material examined : 1♂, 1♀, 10.ix.2005, Hastinapur Range, Coll. N. Sharma; 3♂, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; West Bengal; Sikkim; Assam; Tripura; Nagaland; Arunachal Pradesh.

Elsewhere : Bhutan; Burma; South China; Thailand; Vietnam.

Family 2. PIERIDAE

Genus 3. *Cepora* Billberg, 1820

4. *Cepora nerissa phryne* (Fabricius)

1775. *Papilio phryne* Fabricius, *Syst. Ent.*, : 473.

1939. *Cepora nerissa phryne* : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 362.

Common name : The Common Gull.

Material examined : 1♂, 10.ix.2005, 2♂, 1♀, 11.ix.2005, 3♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Assam; Bihar; Sikkim; Madhya Pradesh; Maharashtra; Tamil Nadu; North-West Himalayas.

Elsewhere : Nepal.

Genus 4. *Catopsilia* Huebner, 1819

5. *Catopsilia pomona* (Fabricius)

1775. *Papilio pomona*, Fabricius, *Syst. Ent.*, : 479.

1939. *Catopsilia pomona* : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 493.

1993. *Catopsilia pomona* : Varshney, *Oriental Ins.*, 27 : 362.

Common name : The Lemon Emigrant.

Material examined : 2♂, 11.ix.2005, 1♂, 14.ix.2005, 2♂, 1♀, 15.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Andaman and Nicobar; Delhi; Bihar; Maharashtra; Tamil Nadu; West Bengal; Nagaland; Tripura; North-West Himalayas.

Elsewhere : Sri Lanka; Pakistan and Myanmar; South China; Australia.

6. *Catopsilia pyranthe pyranthe* (Linnaeus)

1775. *Papilio pyranthe*, Linnaeus, *Syst. Nat.* (ed. 10) : 469.

1939. *Catopsilia pyranthe pyranthe* : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 497.

Common name : The Mottled Emigrant.

Material examined : 2♂, 10.ix.2005, 2♂, 11.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 2♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Andamans; Assam; Tripura; Meghalaya; Nagaland; Gujarat; Tamil Nadu; West Bengal; North-West Himalayas.

Elsewhere : South China; Burma; Java; Sulawesi; Philippines; Sri Lanka; Pakistan

Genus 5. *Terias* Swainson, 1821

7. *Terias hecabe fimbriata* (Wallace)

1867. *Terias fimbriata* Wallace, *Trans. Ent. Soc. Lond.* 4 : 323.

1939. *Eurema hecabe fimbriata* : Talbot, *The Fauna of Brit. India, Butterflies*, 1 : 531-532.

1993. *Terias hecabe* : Varshney, *Oriental Ins.*, 27 : 363.

Common name : The Common Grass Yellow.

Material examined : 2♂, 10.ix.2005, 2♂, 11.ix.2005, 1♂, 2♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 3♂, 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 1♀, 18. ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Assam; Delhi; Himachal Pradesh; Maharashtra; Karnataka; Tamil Nadu; West Bengal; Lakshadweep.

Elsewhere : Sri Lanka.

Family 3. SATYRIDAE

Genus 6. *Ypthima* Huebner, 1818,

8. *Ypthima inica* Hewitson

1865. *Ypthima inica* Hewitson, *Trans. Ent. Soc. Lond.*, (3)2 : 284.

1994. *Ypthima inica*: Varshney, *Oriental Ins.*, 28 : 159.

Common name : The Lesser Three Ring.

Material examined : 2♂, 10.ix.2005, 2♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Central India; Punjab; West Bengal.

Genus 7. *Mycalesis* Huebner, 1818

9. *Mycalesis perseus blasius* (Fabricius)

1798. *Papilio blasius* Fabricius, *Ent. Syst. Suppl.*, p. 426.

1947. *Mycalesis perseus blasius* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 140-143.

Common name : The Common Bushbrown.

Material examined : 1♂, 10.ix.2005, 3♂, 11.ix.2005, 2♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13.ix.2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Punjab; Orissa; West Bengal; Maharashtra; Tamilnadu.

Elsewhere : Sri Lanka.

10. *Mycalesis visala visala* Moore

1857. *Mycalesis visala moore*, *Cat. Lep. Ins. E.I.C.*, 1 : 230.

1947. *Mycalesis visala visala* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 140-143.

Common name : The Long Brand Bushbrown.

Material examined : 2♂, 10.ix.2005, 1♀, 11.ix.2005, 2♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Arunachal Pradesh; Tripura; Meghalaya; Nagaland; Sikkim; Assam; West Bengal.

Elsewhere : Myanmar.

Genus 8. *Melanitis* Fabricius, 1807.

11. *Melanitis leda ismene* (Cramer)

1775. *Papilio ismene* Cramer, *Pap. Exot.*, 1 : 40, pl 26.

1947. *Melanitis leda ismene* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 366-369.

Common name : The Common Evening Brown.

Material examined : 1♂, 10.ix.2005, 1♀, 11.ix.2005, 2♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 13.ix.2005, Sukartal, Coll. N. Sharma; 1♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Throughout India including Andaman and Nicobar Islands.

Elsewhere : Japan; Malaya; Sri Lanka; Myanmar; Sumatra; Taiwan.

Family 4. NYMPHALIDAE

Genus 9. *Junonia* Huebner, 1819

12. *Junonia almana almana* (Linnaeus)

1758. *Papilio almana* Linnaeus, *Syst. Nat.* (ed. 10); 472.
1932. *Precis almana almana* : Evans, *The identification of Indian Butterflies* : 176.
1994. *Junonia almana* : Varshney, *Oriental Ins.*, 28 : 176.

Common name : The Peacock Pansy.

Material examined : 2♂, 10.ix.2005, 1♂, 1♀, 11.ix.2005, 1♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Delhi; West Bengal; Orissa; Punjab; Andamans; Nagaland; Sikkim; Tripura; Manipur (Widely distributed throughout India excluding Car Nicobar).

Elsewhere : Sri Lanka; Myanmar.

13. *Junonia orithya swinhoe* Butler

1885. *Junonia swinhoe*, Butler, *Ann. Mag. nat. Hist.*, 5(16) : 316.
1932. *Junonia orithya swinhoe* : Evans, *The identification of Indian Butterflies* : 176.
1994. *Junonia orithya* : Varshney, *Oriental Ins.*, 28 : 176.

Common name : The Blue Pansy.

Material examined : India : 1♂, 10.ix.2005, 2♂, 11.ix.2005, 1♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 2♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 1♂, 18. ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : Uttar Pradesh; Madhya Pradesh; Bihar; Delhi; Orissa; Punjab; Himachal Pradesh; Tamilnadu; Maharashtra.

Elsewhere : Sri Lanka; Baluchistan; Pakistan; Myanmar.

14. *Junonia lemonias persicaria* (Fruhstorfer)

1912. *Precis persicaria* Fruhstorfer, In Seitz; *The Macrolepidoptera of the World*, 9 : 520.

1932. *Precis lemonias persicaria* : Evans, *The identification of Indian Butterflies* : 176.

1994. *Junonia lemonias* : Varshney, *Oriental Ins.*, 28 : 176.

Common name : The Lemon Pansy.

Material examined : 1 exs., 10.ix.2005, 1 exs., 11.ix.2005, 2 exs. 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2 exs. 13.ix.2005, Sukartal, Coll. N. Sharma; 1 exs. 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Himachal Pradesh; Orissa; Kerala; Tamilnadu; Maharashtra.

Elsewhere : Sri Lanka.

15. *Junonia hierta hierta* (Fabricius)

1798. *Papilio hierta* Fabricius, *Ent. Syst. Suppl.*, 4 : 424.
1932. *Precis hierta hierta* : Evans, *The identification of Indian Butterflies* : 176.
1994. *Junonia hierta* : Varshney, *Oriental Ins.*, 28 : 176.

Common name : The Yellow Pansy.

Material examined : 1♂, 10.ix.2005, 2♂, 11.ix.2005, 1♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 1♂, exs. 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Punjab; Delhi; Himachal Pradesh; Orissa.

Elsewhere : Sri Lanka; Baluchistan; Pakistan.

16. *Junonia atlites* (Linnaeus)

1763. *Papilio atlites* Linnaeus, *Centur. Ins.*, : 24.
1932. *Precis atlites* : Evans, *The identification of Indian Butterflies* : 176.
1994. *Junonia atlites* : Varshney, *Oriental Ins.*, 28 : 176.

Common name : The Grey Pansy.

Material examined : 1♂, 10.ix.2005, 2♂, 14.ix.2005, 1♂, 15.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♀, 13.ix.2005, Sukartal, Coll. N. Sharma; 1♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Orissa; West Bengal; Andaman and Nicobar; Nagaland; Sikkim; Tripura.

Elsewhere : Sri Lanka; Myanmar.

Genus 10. *Hypolimnias* Huebner, 1819

17. *Hypolimnias bolina* (Linnaeus)

1758. *Papilio bolina* Linnaeus, *Sys. Nat.* (ed. 10) 1 : 479.

1932. *Hypolimnias bolina* : Evans, *The identification of Indian Butterflies* : 174.

1994. *Junonia atlites* : Varshney, *Oriental Ins.*, 28 : 177.

Common name : The Great Eggfly.

Material examined : 2♂, 10.ix.2005, 2♂, 1♀, 11.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♀, 13.ix.2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Delhi; Orissa; Arunachal Pradesh; Meghalaya; Nagaland; Sikkim; Andaman and Nicobar; West Bengal.

Elsewhere : Pakistan; Myanmar; Sri Lanka.

Genus 11. *Phalanta* Horsfield, 1829

18. *Phalanta phalantha phalantha* (Drury)

1770. *Papilio phalantha* Drury, *Exot. Inst.*, 1 : 41, pl. 21, figs. 1, 2.

1905. *Atella phalantha* : Bingham, *The Fauna of British India (Butterflies)*, 1 : 412-413, fig. 75.

1932. *Atella phalantha* : Evans, *The identification of Indian Butterflies* : 187.

1980. *Phalanta phalantha phalantha* : Varshney et al., *Rec. zool. Surv. India, Occ. Paper No.*, 31 : 18-19.

Common name : The Common Leopard.

Material examined : 1♂, 1♀, 10.ix.2005, 1♀, 11.ix.2005, 2♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 2 exs. 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Delhi; Orissa; Arunachal Pradesh; Nagaland; Sikkim; Tamilnadu; Nicobar; West Bengal.

Elsewhere : Pakistan; Myanmar; Sri Lanka.

Genus 12. *Ariadne* Horsfield, 1829

19. *Ariadne merione* (Cramer)

1777. *Papilio merione* Cramer, *Pap. Exot.*, 2 : 76, pl.144, figs. G, H.

1994. *Ariadne merione* : Varshney, *Oriental Ins.*, 28 : 167.

Common name : The Common Coster.

Material examined : 2♂, 1♀, 10.ix.2005, 2♂, 11.ix.2005, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 3♂, 13. ix. 2005, Sukartal, Coll. N. Sharma; 1♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Punjab; Delhi; Orissa; West Bengal; Nagaland; Sikkim; Arunachal Pradesh.

Elsewhere : Pakistan; Myanmar; Sri Lanka.

Family 5. DANAIDAE

Genus 13. *Danaus* Kluk, 1780

20. *Danaus chrysippus chrysippus* (Linnaeus)

1758. *Papilio chrysippus* Linnaeus, *Syst. Nat.* (ed. 10) 1 : 471.

1947. *Danaus chrysippus chrysippus* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 20

Common name : The Plain Tiger.

Material examined : 2♂, 1♀, 10.ix.2005, 2♂, 11.ix.2005, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 1♂, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Punjab; Bihar; Delhi; Orissa; Manipur; Nagaland; Assam; Sikkim; Gujrat; Maharashtra; Tamil Nadu; Himachal Pradesh; Andaman and Nicobar; West Bengal.

Elsewhere : Nepal; Pakistan; Bhutan; Sri Lanka; Myanmar; Indonesia; China.

21. *Danaus genutia* (Cramer)

1779. *Papilio genutia* Cramer, *Pap. Exot.*, 3 : 23.

1947. *Danaus plexippus plexippus* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 25.

1993. *Danaus genutia* : Varshney, *Oriental Ins.*, 27 : 365.

Common name : The Common Tiger.

Material examined : 1♂, 10.ix.2005, 1♂, 1♀, 11.ix.2005, 1♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 13.ix.2005, Sukartal, Coll. N. Sharma; 1♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Assam; Bihar; Delhi; Orissa; Punjab; Manipur; Mizoram; Sikkim; Nagaland; Rajasthan; Tamil Nadu; Arunachal Pradesh; Karnataka; Himachal Pradesh; Andaman and Nicobar; West Bengal.

Elsewhere : Thailand; Nepal; Pakistan; Afghanistan; Bhutan; Sri Lanka; Myanmar; South China.

Genus 14. *Tirumala* Moore, 1880

22. *Tirumala limniace leopardus* (Butler)

1866. *Danaus limniace* var. *leopardus* Butler, *Proc. zool. Soc. Lond.*, : 52.

1947. *Danaus limniace leopardus* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 31.

Common name : The Blue Tiger.

Material examined : 1♂, 10.ix.2005, 1♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 13.ix.2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Assam; Bihar; Delhi; Orissa; Punjab; Uttarakhand; Manipur; Sikkim; Nagaland; Tamil Nadu; Karnataka; Himachal Pradesh; Andaman and Nicobar; West Bengal.

Elsewhere : Thailand; Nepal; Pakistan; Afghanistan; Sri Lanka; Myanmar; South China.

Genus 15. *Euploea* Fabricius 1807

23. *Euploea core core* (Cramer)

1780. *Papilio core* Cramer. *Pap. Exot.*, 3 : 133.

1947. *Euploea core core* : Talbot, *The Fauna of Brit. India, Butterflies*, 2 : 67.

Common name : The Common Crow.

Material examined : 2♂, 10.ix.2005, 2♂, 11.ix.2005, 2♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 3♂, 13. ix.2005, Sukartal, Coll.

N. Sharma; 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Bihar; Delhi; Orissa; Sikkim; Uttaranchal; Tamil Nadu; Karnataka; Himachal Pradesh; Andaman and Nicobar; West Bengal; Nagaland.

Elsewhere : Northern Myanmar; Sri Lanka; Nepal and Pakistan.

Family 6. LYCAENIDAE

Genus 16. *Tarucus* Moore, 1881

24. *Tarucus alteratus* Moore

1882. *Tarucus alteratus* Moore, *Proc. zool. Soc. Lond.* : 245.

1932. *Tarucus alteratus* : Evans, *The identification of Indian Butterflies* : 216.

Common name : The Rusty Pierrot.

Material examined : 1♂, 10.ix.2005, 1♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 2♀, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : Himachal Pradesh; Uttar Pradesh; Central India.

Elsewhere : Pakistan; Myanmar.

Genus 17. *Catochrysops* Boisduval, 1832

25. *Catochrysops strabo strabo* (Fabricius)

1793. *Hesperia strabo* Fabricius, *Ent. Syst.* 3 : 287.

1907. *Catochrysops strabo* : Bingham, *The fauna of British India (Butterflies)*, 2 : 211.

1962. *Catochrysops strabo strabo* : Cantile, *The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932* : 67.

Common name : The Spotted Pierrot.

Material examined : 1♂, 1♀, 10.ix.2005, 4♂, 5.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13.ix.2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; West Bengal; Bihar; Madhya Pradesh; Maharashtra; Tamilnadu; Kerala.

Elsewhere : Myanmar; Sri Lanka.

Genus 18. *Euchrysops* Butler, 1900**26. *Euchrysops cnejus* (Fabricius)**

1798. *Hesperia cnejus* Fabricius, *Ent. Syst. Supdt.* : 430.
 1907. *Catochrysops cnejus* : Bingham, *The Fauna of British India (Butterflies)*, 2 : 415.
 1962. *Catochrysops cnejus* : Cantile, *The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932 : 65.*

Common name : The Gram Blue.

Material examined : 2♂, 1♀, 10.ix.2005, 2♂, 11.ix.2005, 3♂, 1♀, 15.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : West Bengal; Uttar Pradesh; Madhya Pradesh; Andamans; Central and South Nicobars.

Elsewhere : Myanmar; Nepal; Pakistan; Sri Lanka.

Genus 19. *Zizina* Chapman, 1910**27. *Zizina otis indica* (Fabricius)**

1874. *Lycaena indica* Murray, *Trans. Ent. Soc. Lond.* (4) : 525, pl. 10, figs. 2, 3.
 1907. *Zizera otis* : Bingham, *The Fauna of British India (Butterflies)*, 2 : 360.
 1962. *Zizina otis indica* : Cantile, *The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932 : 63.*

Common name : The Lesser Grass Blue.

Material examined : 1♂, 10.ix.2005, 1♂, 11.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : Northern India; Andamans; Car and Central Nicobars.

Elsewhere : Myanmar; South-East Asia.

Genus 20. *Zizula* Chapman, 1910**28. *Zizula hylax* (Fabricius)**

1775. *Papilio hylax*, (Fabricius), *Syst. Ent.* : 526.
 1907. *Zizera gaika* : Bingham, *The Fauna of British India (Butterflies)*, 2 : 359.
 1962. *Zizula hylax* : Cantlie, *The Lycaenidae portion*

(except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932 : 65.

Common name : The Tiny Glass Blue.

Material examined : 1♂, 10.ix.2005, 1♂, 11.ix.2005, 2exs. 14.ix.2005, Hastinapur Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; West Bengal; Andaman & Nicobars.

Elsewhere : Myanmar; Pakistan; Sri Lanka.

Genus 21. *Zizeeria* Chapman, 1910**29. *Zizeeria knysna karsandra***

1865. *Polyommatus karsandra* Moore, *Proc. zool. Soc. Lond.* : 505.
 1907. *Zizera lysimon*, Bingham, *The Fauna of British India (Butterflies)*, 2 : 357.
 1962. *Zizeeria knysna karsandra* Cantlie, *The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932 : 65.*

Common name : The Dark Grass Blue.

Material examined : 3♂, 1♀, 10.ix.2005, 2♂, 1♀, 11.ix.2005, 2♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 1♀, 13. ix. 2005, Sukartal, Coll. N. Sharma; 2♂, 2♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : West Bengal; Assam, Arunachal Pradesh; Central to Northern India.

Elsewhere : Myanmar; Pakistan; Sri Lanka.

Genus 22. *Pseudozizeeria***30. *Pseudozizeeria maha maha* (Kollar)**

1848. *Lycaena maha* Kollar, in Hugel's Kashmir, 4 : 422.
 1907. *Zizera maha* : Bingham, *The Fauna of British India (Butterflies)*, 2 : 355.
 1955. *Pseudozizeeria maha maha* : Beuret, 1955, *Mitt. Ent. Ges. Basel*, 5 : 125.
 1962. *Zizeeria maha maha* : Cantlie, *The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932 : 65.*

Common name : The Plae Grass Blue.

Material examined : 3♂, 10.ix.2005, 2♂, 11.ix.2005, 1♂, 1♀, 14.ix.2005, Hastinapur

Range, Coll. N. Sharma; 2♂, 1♀, 13.ix.2005, Sukartal, Coll. N. Sharma; 2♂, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : West Bengal; Assam; Central to Northern India.

Elsewhere : Myanmar; Pakistan; Nepal; Baluchistan.

Genus. 23. *Castalius* Huebner

31. *Castalius rosimon rosimon* (Fabricius)

1775. *Papilio rosimon* (Fabricius), *Syst. Ent.*, : 523.

1907. *Castalius rosimon* : Bingham, *The Fauna of British India* (Butterflies), 2 : 424.

1962. *Castalius rosimon rosimon* : Cantlie, *The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans 'The identification of Indian Butterflies, 1932* : 31.

Common name : Common Pierrot.

Material examined : 3♂, 1♀, 10.ix.2005, 1♂, 1♀, 11.ix.2005, 2♂, 2♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 2♂, 13.ix.2005, Sukartal, Coll. N. Sharma; 2♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : West Bengal; Uttar Pradesh; Widely distributed in India.

Elsewhere : Myanmar; Pakistan; Sri Lanka.

Genus. 24. *Azanus* Moore, 1881

32. *Azanus ubaldus* Cramer

1782. *Papilio ubaldus* Cramer, *Pap. Exot.* 4 : 209.

1882. *Azanus ubaldus* : Moore, List of Lepidoptera collected by the Rev. J.H. Hocking chiefly in the Kangra district, N. W. Himalaya; with descriptions of new genera and species. *Proc. Zool. Soc. Lond.* : 245.

Common name : The Bright Babul Blue

Material examined : 2♂, 18.ix.2005, Dhanora Range Coll. N. Sharma.

Distribution : India : Himachal Pradesh; Uttar Pradesh; Central India.

Elsewhere : Pakistan; Myanmar.

Family 7. HESPERIIDAE

Genus 25. *Caltoris* Swinhoe, 1893

33. *Caltoris cahira* (Moore)

1877. *Parnara cahira* Moore, *Proc. zool. Soc. Lond.*, 5: 593.

1949. *Caltoris cahira* : Evans, *A Catalogue of the Hesperidae from Europe, Asia and Australia in Brit. Mus. (nat. Hist)* : 452.

Common name : The Colon Swift.

Material examined : 2♂, 10.ix.2005, 1♂, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♀, 13 ix. 2005, Sukartal, Coll. N. Sharma; 1♂, 1♀, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Sikkim; Assam; West Bengal; Meghalaya; Manipur; Andaman and Nicobar.

Elsewhere : Pakistan; Myanmar.

Genus 26. *Spialia* Swinhoe, 1912

34. *Spialia galba* (Fabricius)

1793. *Hesperia galba* Fabricius, *Ent. Syst.*, 3(1) : 352.

1932. *Syrichtus galba* : Evans, *The Identification of Indian Butterflies* : 347.

1949. *Spialia galba* : Evans, *A Catalogue of the Hesperidae from Europe, Asia and Australia in Brit. Mus. (nat. Hist)* : 452.

Common name : The Indian Skipper.

Material examined : 2♂, 10.ix.2005, 2♂, 1♀, 14.ix.2005, Hastinapur Range, Coll. N. Sharma; 1♂, 13. ix. 2005, Sukartal, Coll. N. Sharma; 1♂, 18.ix.2005, Dhanora Range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh.

Elsewhere : Saudi Arabia; Baluchistan; Myanmar; Sri Lanka.

Genus 27. *Telicota*, Moore, 1881

35. *Telicota colon* (Fabricius)

1775. *Papilio colon* Fabricius, *Syst. Ent. Insect Orid.* : 531

1992. *Telicota colon* : Eliot, *Butterflies of Malaya peninsula by A. Steven Corbet and H.M. Pendlebury. Malaya Nat. Soc.* :

Common name : The Pale Palmdart.

Material examined : 1♂, 1♀, 10.ix.2005, 1♂, 14.ix.2005, 2♂, 15.ix.2005, Hastinapur Range, Coll. N. Sharma; 4♂, 2♀, 13. ix. 2005, Sukartal, Coll. N. Sharma.

Distribution : India : Uttar Pradesh.

Elsewhere : Malaya, Philippines.

Material examined : 2♂, 18.ix.2005, Dhanora range, Coll. N. Sharma.

Distribution : India : Uttar Pradesh; Madhya Pradesh; Assam; Central Nicobars; Jammu and Kashmir; Maharashtra; Rajasthan; Punjab; Sikkim; West Bengal; South India.

Elsewhere : Papuan and Australian Region.

Genus 28. *Pelopidas* Walker, 1870

36. *Pelopidas mathias mathias* (Fabricius)

1798. *Hesperia mathias* Fabricius, Ent. Syst. Suppl., p 433.

1949. *Pelopidas mathias mathias* : Evans, *A Catalogue of the Hesperidae from Europe, Asia and Australia in Brit. Mus. (nat. Hist)* : 441.

Common name : The Swifts.

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LITERATURE CITED

- BEURET, H. 1955. In Europa and die Systematische Stellung der Zizeerinae (Lepidoptera, Lycaenidae). *Mitt. ent. Ges. Basel* (nf) 5 : 123-130, 3 pls.
- BINGHAM, C.T. 1905. The Fauna of British India including Ceylon and Burma, Butterflies, 1 : xviii + 537 pp., 15 pls. (Published by Taylor and Francis London).
- BINGHAM, C.T. 1907. The Fauna of British India including Ceylon and Burma, Butterflies, 2 : viii + 480 pp., 11-20 pls. (Published by Taylor and Francis London).
- CANTLIE, K. 1962. The Lycaenidae portion (except the Arhopala Group) of Brigadier Evans' The Identification of Indian Butterflies, 1932 : vi+ 156pp., index 12 pp., 5pls. (Published by The Bombay Natural History Society, Bombay).
- DE NICEVILLE, L. 1886. The butterflies of India, Burmah and Ceylon, Vol. 2. Reprinted by A.J. Reprints Agency, New Delhi : 332 pp.
- DE NICEVILLE, L. 1890. The butterflies of India, Burmah and Ceylon, Vol. 3. Reprinted by A. J. Reprints Agency, New Delhi : 503 pp.
- ELIOT, J. N. 1992. Butterflies of Malaya peninsula by A. Steven Corbet and H.M. Pendlebury. 4th Ed. Malaya Nat. Soc. : viii+ 595 pp, 69 pls.
- EVANS, W.H. 1932. The Identification of Indian Butterflies, 2nd ed. Bombay Natural History Society, Bombay : 454 pp.
- EVANS, W.H. 1949. A Catalogue of the Hesperidae from Europe, Asia and Australia in Brit. Mus. (nat. Hist), London, XIX+502 pp., 53pls.
- MARSHALL, G. F. L. and DE NICEVILLE, E. L. 1882. The butterflies of India, Burmah and Ceylon, Vol. 1. Reprinted by A.J. Reprints Agency, New Delhi : 327 pp.
- MOORE, F. 1882. List of Lepidoptera collected by the Rev. J.H. Hocking chiefly in the Kangra district, N. W. Himalaya; with descriptions of new genera and species. *Proc. Zool. Soc. Lond.* (i) : 234-263.

- NAWAB, A. 2000. Plant species composition and structure of Hastinapur Wildlife Sanctuary, U.P. India. M.Sc. Dissertation, Aligarh Muslim University, Aligarh, India
- TALBOT, G. 1939. The Fauna of British India including Ceylon and Burma. Butterflies volume-1. Taylor and Francis, London.
- TALBOT, G. 1947. The Fauna of British India including Ceylon and Burma. Butterflies volume-2. Taylor and Francis, London, 506 pp.
- VARSHNEY, R.K. 1993. Index Rhopalocera indica, Part III, Genera of Butterflies from India and neighboring countries (Lepidoptera) : (A) Papilionidae, Pieridae and Danaidae. *Oriental Ins.*, 27 : 347-372.
- VARSHNEY, R.K. 1994. Index Rhopalocera indica, Part III, Genera of Butterflies from India and neighboring countries (Lepidoptera) : (B) Satyridae, Nymphalidae, Libythidae and Riodinidae. *Oriental Ins.* 28 : 151-198.
- VARSHNEY, R.K., NANDI, B. and NAHAR, S.C. 1980. Butterflies from Hazaribagh National Park (South Bihar) (Lepidoptera : Rhopalocera). *Rec. zool. Surv. India, Occ. Paper No.*, 31 : pp. 38
- WYNTER-BLYTH, M.A. 1957. Butterflies of the Indian region. Bombay nat. Hist. Soc., 1957 : xx + 523 pp, 72pls. (Published by Bombay natural History Society, Bombay).

A COMPENDIUM AND A REVISED KEY OF THE GENUS *APORCELAIMELLUS* HEYNS, 1965 (APORCELAIMIDAE : NEMATODA)

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ABSTRACT

Aporcelaimellus is the richest genus of the family Aporcelaimidae; and not less than 88 nominal species have been described under it, or transferred to it from other genera (Andrassy, 2002). In his overview of the genus, Andrassy (2002) omitted to include the species *A. budauniensis*, erected by Khatoon and Sharma, 2000. Since then, seven new species had been described under the genus *Aporcelaimellus*. A compendium of those eight species is being made along with a revised dichotomous key to the species of the genus.

Keywords : Nematode, *Aporcelaimellus*, identification, compendium, dichotomous key.

INTRODUCTION

The genus *Aporcelaimellus* was first erected by Heyns in 1965, under the family Apocelaimidae Heyns, 1965. The diagnosis of the genus given by Heyns was based solely on study of *Aporcelaimellus obscurus* (Thorne and Swanger, 1936) Heyns, 1965. The genus belongs to the taxonomically rather difficult genera of soil nematodes. It is a widespread genus and cosmopolitan in distribution. Great problems for taxonomists are that several *Aporcelaimellus* species have rather inadequately been described, relatively few of them are unambiguously defined and that many nominal species have not been recovered since their first descriptions (Andrassy, 2002). Andrassy published an up-to-date overview of the genus in the year 2002. He also compiled a "tentative" determination key to the species of *Aporcelaimellus*. But he did not incorporate *A. budauniensis* Khatoon and Sharma, 2000. Since

that valuable review work, seven new species had been established under this genus by different scientists till date. *A. faridpuriensis*, *A. jairajpurii* and *A. nawabganjense* were erected by Singh, Sharma and Khatoon, 2002; *A. futaii* by Khan and Araki, 2002; *A. amazonicus* and *A. insularis* by Andrassy, 2004 and *A. subhasi* by Gantait, Bhattacharya and Chatterjee, 2006. A compendium of those eight species is being made in this paper (Table 1.). A revised key of the genus is also incorporated herein.

DISCUSSION

Heyns, 1965 proposed the genus *Aporcelaimellus* first to accommodate some species of the closely related genus *Aporcelaimus* Thorne and Swanger, 1936 and by transferring many species from the genus *Eudorylaimus* Andrassy, 1959. The generic characters made by Heyns are as follows: medium sized (1-3 mm) nematodes with rather robust body (a =

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20-30); cuticle thickened mostly towards both the extremities, cuticle with fine but distinct transverse striae; oral aperture small, apparently hexagonal in shape; anterior part of pharynx appearing hexagonal in en face view; lips separated from one another; amphids with or without a median support, the chamber apparently never divided into two halves; axial spear with a large aperture, occupying from slightly less to more than half the length of spear; oesophago-intestinal disc absent; obscure ventromedian cuticular pores over entire length of the body; vulva with a small to medium sized pore-like opening, with or without cuticularized lips; mostly two eggs at a time in each uterus; tail relatively short, bluntly rounded, conoid or slightly digitate.

Tjepakema, Ferris and Ferris, 1971 gave a general review of the genus. They had expressed that the genus *Aporcelaimellus* apart from being close to the genus *Aporcelaimus* of the family Aporcelaimidae Heyns, 1965, is also close to the genus *Eudorylaimus* of the family Dorylaimidae De Man, 1876. They had recommended the following changes or additions to the generic characters : cuticle about as thick anteriorly as at mid-body; most species appear to have a thin outer layer and two thicker inner layers of cuticle; spear aperture usually 50% or more of spear length, rarely less than 50%; lips set off from body by a deep constriction; amphids duplex in most species; an oesophago-intestinal disc present.

Determination keys to the species of the genus *Aporcelaimellus* was given by Baqri and Jairajpuri, 1968 for thirteen species and subsequently by Thorne, 1974 for eleven species. Baqri and Khera, 1975 opined that the genus *Aporcelaimellus* is closely related to *Aporcelaimus* and *Eudorylaimus* and perhaps the genus *Aporcelaimellus* is intermediate between the other two genera. They revealed that apart from other characters, the location of oesophageal gland nuclei and their orifices should also be considered important characters to separate the genus *Aporcelaimellus* from *Eudorylaimus*. According to them the distance between S_1N_1 and S_2N_2 is larger in *Aporcelaimellus* spp. than in *Eudorylaimus* species.

The range of distance between S_1N_1 and S_2N_2 calculated in percentage of neck length, in *Aporcelaimellus* and *Eudorylaimus* is 4.2-15.2 and 0.3-4.0 respectively. They had transferred twelve *Eudorylaimus* species to the genus *Aporcelaimellus*.

Jairajpuri and Ahmad, 1992 provided the following diagnostic characters of the genus: medium-sized nematodes, usually with robust body; cuticle thickened mainly towards body ends, finely striated; body pores usually distinct; lip region set off by deep constriction; lips angular, separated from one another; oral aperture apparently hexagonal; odontostylet with wide lumen, aperture about one half length; amphids with or without median support, fovea may be duplex; thin cardiac disc may be present; female reproductive system amphidelphic; vulva transverse, slit or pore like; males with paired, well-built and heavily cuticularised spicules, identical in size and shape; lateral guiding pieces and non-contiguous ventromedian supplements; tail relatively short, bluntly rounded, conoid or slightly digitate, similar in sexes. They have listed 51 species under this genus.

Andrassy, 2002 gave an up-to-date overview of the genus *Aporcelaimellus*. He summarised the following generic characters: robust animals of 0.8 to 3.5 mm body length; double layers of cuticle showing different refraction; labial region set off by deep constriction, lips more or less amalgamated; oral aperture transverse; short and thick odontostylet, aperture generally occupying one-half its length; oesophageal cylindrus strongly muscular; AS nuclei in different level, but always located in the anterior half of gubernaculum; female genetic system amphidelphic; vulva a transverse slit or transversely oval with sclerotized inner labia; males rare or unknown in several species; spicules paired, more or less identical in shape and size, well-built; ventromedian supplements 5-21 (rarely 34); tail similar in both sexes, short, less than half-anal body width to two-anal body width long, conoid-rounded or hemispherical, tail terminus broadly rounded; somatic muscle bands in dorsal side of tail greatly expanded.

Andrassy, 2002 enumerated 88 nominal species under the genus *Aporcelaimellus*. Out of them 41 species were listed as valid, 19 were synonyms and 24 species had already been transferred or should be transferred to other genera. He also grouped 4 species as "species-inquirendae". We listed here total 49 species under this genus as valid species. The lists of other nominal species are also provided.

LIST OF VALID SPECIES

Genus *Aporcelaimellus* Heyns, 1965

Metaporcelaimus Lordello, 1965

TYPE SPECIES

1. *Aporcelaimellus obtusicaudatus* (Bastian, 1865) Altherr, 1968.

Dorylaimus obtusicaudatus Bastian, 1865

Eudorylaimus obtusicaudatus (Bastian, 1865) Andrassy, 1959

Dorylaimus perfectus Cobb, 1893

Dorylaimus obtusicaudatus perfectus Cobb, 1893 (Schneider, 1937)

Dorylaimus ornatus Fuchs, 1930

Dorylaimus obscurus Thorne & Swanger 1936

Eudorylaimus obscurus (Thorne & Swanger, 1936) Andrassy, 1959

Aporcelaimus obscurus (Thorne & Swanger, 1936) Goodey, 1961

Aporcelaimellus obscurus (Thorne & Swanger, 1936) Heyns, 1965

Dorylaimus quietus Kirjanova, 1951

Eudorylaimus quietus (Kirjanova, 1951) Andrassy 1959

Aporcelaimellus quietus (Kirjanova, 1951) Baqri & Khera, 1975

Aporcelaimus spiralis apud Williams, 1959

Aporcelaimellus williamsi Heyns, 1965

Aporcelaimellus obscuroides Altherr, 1968

Aporcelaimellus microhystera Altherr, 1976

Aporcelaimellus sacchari Khan, 1989

OTHER SPECIES

2. *Aporcelaimellus adriaani* Botha & Heyns, 1990

3. *Apocelaimellus alius* Andrassy, 2002

4. *Aporcelaimellus amazonicus* Andrassy, 2004

5. *Apocelaimellus amplexor* (Nesterov & Lisetskaya, 1965) Heyns, 1965

Dorylaimus amplexor Nesterov & Lisetskaya, 1965

6. *Apocelaimellus amylovorus* (Thorne & Swanger, 1936) Heyns, 1965

Dorylaimus amylovorus Thorne & Swanger, 1936

Eudorylaimus amylovorus (Thorne & Swanger, 1936) Andrassy, 1959

7. *Aporcelaimellus baqrii* Ahmad & Jairajpuri, 1982

8. *Aporcelaimellus budauniensis* Khatoon & Sharma, 2000

9. *Aporcelaimellus chauhani* Baqri & Khera, 1975

10. *Aporcelaimellus cocophilus* (Loos, 1949) Andrassy, 2001

Aporcelaimus cocophilus Loos, 1949

11. *Aporcelaimellus conoidus* Thorne, 1974

12. *Aporcelaimellus dubius* (Thorne, 1974) Andrassy, 1986

Eudorylaimus dubius Thorne, 1974

13. *Aporcelaimellus duhouxi* (Altherr, 1963) Baqri & Khera, 1975

Eudorylaimus duhouxi Altherr, 1963

14. *Aporcelaimellus estonicus* (Krall, 1957) Andrassy, 1990

Labronema estonicus Krall, 1957

15. *Aporcelaimellus faridpuriensis* Singh, Sharma and Khatoon, 2002

16. *Aporcelaimellus futaii* Khan and Araki, 2002

17. *Aporcelaimellus gerlachi* (Meyl, 1956) Heyns 1965

Aporcelaimus gerlachi, Meyl, 1956

18. *Aporcelaimellus glandus* Botha & Heyns, 1991

19. *Aporcelaimellus goldeni* Khan & Fatima, 1980

20. *Aporcelaimellus heynsi* Baqri & Jairajpuri, 1968

21. *Aporcelaimellus hylophilus* Tjepkema, Ferris & Ferris, 1971

22. *Aporcelaimellus index* (Thorne, 1939) Andrassy, 1986
Dorylaimus index Thorne, 1939
Eudorylaimus index (Thorne, 1939) Andrassy, 1959
23. *Aporcelaimellus insularis* Andrassy, 2004
24. *Aporcelaimellus jairajpurii* Singh, Sharma and Khatoon, 2002
25. *Aporcelaimellus kikereensis* Baqri & Coomans, 1973
Dorylaimus obtusicaudatus apud Sch. Stekhoven Teunissen, 1938
26. *Aporcelaimellus krygeri* (Ditlevsen, 1928) Heyns, 1965
Dorylaimus krygeri Ditlevsen, 1928
Eudorylaimus krygeri (Ditlevsen, 1928) Andrassy 1959
Aporcelaimus krygeri (Ditlevsen, 1928) Brzeski, 1962
Dorylaimus planipediis Merzheevskaya, 1951
Eudorylaimus planipediis (Merzheevskaya, 1951) Andrassy, 1959
Aporcelaimellus planipediis (Merzheevskaya, 1951) Andrassy, 1990
27. *Aporcelaimellus macropunctatus* (Heyns, 1967) Jimenez Guirado, 1994
Makatinus macropunctatus Heyns, 1967
Aporcelaimellus porcus Thorne, 1974
28. *Aporcelaimellus maitai* Yeates, 1967
29. *Aporcelaimellus malagasi* Heyns, 1996
Aporcelaimellus macropunctatus Heyns, 1995 nec Heyns, 1967
30. *Aporcelaimellus medius* Andrassy, 2002
Dorylaimus krygeri apud Lordello, 1956
31. *Aporcelaimellus micropunctatus* Botha & Heyns, 1990
32. *Aporcelaimellus nawabganjense* Singh, Sharma and Khatoon, 2002
33. *Aporcelaimellus nivalis* (Altherr, 1952) Heyns, 1965
Dorylaimus (Aporcelaimus) nivalis Altherr, 1952
34. *Aporcelaimellus odhneri* (Allgen, 1951) Andrassy, 1990
Dorylaimus odhneri Allgen, 1951
Eudorylaimus odhneri (Allgen, 1951) Andrassy, 1959
35. *Aporcelaimellus papillatus* (Bastian, 1865) Baqri & Khera, 1975
Dorylaimus papillatus Bastian, 1865
Eudorylaimus papillatus (Bastian, 1865) Andrassy, 1959
Dorylaimus domusglauci Cobb, 1893
36. *Aporcelaimellus paracentrocercus* (De Coninck, 1935) Baqri & Coomans, 1973
Dorylaimus paracentrocercus De Coninck, 1935
Eudorylaimus paracentrocercus (De Coninck, 1935) Andrassy 1959
37. *Aporcelaimellus paraconicaudatus* (Meyl, 1956) Heyns, 1965
Aporcelaimus paraconicaudatus Meyl, 1956
38. *Aporcelaimellus parapapillatus* Botha & Heyns, 1990
39. *Aporcelaimellus productus* (Thorne & Swanger 1936) Baqri & Khera, 1975
Dorylaimus productus Thorne & Swanger, 1936
Eudorylaimus productus (Thorne & Swanger, 1936) Andrassy, 1959
Dorylaimus submissus Kirjanova, 1951
Eudorylaimus submissus (Kirjanova, 1951) Andrassy, 1959
Aporcelaimellus submissus (Kirjanova, 1951) Baqri & Khera, 1975
40. *Aporcelaimellus propinquus* (Thorne & Swanger, 1936) Tjepkema, Ferris & Ferris, 1971
Dorylaimus propinquus Thorne & Swanger, 1936
Eudorylaimus propinquus (Thorne & Swanger, 1936) Andrassy, 1959
41. *Aporcelaimellus punctatus* Altherr in Altherr & Delamare Deboutteville, 1972
42. *Aporcelaimellus pycnus* (Thorne, 1939) Baqri and Khera, 1975

- Dorylaimus pycnus* Thorne, 1939
Eudorylaimus pycnus (Thorne, 1939) Andrassy, 1959
43. *Aporcelaimellus samarcandicus* (Tulaganov, 1949) Baqri & Khera 1975
Dorylaimus samarcandicus Tulaganov, 1949
Eudorylaimus samarcandicus (Tulaganov, 1949) Andrassy, 1959
44. *Aporcelaimellus seinhorsti* (Meyl, 1957) Heyns, 1965
Aporcelaimus seinhorsti Meyl, 1957
45. *Aporcelaimellus stilus* (Kirjanova, 1951) Andrassy, 1986
Dorylaimus stilus Kirjanova, 1951
Eudorylaimus stilus (Kirjanova, 1951) Andrassy, 1959
Aporcelaimus mamillatus Williams, 1959
Aporcelaimellus mamillatus (Williams, 1959) Heyns, 1965
46. *Aporcelaimellus subhasi* Gantait, Bhattacharya & Chatterjee, 2006
47. *Aporcelaimellus taylora* Yeates, 1967
Aporcelaimellus clamus Thorne, 1974
Aporcelaimellus raniensis Altherr, 1968
48. *Aporcelaimellus tritici* (Bastian 1865) Andrassy, 1986
Dorylaimus tritici Bastian, 1865
Eudorylaimus tritici (Bastian, 1865) Andrassy, 1959
Aporcelaimus vanderlaani Meyl, 1957
Aporcelaimellus vanderlaani (Meyl, 1957) Heyns, 1965
49. *Aporcelaimellus vitrinus* (Thorne & Swanger, 1936) Baqri & Khera, 1975
Dorylaimus vitrinus Thorne and Swanger, 1936
Eudorylaimus vitrinus (Thorne & Swanger, 1936) Andrassy, 1959
Aporcelaimellus laevis Tjepkema, Ferris & Ferris, 1971

SPECIES TRANSFERRED TO OTHER GENERA

- Apocelaimellus adoxus* Tjepkema, Ferris & Ferris, 1971 : to *Metaporcelaimus*
- A. atheri* Baqri, 1991 : to *Ecumenicus monohystera*
- A. capitatus* (Thorne & Swanger, 1936) Heyns, 1965 : to *Metaporcelaimus*
- A. coomansi* Baqri & Khera, 1975 : to *Metaporcelaimus*
- A. efficiens* (Cobb in Thorne & Swanger, 1936) Baqri & Khera, 1975 : to *Metaporcelaimus*
- A. insignis* Loos 1945 : to *Thonus*
- A. invisus* Tjepkema, Ferris & Ferris, 1971 : to *Metaporcelaimus*
- A. mombucaae* (Lordello, 1965) Loof, Jairajpuri & Ahmad, 1995 : to *Metaporcelaimus*
- A. nothus* (Thorne & Swanger, 1936) Baqri & Khera, 1975 : to *Thonus*
- A. paraobtusicaudatus* (Micoletzky, 1922) Andrassy, 1986 : to *Eudorylaimus*
- A. simplex* (Thorne & Swanger, 1936) Loof & Coomans, 1970 : to *Metaporcelaimus*
- A. simus* (Andrassy, 1958) Andrassy, 1986 : to *Makatinus*
- A. sublabiatus* (Thorne & Swanger, 1936) Thorne, 1974 : to *Metaporcelaimus*
- A. warriari* (Jairajpuri, 1965) Siddiqi, 1969 : to *Moshajia*

SPECIES PROPOSED TO BE TRANSFERRED TO OTHER GENERA

- Aporcelaimellus canis* Gagarin, 1984 : to *Aporcelaimus*
- A. cylindricus* Ahmad, 1995 : to *Metaporcelaimus*
- A. littoralis* Orselli & Vinciguerra, 1999 : to *Metaporcelaimus*
- A. maximus* Rahman, Jairajpuri, Ahmad & Ahmad, 1987 : to *Metaporcelaimus*
- A. monodelphus* Jain & Saxena, 1993 : to *Ecumenicus*

- A. parvus* Thorne, 1974 : to *Metaporcelaimus*
A. placus Thorne, 1974 : to *Metaporcelaimus*
A. saprophilus Gagarin & Gusacov, 2001 :
 to *Metaporcelaimus*
A. silvanus Vinciguerra & Giannetto, 1983 :
 to *Metaporcelaimus*
A. tropicus Jana & Baqri, 1981 : to *Thonus*

SYNONYMIZED SPECIES

- Aporcelaimellus clamus* Thorne, 1974 :
 synonymized with *Aporcelaimellus taylora*
 Yaetes, 1967
A. conicaudatus (Altherr, 1953) Monteiro,
 1970 : with *Metaporcelaimus labiatus*
A. indicus Baqri & Heyns, 1968 : with
Metaporcelaimus mombuca
A. laevis Tjepkema, Ferris & Ferris, 1971 :
 with *Aporcelaimellus vitrinus*
A. macropunctatus Heyns, 1995 : with
Aporcelaimellus malagasi
A. mamillatus (Williams, 1959) Heyns, 1965 :
 with *Aporcelaimellus stilus*
A. microhystera Altherr, 1976 : with
Aporcelaimellus obtusicaudatus
A. obscuroides Altherr, 1968 : with
Aporcelaimellus obtusicaudatus
A. obscurus (Thorne & Swanger, 1936)
 Heyns, 1965 : with *Aporcelaimellus*
obtusicaudatus
A. planipediis (Merzheevskaya, 1951)
 Andrassy, 1990 : with *Aporcelaimellus krygeri*
A. porcus Thorne 1974 : with *Aporcelaimellus*
macropunctatus
A. quietus (Kirjanova, 1951) Baqri & Khera,
 1975 : with *Aporcelaimellus obtusicaudatus*
A. raniensis Altherr, 1968 : with
Aporcelaimellus taylora
A. sacchari Khan, 1989 : with *Aporcelaimellus*
obtusicaudatus
A. shamimi Ahmad, 1995 : with
Metaporcelaimus digitalis
A. submissus (Kirjanova, 1951) Baqri &
 Khera, 1975 : with *Aporcelaimellus productus*
A. vanderlaani (Meyl, 1957) Heyns, 1965 :
 with *Aporcelaimellus tritici*

- A. wilhelmschneideri* (Altherr, 1965) Altherr,
 1974 : with *Aporcelaimus eurydoris*
A. williamsi Heyns, 1965 : with
Aporcelaimellus obtusicaudatus

SPECIES INQUIRENDAE

- Aporcelaimellus barelicus* Jain & Saxena, 1992
A. concavus Xie & Feng, 1994
A. radicus Jain & Saxena, 1993
A. subsimilis (Cobb, 1983) Baqri & Khera,
 1975

Tentative key to the species of *Aporcelaimellus*

1. Tail as long as 1.5–2 anal body diameter 2
 - Tail shorter than 1.5 anal body diameter 8
2. Tail with concave dorsal contour 3
 - Tail with straight or convex dorsal contour 6
3. Stylet 17–20 μ m long, aperture $\frac{1}{2}$ of its length. (female : 1.0–1.4 mm; male : unknown)
 *A. chauhani* Baqri & Khera, 1975
 - Stylet 11–14 μ m long, aperture about $\frac{2}{3}$ of its length 4
4. Lateral chord granular. (female : 0.9–1.2 mm; male : unknown)
 *A. heynsi* Baqri & Jairajpuri, 1968
 - Lateral chord with large gland cells 5
5. Body shorter. (female : 0.8–1.0 mm; male: unknown) *A. maitai* Yeates, 1967
 - Body somewhat longer. (female : 1.0–1.5 mm; male: unknown)
 *A. glandus* Botha & Heyns, 1991
6. Tail straight. (female : 1.4 mm; male : 1.0–1.3mm)
 .. *A. paraconicaudatus* (Meyl, 1956) Heyns, 1965

- Tail convex dorsally 7
- 7. Body smaller. (female : 0.8 mm; male : unknown)
 A. dubius (Thorne, 1974) Andrassy, 1986
- Body larger. (female : 1.48–1.71 mm; male : unknown)
 *A. subhasi* Gantait *et al.*, 2006
- 8. Tail with concave dorsal contour, often mammillate (with shorter or longer peg-like tip) 9
- Tail with convex dorsal contour, its tip not peg-like 24
- 9. Very large species, more than 3 mm; ventromedian supplements about 20 10
- Average body length shorter than 3 mm, ventromedian supplements 15 or less 11
- 10. Female tail longer than anal body diameter; supplements continuous with the adanal pair. (female : 3.4 mm; male : 3.3 mm) ...
 A. cocophilus (Loos, 1949) Andrassy, 2001
- Female tail shorter than anal body diameter; supplements well separated from the adanal pair. (female : 3.4 mm; male : 3.3–3.4 mm)
 A. estonicus (Krall, 1957) Andrassy, 1990
- 11. Tail mammillate (with a short subdigitate projection) 12
- Tail not mammillate 17
- 12. Body small, less than 1.5 mm 13
- Body over 1.5 mm 14
- 13. Tail length equal to anal body diameter
 *A. kikereensis* Baqri & Coomans, 1973
- Tail quite short, only half of anal body diameter *A. insularis* Andrassy, 2004
- 14. Average body length 2.5 mm; cuticle heavily radially striated. (female : 2.2–3.3 mm; male : unknown)
 *A. malagasi* Heyns, 1996
- Average body length 2 mm or less; cuticle finely radially striated 15
- 15. Tail projection subterminal (ventrally shifted). (female : 1.9 mm; male : unknown)
 *A. paracentrocercus* (De Coninck, 1935) Baqri & Coomans, 1973
- Tail projection terminal 16
- 16. Tail more or less conoid. (female : 1.9–2.2 mm; male : 1.7–1.9 mm)
 *A. gerlachi* (Meyl, 1956) Heyns, 1965
- Tail broad, conoid–rounded. (female: 1.5–2.3 mm; male : 1.7 mm)
 *A. stilus* (Kirjanova, 1951) Andrassy, 1986
- 17. Body small, 1.3 mm or less; vulva in 62 %. (female : 1.1 mm; male : 1.3 mm)
 A. duhouxi (Altherr, 1963) Baqri & Khera, 1975
- Body larger, 1.5 mm or more; vulva more anterior 18
- 18. Larger species, 2.5– 3.0 mm; stylet 25–30 μ m 19
- Smaller species, 1.5–2.3 mm; stylet 18–23 μ m 20
- 19. Tail shorter than half an anal body diameter; AS₂ nucleus close to the middle of glandularium. (female : 2.5–3.0 mm; male : unknown)
 A. krygeri (Ditlevsen, 1928) Heyns, 1965
- Tail nearly as long as one anal body diameter; AS₂ nucleus at the first quarter of glandularium. (female: 2.5–2.9 mm; male: 2.7 mm)
 A. pycnus (Thorne, 1939) Baqri & Khera, 1975
- 20. Tail longer than anal body width. 21
- Tail shorter than anal body width 22
- 21. Body large in size. (female: unknown; male: 2.3 mm)
 ... *A. seinhorsti* (Meyl, 1957) Heyns, 1965
- Body small in size. (female: 1.62–1.73 mm; male: unknown)
 *A. amazonicus*, Andrassy, 2004

22. Stylet 18–19 μm long; body shorter. (female : 1.5–1.7 mm; male : unknown)
A. samarcandicus (Tulaganov, 1949) Baqri & Khera, 1975
- Stylet 21–23 μm long; body longer 23
23. Tail as long as 0.5 anal body width or shorter, outer layer of cuticle (+ lacuna) on tail tip as thick as or thinner than inner (transparent) layer. (female : 1.7–1.9 mm; male : 1.7 mm)
A. medius Andrassy, 2002
- Tail as long as 0.7–1.0 anal body width, outer layer of cuticle (+ lacuna) on tail tip always thicker than inner layer. (female : 1.8–2.2 mm; male : unknown)
A. alius Andrassy, 2002
24. Small species, less than 2 mm 25
- Larger species, 2 mm or more 28
25. Tail conoid with finely rounded tip .. 26
- Tail conoid with broadly rounded tip 27
26. Tail with a pair of caudal pores on each side. (female : 1.0–1.9 mm; male : 1.0–1.5 mm)
A. budauniensis Khatoon & Sharma, 2000
- Tail without caudal pores. (female : 1.2 mm; male : 1.2 mm)
A. productus (Thorne & Swanger, 1936) Baqri & Khera, 1975
27. Spear-aperture occupying one-half of its length. (female : 1.1 mm; male : 1.1 mm)
A. propinquus (Thorne & Swanger, 1936) Tjepkema, Ferris & Ferris, 1971
- Spear-aperture occupying less than one-half of its length. (female : 1.02–1.20 mm; male : unknown)
A. jairajpurii Singh *et al.*, 2002
28. Stylet 30 μm long 29
- Stylet shorter 30
29. Tail conoid–rounded. (female : 2.8 mm; male : unknown)
A. nivalis (Altherr, 1952) Heyns, 1965
- Tail almost hemispherical. (female : 2.5–2.7 mm; male : unknown)
A. goldeni Khan & Fatima, 1980
30. Vulval lips not sclerotized 31
- Vulval lips strongly sclerotized 35
31. Body shorter than 2 mm. (female : 1.2–1.9 mm; male : 1.6–1.8 mm)
A. adriaani Botha & Heyns, 1990
- Body longer than 2 mm 32
32. Lip region wider, 18–23 μm ; supplements less in number 33
- Lip region narrower; 15–17 μm ; supplements more in number 34
33. Mural tooth on the ventral wall of pharynx. (female : 1.9–2.8 mm; male : 2.0–2.5 mm)
A. faridpuriensis Singh *et al.*, 2002
- Pharynx has no mural tooth. (female : 2.2–2.8 mm; male : 2.1–2.4 mm)
A. papillatus (Bastian, 1865) Baqri & Khera, 1975
34. Tail long, 45–50 μm . (female: 2.0–2.9 mm; male: unknown)
A. nawabganjense Singh *et al.*, 2002
- Tail short, 35.5 μm . (female : 2.1–2.5 mm; male : 2.3–2.4 mm)
A. parapapillatus Botha & Heyns, 1990
35. Body length near 2 mm or less 36
- Average body length about 2.5 mm ... 45
36. Tail short, about $\frac{1}{2}$ anal body diameter. (female : 1.9–2.0 mm; male : unknown).
.....
A. odhneri (Allgen, 1951) Andrassy, 1990
- Tail distinctly longer than $\frac{1}{2}$ anal body diameter 37
37. Tail equal to anal body diameter or longer 38
- Tail shorter than one anal diameter ... 42
38. Stylet 20–22 μm long 39
- Stylet 24–25 μm long 41

39. Tail more convex ventrally than dorsally.
(female : 1.7–2.1 mm; male : 1.9 mm)
.....
A. amylovorus (Thorne & Swanger, 1936)
Heyns, 1965
Tail more convex dorsally than ventrally
..... 40
40. Body longer. (female : 2.1–2.3 mm; male :
2.2–2.3 mm) *A. taylori* Yeates, 1967
– Body shorter. (female : 1.3–1.6 mm; male :
unknown)
A. vitrinus (Thorne & Swanger, 1936) Baqri
& Khera, 1975
41. Prerectum longer, 3–4 anal body widths.
(female : 1.5–2.0 mm; male : unknown).
.....
A. conoidus Thorne, 1974
– Prerectum shorter, 1.5 anal body widths.
(female : 1.6–2.1 mm; male : unknown).
.....
.. *A. hylophilus* Tjepakema, Ferris & Ferris,
1971
42. Stylet short, 10–12 μ m. (female : 1.8–1.9
mm; male : unknown) *A. amplexor*
(Nesterov & Lisetskaya, 1965) Heyns, 1965
– Stylet 20 μ m or longer 43
43. Tail more or less conoid with narrowly
rounded tip. (female : 1.9–2.6 mm; male :
unknown) *A. micropunctatus* Botha &
Heyns, 1990
– Tail blunt, conoid with broadly rounded
tip 44
44. Stylet 20–22 μ m, broad. (female : 1.9 mm;
male : unknown)
.. *A. tritici* (Bastain, 1865) Andrassy, 1986
– Stylet 24–26 μ m long, slender. (female : 1.8–
2.0 mm; male : 1.9 mm)
..... *A. baqrii* Ahmad & Jairajpuri, 1982
45. Tail conoid with narrowly rounded tip.
(female : 2.4 mm; male : unknown)
.....
A. punctatus Altherr in Altherr & Delamare
Deboutteville, 1972
– Tail conoid–rounded or hemispheroid with
blunt terminus 46
46. Ventromedian supplements more than 20.
(female : unknown; male : 2.4 mm)
.....
A. index (Thorne, 1939) Andrassy, 1986
– Ventromedian supplements less than 15
..... 47
47. Supplements 11–14 in number. (female :
2.0–3.3 mm; male : 2.1–3.0 mm)
A. obtusicaudatus (Bastian, 1865) Altherr,
1968
– Supplements 7–10 in number 48
48. Inner cuticle with very strong radial
striaion; stylet as thick as cuticle at same
level. (female : 2.5–3.2 mm; male : 2.5–2.8
mm)
A. macropunctatus (Heyns, 1967) Jimenez
Guirado, 1994
– Inner cuticle with weak striaion; stylet
much thicker than cuticle at same level.
(female : 2.4–2.9 mm; male : 2.6–2.9 mm)
..... *A. futaii* Khan & Araki, 2002

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Table 1. Measurements of eight species of *Aporcelaimellus* (L in mm, others in μm)

Morphometric parameters	<i>A. budauniensis</i> Khatoon and Sharma, 2000			<i>A. futaii</i> Khan and Araki, 2002			<i>A. faridpuriensis</i> Singh, Sharma & Khatoon, 2002			<i>A. jairajpurii</i> Singh Sharma & Khatoon, 2002		
	Holo type female	Para type females (n=4)	Para type males (n=3)	Holo type female	Para type females (n=5)	Para type males (n=3)	Holo type female	Para type females (n=3)	Para type male (n=4)	Holo type female	Para type females (n=4)	Male Not found
L	1.2	1.0 – 1.9	1.0 – 1.5	2.8	2.4 – 2.9 (2.6 $\pm$ 0.14)	2.6 – 2.9	2.4	1.9 – 2.8 (2.4 $\pm$ 0.56)	2.0 – 2.5 (2.2 $\pm$ 2.51)	1.2	1.02 – 1.20 (1.1 $\pm$ 4.34)	–
a	19.7	15.0 – 24.0	25 – 30	31	25 – 33 (28.8 $\pm$ 2.6)	34 – 37	21.6	20 – 27 (24 $\pm$ 3.60)	20 – 23 (21 $\pm$ 1.52)	26.3	25 – 35 (29 $\pm$ 4.20)	–
b	5.4	4.5 – 5.5	0.35 – 0.40	4.6	4.1 – 4.6 (4.4 $\pm$ 0.11)	4.3 – 4.5	4.3	3.9 – 4.7 (4.3 $\pm$ 4.18)	4.0 – 4.5 (4.3 $\pm$ 2.64)	3.7	3.0 – 4.0 (3.4 $\pm$ 0.34)	–
c	35.7	30.0 – 40.0	30 – 35	80	60 – 80 (69.3 $\pm$ 5.4)	55 – 58	67.2	56 – 69 (61 $\pm$ 7.0)	73 – 75 (74 $\pm$ 1.0)	53.6	50.0 – 59.0 (53 $\pm$ 3.87)	–
c'	1.2	0.9 – 1.8	0.9 – 1.5	–	0.8 – 0.9 (0.8 $\pm$ 0.06)	1.0 – 1.1	64	60 – 68 (64 $\pm$ 5.13)	0.5 – 0.7 (0.6 $\pm$ 1.0)	0.85	0.5 – 1.5 (1.0 $\pm$ 0.20)	–
V	53	50 – 55	–	56	56 – 58 (56.3 $\pm$ 1.4)	–	52.3	45 – 55 (50 $\pm$ 2.44)	–	58.2	55 – 62 (57 $\pm$ 3.10)	–
Odontostylet length	32	28 – 35	18 – 21	22	22 – 26 (23 $\pm$ 1.2)	23 – 25	36	35 – 39 (37 $\pm$ 2.44)	73 – 75 (74 $\pm$ 1.0)	24	22 – 30 (25 $\pm$ 3.41)	–
Odontophore length	32	27 – 36	17.2	48	40 – 48 (44 $\pm$ 2.4)	46 – 48	24	22 – 30 (25 $\pm$ 4.12)	73 – 74 (73 $\pm$ 1.0)	32	30 – 35 (31 $\pm$ 1.38)	–

Morphometric parameters	<i>A. budauniensis</i> Khatoon and Sharma, 2000			<i>A. futaii</i> Khan and Araki, 2002			<i>A. faridpuriensis</i> Singh, Sharma & Khatoon, 2002			<i>A. jairajpurii</i> Singh Sharma & Khatoon, 2002		
	Holo type female	Para type females (n=4)	Para type males (n=3)	Holo type female	Para type females (n=5)	Para type males (n=3)	Holo type female	Para type females (n=3)	Para type male (n=4)	Holo type female	Para type females (n=4)	Male Not found
Oesophageal length	–	–	–	633	576 – 633 (599 ± 18.6)	580 – 626	–	–	–	8.0	–	–
Height of lip region	8	–	–	–	7 – 10	–	8.0	–	–	16	–	–
Width of lip region	20	–	–	–	21 – 27	–	20	–	–	8	–	–
Guiding ring from anterior end	65.2	–	–	–	14 – 16	–	16	–	–	150	–	–
Nerve ring from anterior end	146	–	–	–	195 – 216	–	140	–	–	–	–	–
Length of cardia	16	–	–	–	28 – 37	–	–	–	–	40	–	–
Prerectum	70	–	–	128	85 – 128 (101 ± 10.8)	130 – 150	145	–	–	24	–	–
Rectum	50	–	–	71	55 – 69 (61 ± 4.4)	60 – 65	150	–	–	–	–	–
Length of spicule	–	–	34 – 39	–	–	82 – 90	–	–	50 – 55 (51 ± 2.51)	–	–	–
Tail length	36	35 – 45	34 – 37	36	35 – 41 (38.5 ± 2.4)	45 – 48	36	34 – 45 (40 ± 1.68)	30 – 33 (31 ± 1.68)	24	22 – 30 (25 ± 3.31)	–

Table 1. *Contd.*

Morphometric parameters	<i>A. nawabganjense</i> Singh, Sharma & Khatoon, 2002			<i>A. amazonicus</i> Andrassy, 2002			<i>A. insularis</i> Andrassy, 2002			<i>A. subhasi</i> Gantait et al. 2006		
	Holo type female	Para type females (n=3)	Male Not found	Holo type female	Para type females (n=2)	Male Not found	Holo type female	Para type females (n=8)	Male Not found	Holo type female	Para type females (n=17)	Male Not found
L	2.2	2.0 – 2.9 (2.4 ± 1.84)	–	1.62	1.63 – 1.73	–	1.39	1.20 – 1.46	–	1.50	1.48 – 1.71 (1.66 ± 0.06)	–
a	3.4	3.3 – 3.9 (3.6 ± 3.0)	–	25	21 – 23	–	18	14 – 18	–	25.7	24.6 – 29.0 (27.63 ± 1.55)	–
b	4.8	4.5 – 5.0 (4.7 ± 2.64)	–	3.5	4.3 – 4.4	–	3.7	3.3 – 3.9	–	3.9	3.1 – 4.2 (3.96 ± 0.24)	–
c	47.2	45.0 – 52.0 (48 ± 3.53)	–	41	36 – 41	–	57	63 – 70	–	27.9	26.5 – 29.0 (28.52 ± 0.79)	–
c'	1.25	0.9 – 1.5 (1.1 ± 3.24)	–	1.1	1.0 – 1.5	–	0.6	0.5 – 0.6	–	1.64	1.61 – 1.66 (1.64 ± 0.02)	–
V	60	58 – 65 (61 ± 3.60)	–	49	44 – 45	–	54	52 – 54	–	52.4	50.6 – 53.4 (52.91 ± 0.72)	–
Odontostylet length	19.5	19.0 – 25.0 (22 ± 3.53)	–	26	–	–	28	28 – 30	–	19.83	19.0 – 21.4 (20.68 ± 0.68)	–
Odontophore length	21.0	20 – 25 (22 ± 2.51)	–	–	–	–	–	–	–	29.64	29.0 – 32.0 (30.91 ± 1.04)	–

Morphometric parameters	<i>A. nawabganjense</i> Singh, Sharma & Khatoon, 2002			<i>A. amazonicus</i> Andrassy, 2002			<i>A. insularis</i> Andrassy, 2002			<i>A. subhasi</i> Gantait <i>et al.</i> 2006		
	Holo type female	Para type females (n=3)	Male Not found	Holo type female	Para type females (n=2)	Male Not found	Holo type female	Para type females (n=8)	Male Not found	Holo type female	Para type females (n=17)	Male Not found
Oesophageal length	458.33	–	–	–	380 – 450	–	–	360 – 406	–	382.15	381.72 – 387.36 (384.93 ± 2.15)	–
Height of lip region	–	7 – 9	–	–	–	–	–	–	–	–	–	–
Width of lip region	–	16 – 20	–	–	18 – 19	–	–	–	–	–	–	–
Guiding ring from anterior end	6.48	–	–	–	–	–	–	–	–	7.2	7.0 – 8.4	–
Nerve ring from anterior end	190.0	–	–	–	–	–	–	–	–	134.4	132.0 – 146.0 (140.9 ± 5.15)	–
Length of cardia	15	–	–	–	–	–	–	–	–	–	–	–
Prerectum	244.5	–	–	–	64.6 – 91.2	–	–	41.0 – 73.8	–	–	–	–
Rectum	260.8	–	–	–	41.8 – 60.8	–	–	41.0 – 61.5	–	–	–	–
Tail length	47	45 – 50 (47 ± 2.51)	–	39.51	40 – 48	–	20.5	–	–	54.12	53.6 – 66.8 (62.47 ± 5.61)	–

LITERATURE CITED

- ANDRASSY, I. 1959. Taxonomisch Übersicht der Dorylaimen (Nematoda), I. *Acta Zoologica Hungarica*, 6 : 1-28.
- ANDRASSY, I. 2002. Free-living nematodes from the Ferto- Hansag National Park. Hungary. In Mahunka, S. (ed.) : *The fauna of the Ferto-Hansag National Park*, 21-97.
- ANDRASSY, I. 2004. Two new species of *Aporcelaimellus* Heyns, 1965 (Nematoda : Dorylaimida) from the tropics. *Acta Zoologica Academiae Scientiarum Hungaricae*, 50(2) : 97-107.
- BAQRI, Q. H. and JAIRAJPURI, M. S. 1968. On six new species of Dorylaimida (Nematoda). *Journal of Helminthology*, 42 : 243-256.
- BAQRI, Q. H. and KHERA, S. 1975. Two new species of the genus *Aporcelaimellus* Heyns, 1965 with some remarks on the relationship of *Aporcelaimellus* with *Eudorylaimus* Andrassy, 1959 (Dorylaimoidea : Nematoda). *Dr. B. S. Chauhan Commemoration Volume, Zoological Survey of India* : 171-180.
- DE MAN, J. G. 1876. Onderzoekingen over vrij in de aarde levende Nematoden. *Tijdschr. ned. dierk. Ver.*, 2 : 78-196.
- GANTAIT, V. V., BHATTACHARYA, T. and CHATTERJEE, A. 2006. Two new species of Dorylaims (Nematoda : Dorylaimida) associated with banana from India. *Nematologia Mediterranea*, 34 : 129-134.
- HEYNS, J. 1965. On the morphology and taxonomy of Aporcelaimidae, a new family of dorylaimoid nematodes. *Entomology Memoirs of Department of Agricultural Technical Services of Southern Africa*, 10 : 1-51 pp.
- JAIRAJPURI, M. S. and AHMAD, W. 1992. Dorylaimida : Free-living, Predaceous and Plant Parasitic Nematodes. *Oxford and IBH Publishing Company Private Limited, New Delhi* : pp.458
- KHATOON, M. and SHARMA, S. 2000. A new species of soil nematode of *Aporcelaimellus* Heyns, 1965 (Dorylaimoidea : Aporcelaimidae) from Uttar Pradesh. *Indian Journal of Nematology*, 30(2) : 228-230.
- KHAN, Z. and ARAKI, 2002. Study of dorylaims (Nematoda) from Japan with descriptions of five new species. *International Journal of Nematology*, 12(1) : 1-12.
- SINGH, K., SHARMA, S. and KHATOON, M. 2002. Three new species of the genus *Aporcelaimellus* (Dorylaimida: Aporcelaimidae) associated with Pulse crops from Rohilkhand Division, U. P. *Indian Journal of Nematology*, 32(1) : 66-72.
- THORNE, G. and SWANGER, H. H. 1936. A monograph of the nematode genera *Dorylaimus* Dujardin, *Aporcelaimus* n. g., *Dorylaimoides* n. g. and *Pungentus* n. g. *Capita Zoologica*, 6 : 1-223.
- THORNE, G. 1974. Nematodes of the Northern Great Plains. Part II. Dorylaimoidea in part (Nemata: Adenophorea). *Technical Bulletin of Agricultural Experiment Station. South Dakota State University, Brookings*, 41 : 120 pp.
- TJEPKEMA, J. P., FERISS, V. R., and FERISS, J. M. 1971. Review of the genus *Aporcelimellus* Heyns, 1965, and six species groups of the genus *Eudorylaimus* Andrassy, 1959 (Nematoda: Dorylaimida). *Research Bulletin of Agricultural Experiment Station, Purdue University, Lafayette*, 882 : 1-52.

PERTINENCE OF BIODIVERSITY CRITERIA IN FIXING CONSERVATION PRIORITY OF TERMITES (ISOPTERA) IN THE EASTERN GHATS, INDIA

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ABSTRACT

The paper deals with the detailed distribution of the termite fauna of the Eastern Ghats including in its three distinct physiographic units, namely, Tamil Nadu Hills, Cuddaph Range (A.P.) and Orissa Hills. The object is to suggest which unit /species of termites deserves priority of conservation over others based on the relative importance of biodiversity values or criteria of species occurring in the different units. Out of 42 species known so far from the Eastern Ghats, Tamil Nadu Hills supports 34 species, while Cuddaph Range 19 and Orissa Hills 13 species along with some common species in all the units. Biodiversity criteria or values of termites taken into accounts are taxonomic diversity and uniqueness, phylogenetic divergence, diversity enhancement, ecological roles, reproductive vulnerability, co-evolutionary relationship, species richness, etc. It has been concluded that the Tamil Nadu Hills unit seems to gain priority of conservation as an area including its termite species over others, while Cuddaph Range and Orissa Hills remain in relatively decreasing importance.

Key words : Isoptera, Conservation, Eastern ghats.

INTRODUCTION

Urgency impels now-a-days to conserve biological diversity including its habitats due to its rapid loss everywhere, caused by some natural and anthropogenic factors. No doubt the rate of losses is accelerated through our greed beyond need, stupidity and uncaring attitude. As such, it needs care and conservation. The strategies of conservation from its age old infancy were directed to some charismatic animals and colourful plants, then to the target species and its habitats, subsequently to the ecosystems and to day to biological diversity.

Conservation of biodiversity in the recent past means conserving totality of life in the level of genetic, morphological and ecosystem diversities, conserving variety of ecological processes and life-supporting systems

(agriculture, forest, fishery, etc.), conserving variety of rare breeds and cultivars, variety of population, etc. Since the task is enormous in considering the vast wilderness, the priority of conservation is about deciding which animal population and species to conserve, which habitats to manage, which areas of land, sea, water enriched with resources to take into account.

India being a megadiversity country, its fauna is as vast as the country itself. It supports some 65,000 species animals except the microbials while many more remain unknown. As such, it is impossible to conserve all species and areas. Moreover, it cannot be pleaded fully to conserve a friendly or useful species and to indicate the harmful one when two are very much mixed together. As for example, termites (Isoptera) are predominantly known as pest, but their immense role in increasing fertility of

soil is more important. Further, conservation strategy is normally directed to establish numerous fairly large nature reserves in our country ensuring the diversity of our living resources with main focus of charismatic animals. But in reality, these reserves are not adequate to safeguard the vast diversity due to ill management, exploitation, insufficient in number and size, unsuitable location, etc.

In any conservation efforts, it needs choice to be made on relative biodiversity values or criteria based on which priority of conservation clues could be traced. Nevertheless, the indepth study and understanding of biodiversity (as we conceive to day) of a given area or taxon, are sure to provide the clues of conservation in general and priority in particular.

Biodiversity as we understand today is the variety and variability of organisms (species diversity), of genetic material (genetic diversity) and of ecosystem or community (ecosystem diversity). This includes diversity within species (genetic diversity), between species (species diversity) and ecosystem or community (ecosystem diversity). In depth understanding of each of these three components, will certainly provide some clues of biological conservation priority based on relative biodiversity values or criteria of species. Keeping aside genetic and community diversities, if only species diversity is considered, then many aspects need to be addressed, the discussion of which is the main theme of the present contribution. For examples, species diversity does not mean only the number of species (species-richness). It includes many species criteria, such as, relatively unique at the highest level of classification, primitiveness and phylogenetic divergence, biological and functionally importance, ecologically significant, vulnerability in reproduction and population, co-evolutionary roles, etc. These are the basic clues of conservation used on priority basis for fixing the conservation of species in isolation or species congregation in a particular area.

The paper devotes to suggest which area/species deserves priority of conservation over others based on relative importance of

biodiversity values or criteria of termites as referred to above.

TERGET FAUNA

Termites belonging to small insect Order Isoptera, are one of the most vital components of tropical ecosystems inhabiting wood, soil and different types of self-made nests. They generally play very contrasting roles of both beneficial as decomposers and harmful as pests of anything of cellulosic origin. Predominantly such soil inhabiting decomposers like termites face immediate disaster with minor disturbances in the ecosystems caused by men as well as natural calamities. Hence, according to their merits of pests and beneficial roles, they deserve protection or management along with their habitats. The deep understanding of the conceptual biodiversity has certainly provided insight into the strategies of finding out some clues of conservation on priority basis.

Although the first ever taxonomic work on Indian Termites was initiated in south India as early as in 1779 by Koning, but the exact locality from where collections made were unknown. There was no exact record of occurrence of termites in the Eastern Ghats until Bose and Das (1982), Bose (1984), Roonwal and Chhotani (1989) and Chhotani (1997) had reported many species from the area (Table-I). Present paper is mainly based on these papers as well as has utilized the long experience of collection and study of termites by the author around the country including the Eastern Ghats. The phylogenetic trees of termite genera framed, have been devised and modified by the author based on the contributions of Ahmad (1950) and Krishna (1969).

PHYSIOGRAPHY OF THE EASTERN GHATS

The Eastern Ghats—a distinct and disrupted physiographic hilly unit of India—stretches from the Mahanadi in the north-east (Orissa) to the Shevroy Hills in the south-west (Tamil Nadu) via the districts of Nallamalai, Velikonda, Erramalai, Seshachalam and Palkonda range in the middle of Andhra Pradesh. Due to its

Table-1. Distribution of Species in three different units of Eastern Ghats

	Tamil Nadu Hills	Cuddaph Range (A. P.)	Orissa Hills
Family HODOTERMITIDAE Desneux			
Subfamily HODOTERMITINAE Desneux			
1. <i>Anacanthotermes viarum</i> (König)	+	-	-
Family KALOTERMITIDAE Froggatt			
Subfamily KALOTERMITINAE Froggatt			
2. <i>*Neotermes dhirendrai</i> Bose	+	-	-
3. <i>*N. fletcheri</i> Holmgren and Holmgren	+	-	-
4. <i>*N. krishnai</i> Bose	+	-	-
5. <i>Procryptotermes dhari</i> Roonwal and Chhotani	+	-	-
6. <i>Cryptotermes dudleyi</i> Banks	-	-	+
Family RHINOTERMITIDAE Froggatt			
Subfamily COPTOTERMITINAE Holmgren			
7. <i>Coptotermes ceylonicus</i> Holmgren	+	+	-
8. <i>C. heimi</i> (Wasmann)	+	-	+
Subfamily Heterotermitinae Froggatt			
9. <i>Heterotermes balwanti</i> Mathur and Chhotani	-	-	+
Family STYLOTERMITIDAE Holmgren and Holmgren			
10. <i>Stylotermes fletcheri</i> Holmgren and Holmgren	+	-	-
Family TERMITIDAE Westwood			
Subfamily AMITERMITINAE Kemner			
11. <i>Speculitermes dharwarensis</i> Roonwal and Chhotani	-	+	-
12. <i>S. sinhalensis</i> Roonwal and Sen Sarma	+	+	-
13. <i>Eurytermes buddha</i> Bose and Maiti	+	-	-
14. <i>Eulamitermes dentatus</i> Thakur and Chatterjee	-	+	-
15. <i>E. indicus</i> Holmgren and Hotmgren	+	-	-
16. <i>Microcerotermes cameroni</i> Synder	-	+	-
17. <i>M. ganeshi</i> Bose	+	-	-
18. <i>M. minor</i> Holmgren	+	+	-
19. <i>Eremotermes fletcheri</i> Holmgren and Holmgren	+	-	-
20. <i>E. paradaxalis</i> Holmgren	+	-	-
Subfamily TERMITINAE Sjöstedt			
21. <i>Pseudocapritermes fletcheri</i> (Holmgren and Holmgren)	+	-	-
22. <i>Pericapritermes topslipensis</i> Thakur	+	-	-
Subfamily MACROTERTERMITINAE Kemner			
23. <i>Macrotermes convulsionarius</i> (König)	+	+	+
24. <i>Odontotermes assmuthi</i> Holmgren	+	-	+
25. <i>O. bellahunisensis</i> Holmgren and Holmgren	+	-	-
26. <i>O. boveni</i> Thakur	+	+	-
27. <i>O. brunneus</i> (Hagen)	+	+	+
28. <i>O. ceylonicus</i> (Wasmann)	+	-	+

	Tamil Nadu Hills	Cuddaph Range (A. P.)	Orissa Hills
29. <i>O. distans</i> Holmgren and Holmgren	+	–	–
30. <i>O. feae</i> (Wasmann)	+	+	+
31. <i>O. horni</i> (Wasmann)	+	+	+
32. <i>O. obesus</i> (Rambur)	+	+	+
33. <i>O. redemanni</i> (Wasmann)	+	+	+
34. <i>O. wallonensis</i> (Wasmann)	+	+	+
35. <i>Microtermes incertoides</i> Holmgren	–	+	–
36. <i>M. obesi</i> Holmgren	+	+	+
Subfamily NASUTITERMITINAE Hare			
37. <i>Nasutitermes anamalaiensis</i> Synder	–	+	–
38. <i>N. brunneus</i> Snyder	+	–	–
39. <i>N. fletcheri</i> (Holmgren and Holmgren)	+	–	–
40. <i>Trinervitermes biformis</i> (Wasmann)	+	+	–
41. <i>T. fletcheri</i> Chatterjee and Thakur	+	–	–
42. <i>T. sensarmai</i> Bose	–	+	–
	34	19	13

*Species marked with asterisk are endemic to E.G.

disrupted nature, three distinct units are named as Orissa Hills in the north, Cuddapah range in the central A.P. and Tamil Nadu Hills in the south-west.

Although the vegetation of the Eastern Ghats is remarkable at places, but concentration of tropical, subtropical and temperate species and of evergreen at elevations above 1070 m above mean sea-level, is as a whole, typically deciduous and scrubjungle in nature in most places.

The Eastern Ghats serve as an important repository of biological resources. Such important ecosystems including its fauna and flora is under severe threat due to development of ecotourism, extension of agriculture, industries and urbanization, grazing, clearance of forest, etc. Therefore, the fauna and flora of this crisis area need inventorization and conservation before any severe ecodisaster takes place in the area.

OBSERVATIONS

Fauna Assessment

The scrutiny of all the existing literature reveals the occurrence of 42 species of termites belonging to 19 genera under 5 families in the Eastern Ghats. Most of the genera are poorly

represented with about 2-3 species, except the most common genus *Odontotermes* with 11 species. The area supports about 12.50 per cent of the total 337 species known from the Indian subregion. As a whole, it is not at all very rich in termite faunal strength. Neither the species occur uniformly throughout the entire ranges of the Ghat area, nor it is the homogeneous assemblage of fauna. Rather, the termite fauna seems to be an assemblage of heterogenous genera and species including its own endemics of nine species (vide, List of species, Table-1, with asterisk).

Species Diversity Gradient

As already mentioned, there is hardly any uniformity in the distribution of either species richness or taxonomic diversity of termites in the Eastern Ghats. Rather nonuniformity exists everywhere. However, not a single process or theory can explain this complex phenomenon of unequal distribution. The discussion on these aspects may involve many ecological, evolutionary, geological and biogeographical process and how these processes interact (Huston, 1994) is beyond the scope of the present paper. However, only the latitudinal gradients of termite distribution is of some importance.

Latitudinal Gradient : It is observed in large majority of organisms that species richness decreases towards higher latitudes and increases towards lower latitudes. This is also no exception to termites of the Eastern Ghats. The Tamil Nadu Hill range situated in lower latitudes supports more species and higher taxa than the two units situated gradually toward higher latitudes in the north-east (Table-1). This observation remains quite tentative since the species richness is related to area in a very complicated manner. As such, caution calls forth in comparing the diversity of area that greatly differs in size.

Conservation Priority

As already mentioned in the Introduction that the priority of conservation of species/ area is primarily based on the relative importance of biodiversity values or criteria. These criteria have been discussed here with notes of which unit of the Eastern Ghats deserve conservation priority over others on the basis of relative weight and richness of species.

1. Taxonomic Diversity : Higher taxa richness or taxonomic diversity is not same in all three units of the Eastern Ghats. For examples, the number of families, subfamilies and genera recorded from the Tamil Nadu Hills indicates more taxonomic diversity with five families, nine subfamilies and 17 genera than those in the Cuddaph with two families, five subfamilies and nine genera and Orissa Hill ranges with two families five subfamilies six genera respectively (Table-1). More taxonomic diversity in Tamil Nadu Hill Unit generally indicates its more potentiality of occurrence of more species, yet to be explored. This criteria is one of the most important parameters for fixing conservation priority of area over others.

2. Phylogenetic divergence and taxonomic uniqueness : The scrutiny of phylogenetic tree of termite genera clearly helps in determining the relative taxonomic uniqueness, phylogenetic divergence, primitiveness and evolutionary advance species of termites occurring in the Eastern Ghats (Table-3). These criteria of each and every species in an assemblage in a site are

widely considered while fixing the priority of conservation of the species over the others, inspite of numerical strength of species being the first priority.

In the Eastern Ghats, the Tamil Nadu Hill Unit certainly gets priority of conservation over others with reference to all these consideration. There are 34 species on record from this unit amongst a total of 42 species in the Eastern Ghats. The examination of the phylogenetic sequence of termites occurring in the Tamil Nadu Hills (Table-2) shows the presence of *Anacanthotermes viarum* (Köni). This species represents a relict primitive family Hodotermitidae which has adapted to arid and grass land habitat in the latter stage of evolution, inspite of its tertiary temperate habitat (Emerson, 1955). Its taxonomic uniqueness is recognised, since its only close by related species *A. macrocephalus* (Desneux) occurs in the northern arid zone of India. Likewise, the members of the primitive wood-inhabiting genera *Neotermes*, *Procrystotermes*, *Stylotermes*, etc. are present in this unit which are absent in other units. As an area Tamil Nadu Hill unit gets priority of conservation over other units, both supporting more number of species (species-richness) and containing more conservation focused species as referred to above.

3. Enhancement of diversity : All the termite species occurring in the Eastern Ghats do not have the same potentiality in contributing to the local biodiversity. The wood-eating termites belonging to the families Kalotermitidae and Rhinotermitidae harbour numerous protozoan flagellates in their guts as symbionts and help digestion of cellulose. The Tamil Nadu Hill Unit has 10 species of these higher wood-eating termites which have potentiality to add to the local diversity as regards total species richness. Only single species, *Neotermes dhirendrai* Bose support 5 species in its gut (Mukherjee and Maiti, 2007, in press) which is no doubt a very important conservation criterion (Table-4). Another species, *Coptotermes heimi* (Wasmann) occurring in Tamil Nadu Hill unit as well as in Orissa Hill Unit contains 18 flagellate species

Table 2. Phylogenetic Sequence of Termite Taxa (Eastern Ghats)

				Tamil Nadu Hills	Cudaph Range	Orissa Hills
Family	Subfamily	Genus				
Blattoid Ancestor	Kalotermitidae	Kalotermitinae	Cryptotermes	-	-	1
			Procryptotermes	1	-	-
			Neotermes	3	-	-
	Hodotermitidae	Hodotermitinae	Anacanthotermes	1	-	-
	Stylotermitidae	Stylotermitinae	Stylotermes	1	-	-
	Rhinotermitidae	Heterotermitinae	Heterotermes	-	-	1
		Coptotermitinae	Coptotermes	2	1	1
	Termitidae	Amitermitinae	Speculitermes	1	2	-
			Eurytermes	1	-	-
			Euhamitermes	1	1	-
			Microcerotermes	2	2	-
			Eremotermes	2	-	-
		Termitinae	Pseudocapritermes	1	-	-
			Pericapritermes	1	-	-
		Macrotermitinae	Microtermes	1	2	1
			Odontotermes	11	7	8
			Macrotermes	1	1	1
		Nasutitermitinae	Nasutitermes	2	1	-
			Trinervitermes	2	2	-
Total				34	19	13

recorded from different parts of the Eastern India (Mukherjee and Maiti, 2007, in press). This criterion also deserves consideration while fixing priority of conservation, since these termites add to the total species richness. Single species protected helps conserving many species indirectly, whether those may be termites or others associated organisms.

4. Distinctiveness of ecological role : Distinct ecological role played by some species of termites of the genera, *Odontotermes*, *Microtermes* and *Macrotermes* belonging the subfamily Macrotermitinae is another criteria. *Odontotermes obesus*—a most common mound building termite in India (common in the Eastern Ghats) helps growing many species of

fungus in its fungus-garden within the mounds. Among these fungus, *Aspergillus flavus*, *A. aryzae*, *A. ustus*, *Allernaria* sp., *Currularia* sp. etc. are commonly known. The sponge-like fungus-garden build from vegetable residues supports, as mycelium with white nodules of conidia and conidiospores (Sen-Sarma 1974, reported). It is believed that conidia might be used as food for newly hatched young nymphs, comb seems to be eaten by termites and the fungus garden serves as the humidity regulator. Although, the exact relationship of termites with fungi is unknown, there is little doubt that the termites are nutritionally and ecologically dependent on fungi. Such association scores well on the measure of ecological distinction for selection on priority basis.

5. Vulnerability of species in relation to reproduction and population biology : This is another very important criteria of species for conservation. The primitive kalotermitid species with low reproductive rate (comparatively fewer eggs laid) needs more attention than others for protection, since it occupies distinct position in the evolution of termites from the ancestral roaches. The kalotermitid species of the genera *Neotermes* (3 species), *Procryptotermes* (1 sp.) and *Cryptotermes* (1 sp.) lay few eggs resulting to smaller population in comparison with other species with production of thousands of population. Though there is no direct record of low reproductive potentiality of species occurring in the study area, reference may be made of a oriental species *Neotermes tectonae*. It's colonies normally contain about 3000 individuals and reproductive forms (imagos) are not produced before six years. (Kalshoven, 1959). However, these wood inhabiting kalotermitid species are represented in the Tamil Nadu Hills and absent in other two units. The unit supporting such species needs attention.

6. Co-evolutionary relationship with other species in the nest : The most important termitophilous insects in India are Staphilinidae (Coleoptera) and Phoridae (Diptera). The distribution and phylogeny of the termitophilous are considered as the mirror

images of those termites. The main specialization associated with termitophily, are physogastry, lumiloid outline of body and presenc of exudatory appendages. Generally termites lick the physogastric abdomen and exudatory appendages of the termitophile insects which in return obtain shelter and food from the termites (Sen-Sarma, 1974). Although, there is no direct record of staphilinid-beetles from the nests of termites in the study area, some records are not uncommon. The staphilinids, namely, *Termitodiscus heimi* Wasm., *T. butteli* Wasm. and *Odontoxenus termitophilus* are known to occur in the nests of *Odontotermes obesus* and *Hypotermes obscurriceps* in India and SriLanka (Cameron, 1932). Such excellent co-evolutionary relationship needs to be considered.

7. Practical factors : Besides these criteria, assessment of how seriously endangered a species is and its relationship to other sharing its probable fate within the frame work of concerned ecosystem. These criteria are critically endangered, endangered and vernarable. This triage status is not yet assessed in the termite fauna of the Eastern Ghat.

8. Species richness and its related problems : Biodiversity can be measured at different levels of taxonomic hierarchy, such as species, genera, families, etc. of which species has been taken as the fundamental unit and its numerical list (species richness) becomes a indicator of biodiversity. Species diversity does not mean only the number species, but its includes many other biodiversity criteria which have been discussed above.

These criteria are of immense help as and when the number of species are same in two different areas as studied below.

For clarity, the study shows the presence of same number of species to a total of 20 in two different localities, namely, Coimbatore situated at the western fringe of the Eastern Ghats and Topslip on Nilgiri Hills situated at the junction of the Eastern and Western Ghats (Table-3). Although the number of species occurring in both the localities are same but they contain

Table 3. Distribution of Termite Species Localities (E.G.)

	Top (Nilgiri) Hills	Coimbatore (Tamil Nadu)
Family KALOTERMITIDAE		
Subfamily KALOTERMITINAE		
<i>Neotermes venkateshwara</i> Bose	+	-
<i>Glyptotermes coorgensis</i> Holmgren and Holmgren	+	-
Family RHINOTERMITIDAE		
Subfamily RHINOTERMITINAE		
<i>Coptotermes ceylonicus</i> Holmgren		+
<i>C. heimi</i> (Wasmann)	+	+
Family TERMITIDAE		
Subfamily AMITERMITINAE		
<i>Speculitermes sinhalensis</i> Roonwal and Sen-Sarma	+	+
<i>Eurytermes buddha</i> Bose and Maiti	-	+
<i>E. topslipensis</i> (Chatterjee and Thopa)	+	+
Subfamily TERMITINAE		
<i>Eremotermes fletcheri</i> Holmgren and Holmgren	-	+
<i>E. paradoxalis</i> Holmgren		+
<i>Homallotermes pilosus</i> (Mathur and Thapa)	+	-
<i>Dicuspiditermes graveyi</i> (Silvestri)	+	-
<i>Pericapritermes perparvus</i> (Holmgren)	+	-
<i>P. topslipensis</i> Thakur	+	+
<i>Pseudocapritermes fletcheri</i> Holmgren and Holmgren	+	-
Subfamily MACROTERMITINAE		
<i>Odontotermes anamallensis</i> Holmgren and Holmgren	+	-
<i>O. bellahunisensis</i> Holmgren and Holmgren	-	+
<i>O. brunneus</i> (Hagen)	-	+
<i>O. ceylonicus</i> (Wasmann)	-	+
<i>O. feae</i> (Wasmann)	+	+
<i>O. globicola</i> (Wasmann)	-	+
<i>O. horni</i> (Wasmann)	+	+
<i>O. obesus</i> (Rambur)	+	+
<i>O. redemanni</i> (Wasmann)	+	+
<i>O. wallonensis</i> (Wasmann)	-	+
<i>Hypotermes obscuriceps</i> (Wasmann)	+	-
<i>Macrotermes convulsionarius</i> (König)	+	+
<i>Nasutitermes anamalaiensis</i> Synder	+	-
<i>N. fletcheri</i> (Holmgren and Holmgren)	+	-
<i>Trinervitermes biformis</i> (Wasmann)	-	+
<i>T. fletcheri</i> Mathur and Sen-Sarma	-	+
<i>Grallatotermes niger</i> Chatterjee and Thapa	+	-
	20	20

Table-4. List of Flagellates (Protozoa) known from Termite Hosts

Host	Flagellates
<i>Neotermes dhirendrai</i> Bose	<i>Foaina costata</i> Kirby <i>F. gracilis</i> Janicki <i>Caduceia bugnioni</i> Kirby <i>Trichomitopsis cartagoensis</i> (Kirby)
<i>Coptotermes heimi</i> (Wasmann)	<i>Holomastigotoides bengalensis</i> Chakraborty and Banerjee <i>H. campanula</i> (De Mello) <i>H. dharwarensis</i> Karandikar and Vittal <i>H. emersoni</i> Das <i>H. elongata</i> Uttangi <i>H. hemigynim</i> Grassi <i>H. magnus</i> Uttangi <i>H. ogivalis</i> De Mello <i>H. rayi</i> Karandikar and Vittal <i>H. saccusiformis</i> Uttangi <i>H. sphaeroidalis</i> De Mello <i>H. turboformis</i> Uttangi <i>Pseudotrichonympha subapicalis</i> Karandikar and Vittal <i>Spirotrichonympha bhadreshwarensis</i> Tiwari <i>S. roonwali</i> Das <i>Tricercomitus divergens</i> De Mello

different composition of species with different criteria for conservation.

The detailed examination of the fauna shows that the species of Top slip is more diverse and supports more species of relatively important conservation criteria or biodiversity values than that of Coimbatore. Occurrence of 20 species belonging to three families and 15 genera in Top slip in comparison to two families and nine genera in Coimbatore clearly indicates its rich taxonomic diversity. Likewise, the former locality supports more primitive species of the genera *Neotermes* and *Glyptotermes* as well as more advanced species of *Nasutitermes* and *Grallatotermes*, which are not yet recorded from Coimbatore. Similarly, ecologically significant species of *Odontotermes*, *Microtermes*, *Macrotermes*, etc. are more in number in Top slip than those of Coimbatore.

Concluding Remarks

An attempt has been made to outline the strategies of conservation of the Eastern Ghats based on the biodiversity values of termites occurring in the area. This disrupted vast hilly tract, no doubt, offers ample scope of exploring more termite species as against only 42 species known by poor surveys done so far. Therefore, any discussion on conservation strategies based on such incomplete information surely remains tentative unless further detailed exploration is made. However, any such discussion is significant realizing the urgency of conservation of even a minor organism to safeguard our natural resources. Any attempt concerning conservation will however be incomplete, unless it takes into account of nonbiological environmental factors in which the species

occur. These include an assessment of how seriously endangered a habit to which the organisms are closely linked. To answer all these questions, it needs further research.

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LITERATURE CITED

- AHMAD, M. 1950. The phylogeny of termite genera based on imago-worker mandibles. *Bull. Am. Mus. Nat. Hist.*, 95(Art. 2) : (1-6) + 43-86.
- BOSE, G. 1984. Termite fauna of Southern India. *Rec. zool. Surv. India, Occ. Pap. No.*, 49 : 1x + 1-270 + 1 PP.
- BOSE, G. and DAS, B. C. 1982. Termite fauna of Orissa, eastern India. *Rec. Zool. Surv. India*, 80 : 197-213 (1982).
- CAMERON, M. 1932. *Faun of India, Coleoptera : Staphylinidae*, Vol. III, XII + 443 pp.
- CHHOTANI, O. B. 1997. *Fauna of India, Isoptera (Termites)*, Vol-II, 800 pp. (Pub. Zool. Surv. India).
- EMERSON, A. E. 1955. Geographical origin and dispersion of Termite Genera. *Fieldiana Zoology*, 37 : 465-521.
- HUSTON, M. A. 1994. Biological Diversity : The co-existence on changing landscape, 15-50 pp., Cambridge Univ. Press.
- KONIG, J. G. 1779. Naturgeschichte der sogenannten weissen Ameisen. *Beschr. Berlin Ges. Naturf. Freunde* : 4 : 1-128.
- KALSHOVEN, L. G. E. 1930. Diebiologie van de djatitermiet (*Neotermes tectonae* Damm.) in verband met zijn bestrijding. Thesis. Wageningen also as Mededeet. Inst. Plantenziekten, No. 76 : 1-154 (1930).
- KRISHNA, K. 1969. Introduction. In : *Biology of termites* (Eds. Krishna, K. and F. M. Weesner), Vol. 1 : 1-17.
- MUKHERJEE, P. and MAITI, P. K. 2007. Studies on symbiotic flagellates (*Protozoa*) of some Indian Termites. *Memoirs. Zool. Surv. India* (in press).
- ROONWAL, M. L. and CHHOTANI, O.B. 1989. *Fauna of India, Isoptera (Termites)*, Vol. I, 672 pp. (Publ. Zool. Surv. India).
- SEN-SHARMA, P. K. 1974. Ecology and biogeography of Termites of India. In : *Ecology and Biogeography in India* (Ed M. S. Mani) : 421-472. The Hague W. Junk Publ.

SPATIAL AND TEMPORAL VARIATION OF ELASMOBRANCHS IN AND AROUND INDIAN SUNDARBANS

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ABSTRACT

Elasmobranchs (Chondrichthyes) are important part of marine and estuarine nekton and are of great commercial importance all over the globe, apart from being an important component in marine food web. The annual catch of elasmobranchs in India is around 70,000 tonnes, which is over 4% of total marine fish landings.

According to MPEDA (1999) the annual average landing of elasmobranchs during 1995-98 was 75,037 tons and the estimated potential of this group is 1,68,000 tones. The major elasmobranchs contributing to Indian fisheries are *Rhizoprionodon oligoinx*, *Isurus oxyrinchus*, *Sphyrna blochii*, *S. mokarran*, *Rhynchobatus djiddensis*, *Rhinobatus granulatus*, *Rhina ancylostoma*, *Dasyatis sephen*, *D. uarnak*, *D. imbricatus*, *D. marginatus*, *Himantura alcockii*, *Aetobatus narinari*, *Aetomylaeus mehotii*, *A. maculatus*, *Rhinoptera javanica*, *Gymnura poecilura* and *Mobula diabolus*.

The Indian Sundarbans with a biosphere reserve area of 9630 sq. km. is one of the most taxonomically diverse mangrove dominated ecosystem of the tropics, sustaining a considerable population of shark species. The important shark species in and around mangrove dominated Indian Sundarbans are *Scoliodon laticaudus*, *Carcharhinus dussumieri*, *C. limbatus*, *Sphyrna blochii*, *S. zygaena*, *Glyphis gangeticus*, *G. glyphis* etc.

The present paper is an attempt to highlight the seasonal abundance of elasmobranchs in different locations (particularly fish landing stations) in and around Indian Sundarbans. The data collected since 1994-95 to 2001-02 indicates the rarity of *Glyphis gangeticus* in the gangetic stretch of the maritime state of West Bengal.

Key words : Spatial and temporal variation elasmobranchs, Sundarbans.

INTRODUCTION

The Indian Sundarbans at the apex of the Bay of Bengal (between 21°13' N to 22°40' N latitude and 88°03' E to 89°07' E longitude) is located on the southern fringe of the state of West Bengal, covering the major portions of the North and South 24 Parganas districts. The region is bordered by Bangladesh in the east, the Hugli River in the west, 'Dampier-Hodges Line' in the north and the Bay of Bengal in the south.

The Indian Sundarbans is extremely vibrating and dynamic in nature exhibiting a mixed characteristic of marine, estuarine and even fresh water ecosystems. The deltaic lobe

at the apex of the Bay of Bengal may therefore be divided in three salinity regimes (Table 1).

Almost all the physico-chemical characteristics of this famous mangrove ecosystem (like nutrient load, DO, pH, phytoplankton concentration, pollutant concentration etc.) show a significant temporal variation through out seasons. (Mitra, 2000). The seasonal climate in Sundarbans may be conveniently categorized into **premonsoon** (March to June), **monsoon** (July to October) and **postmonsoon** (November to February). (Mitra and Pal, 2002). Each season has a characteristic feature of its own, which is very distinct and unique.

Table 1. Division of Indian Sundarbans on the basis of salinity

Zone	Areas Included
High Saline	Pathar Pratima, Namkhana, Sagar, Kultali, Gosaba and Basanti
Medium Saline	Canning I & II, Kakdwip, Mathurapur-II, Jainagar-II
Low Saline	Diamond Harbour-I & II, Kulpi, Mathurpur-I

Source : A draft report on Sundarbans Wetland (2000), Govt. of West Bengal.

The Sundarbans Biosphere Reserve houses diverse types of habitats ranging from mud flats to sandy beaches and extreme saline to almost fresh water zones each exhibiting distinct seasonal oscillations of physico-chemical variables like salinity, pH and dilution factor. The various species thriving in this vibrating ecosystem exhibit high degree of adaptive modifications as insurance against the fluctuating environmental conditions. Sharks are dominant species under elasmobranchs and play a vital role in both ecology and economics. The various direct and indirect products obtained from sharks are today used as food, tourism and pharmaceutical industries. Because of such multiple uses, the community is presently under threat due to overexploitation and water quality deterioration. The deterioration of water quality due to effect of intense industrialization and urbanization has been reported by a large number of workers, which might pose an adverse impact on the population and abundance of *Glyphis* spp., which are highly sensitive to ambient water quality.

MATERIALS AND METHODS

The entire network involves the secondary data collection from Department of Fishery, Govt. of West Bengal, Department of Marine Science, University of Calcutta and some relevant publication in this field. Few field visits were done in different pockets of Indian Sundarbans to get an account of the quantum and diversity of shark species. The landing stations like Diamond Harbour, Kakdwip, Frezergunj, Roydighi, Canning, Namkhana and Sagar were visited in three different seasons during the tenure of the study and finally cross-checked with the secondary data.

Physico-chemical variables like dissolved oxygen (mg/l), surface water temperature (°C), surface water salinity (‰) and surface water pH were analysed as per standard procedure stated in Strickland and Parsons (1968) (Table 2).

RESULTS AND DISCUSSION

The coastal zone of West Bengal is the dwelling place and migratory corridor of a

Table 2. Protocol followed to measure different parameters

Parameters	Protocol followed
Surface water temperature (°C)	Monitored by Celsius thermometer.
Surface water salinity (‰)	Checked in the field by Refractometer and crossed checked in the laboratory by argentometric method.
Surface water pH	Checked in the field by portable pH meter (Sensitivity = ± 0.1).
Dissolved oxygen (mg/l)	Checked in the field by DO meter and crossed checked in the laboratory by Winkler's method.

variety of shark species. This is revealed from the significant catch percentage of shark species in the fish landing data during 1994-95 to 2001-

02 (Fig. 1-8). The entire aquatic system in the coastal West Bengal has contrasting feature of physico-chemical variables (Table 3 & 4) due to

Table 3. Seasonal variation of physico-chemical characteristics in three distinct salinity regimes in coastal West Bengal (average of 1994 -1999)

Season	DO(mg/l)	Surface water temperature (°C)	Salinity ‰	pH
Upper Stretch				
A	4.8	34.1	1.7	8.00
B	5.7	33.7	0.0	7.52
C	5.1	22.3	1.3	7.83
Middle Stretch				
A	5.8	33.6	10.7	8.31
B	6.3	33.4	1.2	7.90
C	6.0	23.8	4.1	8.21
Lower Stretch				
A	6.2	34.2	27.2	8.34
B	6.9	33.6	10.1	8.15
C	6.4	25.1	19.8	8.29

A = Premonsoon, B = Monsoon, C = Postmonsoon.

Table 4. Seasonal variation of physico-chemical characteristics in three distinct salinity regimes in coastal West Bengal (average of 1999-2002)

Season	DO(mg/l)	Surface water temperature (°C)	Salinity ‰	pH
Upper Stretch				
A	6.0	34.0	1.5	8.00
B	5.9	33.5	0.0	7.48
C	5.8	22.1	1.0	7.90
Middle Stretch				
A	6.3	33.5	10.5	8.30
B	6.2	33.0	0.0	7.89
C	5.9	25.1	3.3	8.20
Lower Stretch				
A	6.9	33.9	26.1	8.36
B	6.8	33.2	8.5	8.12
C	6.3	26.0	20.0	8.28

A = Premonsoon, B = Monsoon, C = Postmonsoon.

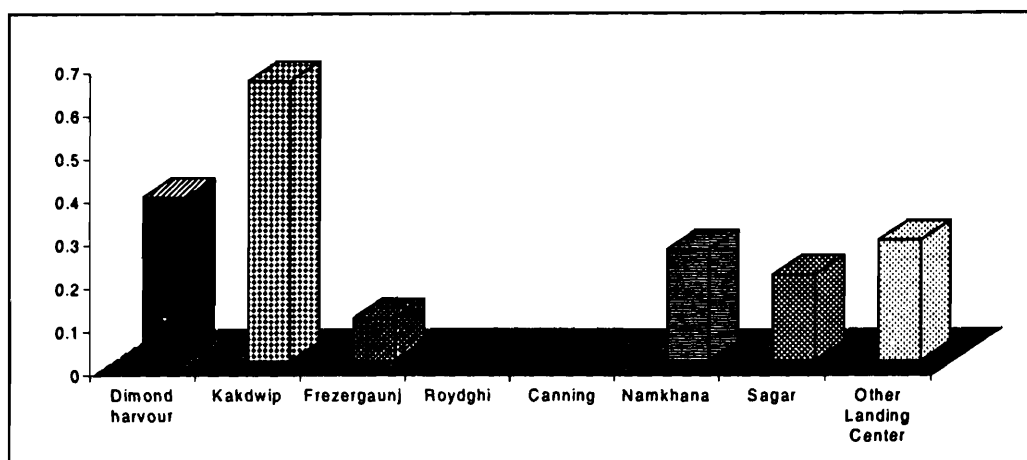


Fig. 1. Catch of shark (in 000' tonnes) in the major landing stations during 1994-95

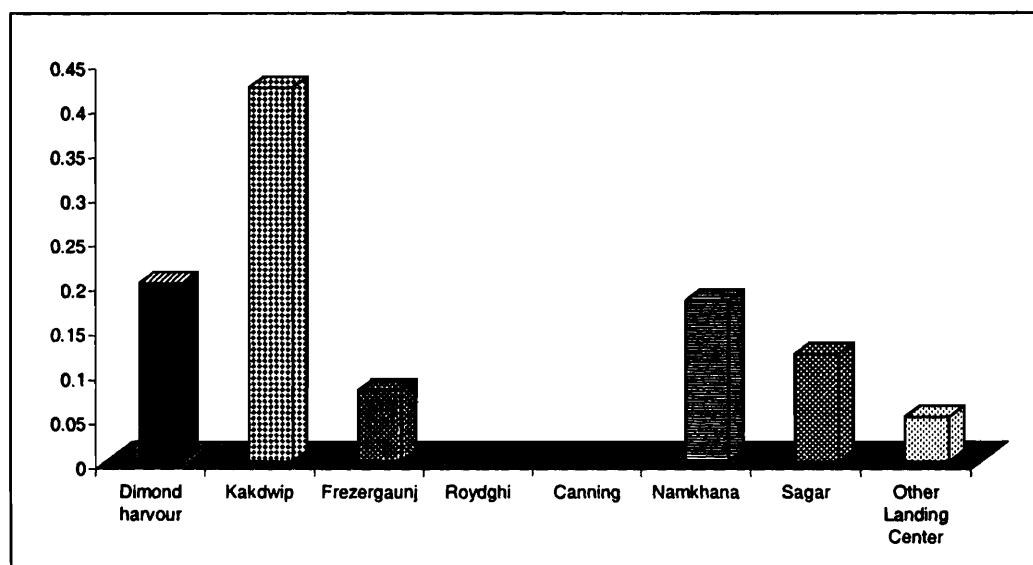


Fig. 2. Catch of shark (in 000' tonnes) in the major landing stations during 1995-96

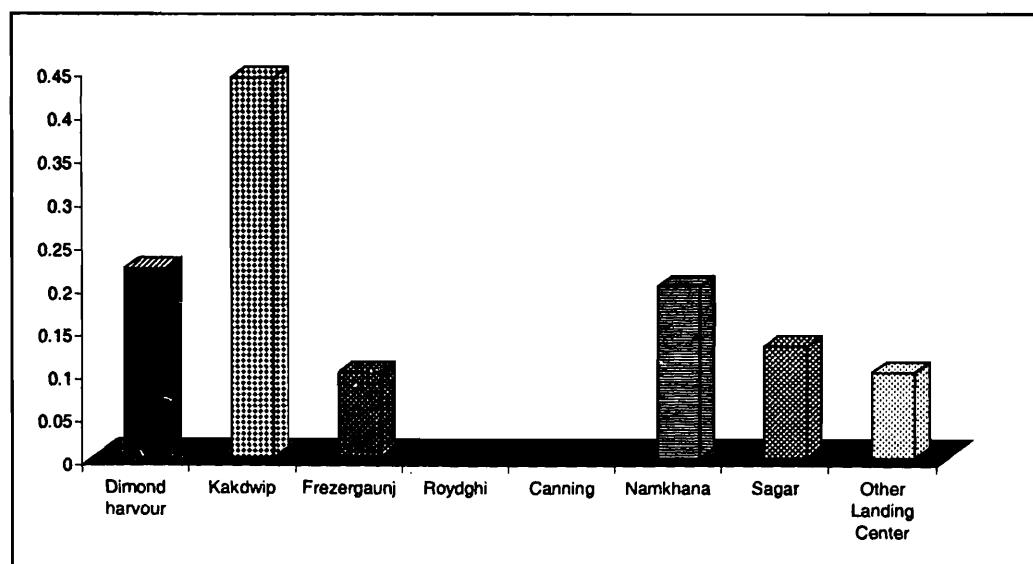


Fig. 3. Catch of shark (in 000' tonnes) in the major landing stations during 1996-97

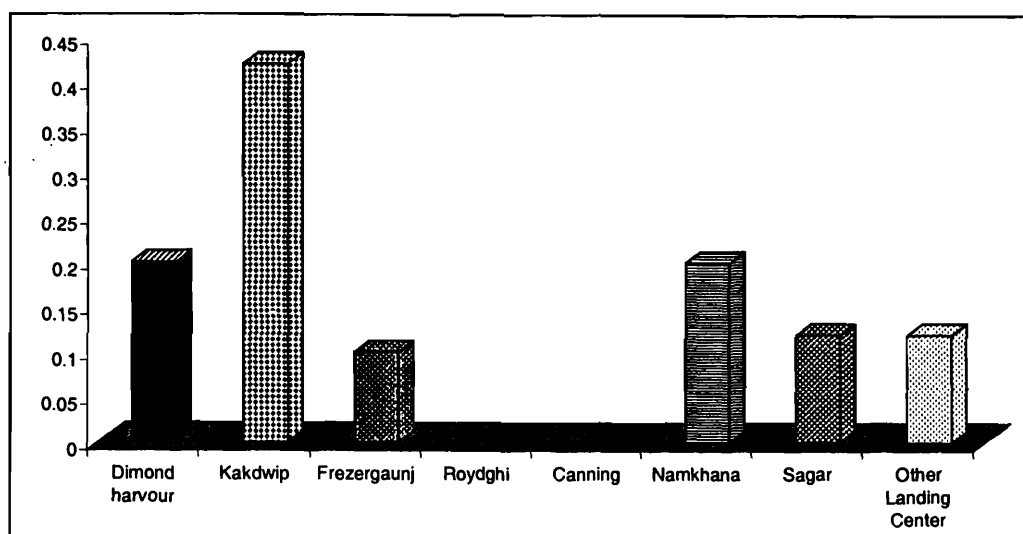


Fig. 4. Catch of shark (in 000' tonnes) in the major landing stations during 1997-98

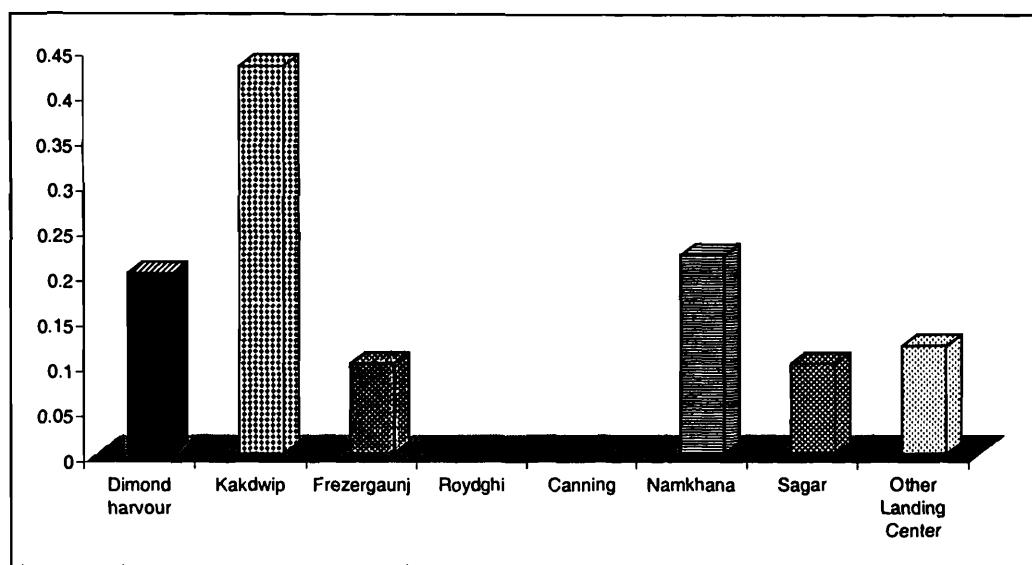


Fig. 5. Catch of shark (in 000' tonnes) in the major landing stations during 1998-99

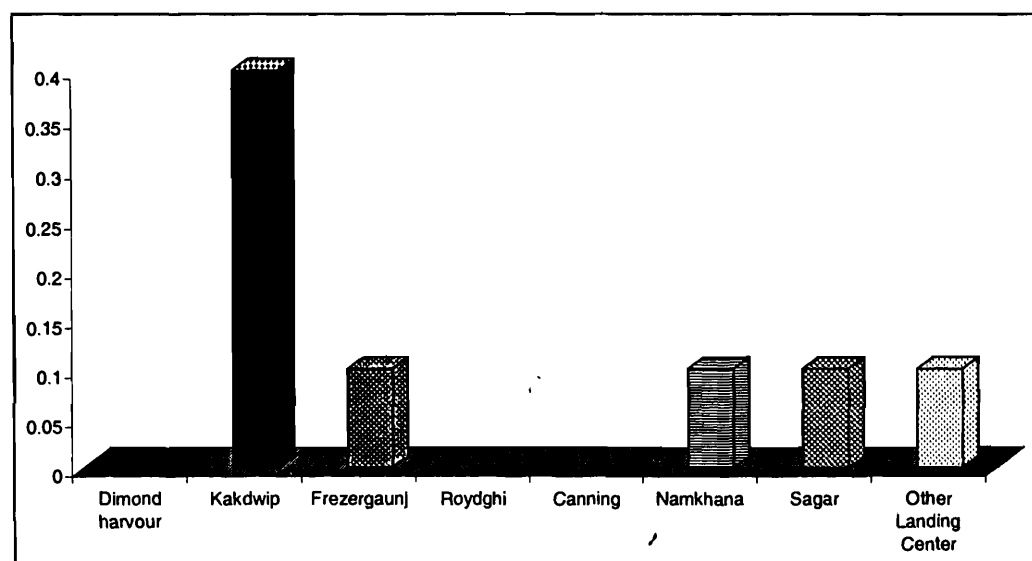


Fig. 6. Catch of shark (in 000' tonnes) in the major landing stations during 1999-2000

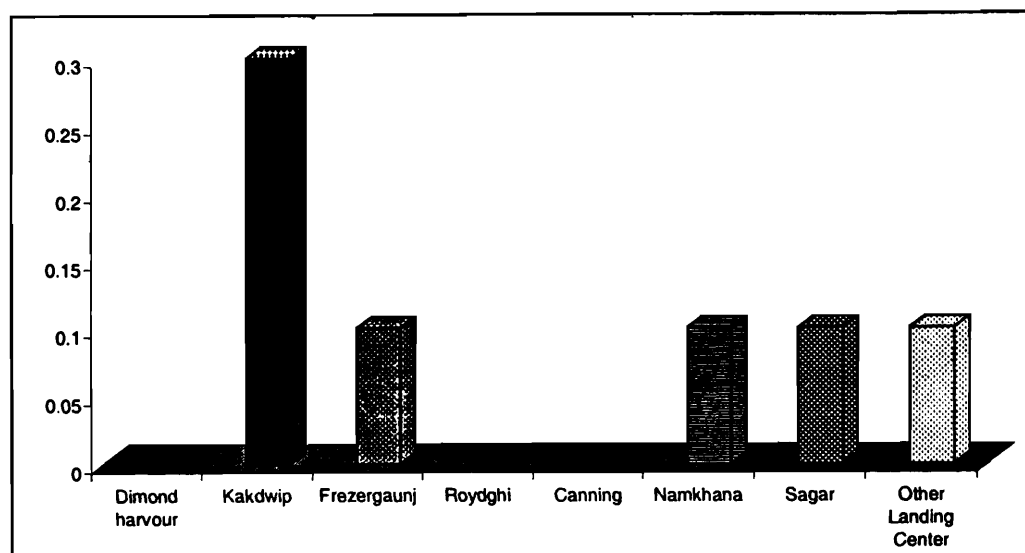


Fig. 7. Catch of shark (in 000' tonnes) in the major landing stations during 2000-01

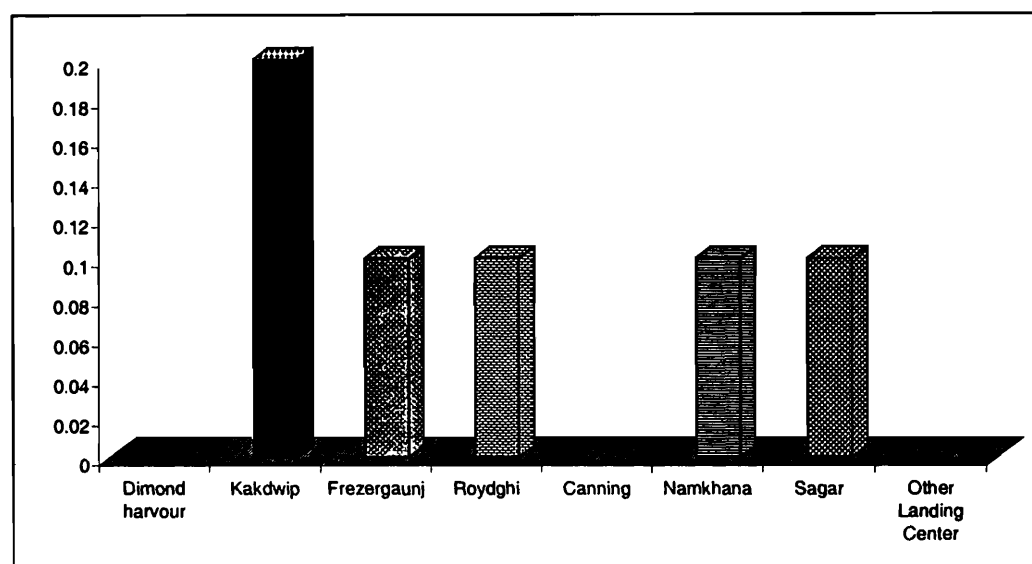


Fig. 8. Catch of shark (in 000' tonnes) in the major landing stations during 2001-02

which species of shark often exhibit zone specificity. The important shark species in and around Indian Sundarbans are highlighted in Table 5 and the year wise proportion of catch of shark are shown in Fig. 9.

The physico-chemical variables exhibit significant spatial and temporal variations. The salinity in all stretches of Indian Sundarbans was highest during premonsoon and lowest in monsoon; similar trend in pH was also noticed during study period, due to increased precipitation and run-off from adjacent landmasses (Mitra, 2000). The surface water temperature was also highest during premonsoon and lowest during monsoon and

in case of dissolved oxygen a mosaic behaviour was observed. The environmental parameters regulated the shark diversity accordingly and interactions with the local fisherman through Questionnaire point towards spatial heterogeneity of shark population in and around Indian Sundarbans. The lower stretch of Indian Sundarbans is dominated by *Carcharhinus limbatus*, *Carcharhinus dussumieri*, *Sphyrna blochii*, *Sphyrna zygaena*, *Galiocercus*, *Carcharhinus leucus*, the middle stretch exhibited the dominance of *Scoliodon laticaudus* and the upper most fresh water dominated zone is dominated by *Glyphis gangeticus*, *Glyphis glyphis* and *Glyphis siamensis*.

Table 5. Common shark species in and around Sundarbans

Species	Common Name	Distribution	Peak Season	Diet	Length
<i>Carcharhinus limbatus</i> (IUCN status : Lower risk)	Black-tip shark	West Bengal coast and Sundarbans region	Through out the year particularly from September to April	Fish (Sardine, Mackerel, Croaker) Cephalopods & crustaceans.	Male-140 to 150 cm, female - 150 -160
<i>Carcharhinus dussumieri</i> (IUCN status: Lower risk)	White-cheeked shark	West Bengal coast and Sundarbans region	September to April	Small fishes, squids and crustaceans.	Male-65 cm, female-75 cm
<i>Scoliodon laticaudus</i> (IUCN status : Lower risk)	Indian dog shark	West Bengal coast and Sundarbans region	September to April	Small fishes, squids and crustaceans.	Male-30 cm, female-35 cm.
<i>Sphyrna blochii</i> (IUCN status : Vulnerable)	Slender hammerhead shark	Entire stretch of coastal West Bengal.	March to May	Fish, rays, cephalopods, and crustaceans	3 to 7 m long
<i>Sphyrna zygaena</i> (IUCN status : Vulnerable)	Hammer headed shark	West Bengal coast and Sundarbans region	January to May	Fish, rays, cephalopods, and crustaceans	2 to 6 m long
<i>Glyphis gangeticus</i> , (IUCN status : Extremely endangered; Wild Life Protection Act: Schedule I)	River shark	Hoogly-Ganges river system of West Bengal	Through out the year.	Fish	Max. length is around 200 cm.
<i>Glyphis glyphis</i>	Sharp teeth shark	Hoogly-Matla estuarine system	Through out the year.	Fish	Max. length is around 100 cm.
<i>Glyphis Siamensis</i>	Irrawady river shark	Hoogly-Matla estuarine system	Through out the year.	Fish	Max. length is around 63 cm.
<i>Galiocerdo cuvier</i> (IUCN status : Lower risk)	Tiger shark	Entire stretch of Indian Sundarbans & aquatic phase of Bay of Bengal	Through out the year.	Eels, catfish, parrotfish, flatfish, flying fish, skates, rays, marine turtle, sea snake, sea birds, sea-lion, dolphin.	Matured ones are 7.4 m.
<i>Carcharhinus leucus</i> (IUCN status : Lower risk)	Bull shark	Entire stretch of Indian Sundarbans & aquatic phase of Bay of Bengal	Through out the year.	Unknown	Matured ones are 2.04 m.

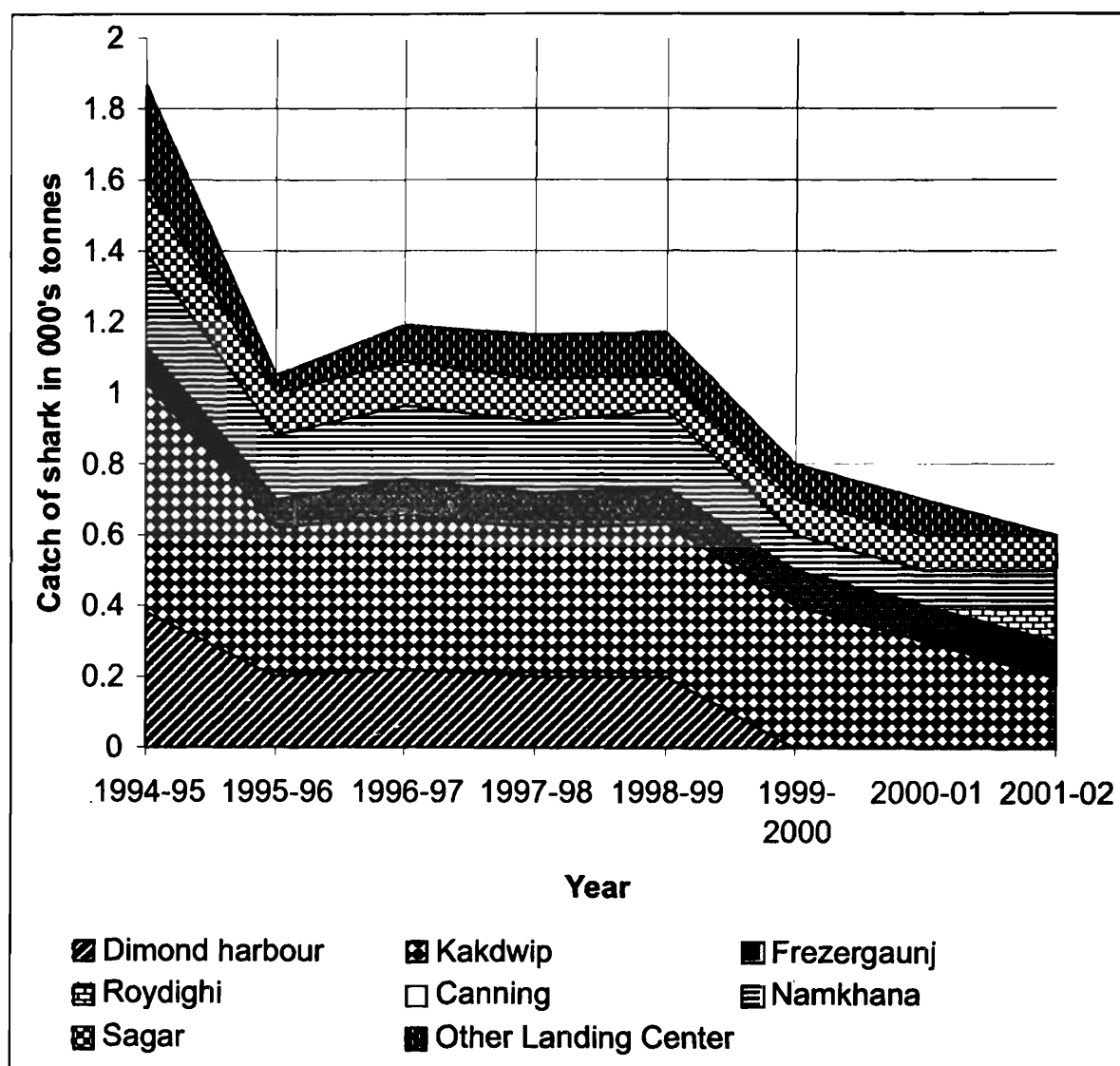


Fig. 9. Catch of shark (in 000' tonnes) in the major landing stations from year 1994-2002

Despite several threats operation on shark community like illegal catch, water quality deterioration etc. no pin pointed data has been achieved to identify the threats on shark community species wise. Today the Ganges Shark is known from the three museum specimens all collected in the nineteenth century. *Glyphis gangeticus* is listed as critically endangered in the 1996 IUCN Red List of Threatened Species. All these information indicate that the sharks are rapidly losing their identity from the aquatic ecosystem. Keeping the commercial, ecological, biomedical value of this cartilaginous community into consideration, proper conservation plan is needed which must incorporate the reduction

of fishing pressure. In addition, proper monitoring and eco-restoration policy need to be undertaken to preserve the water quality as many as species of shark like *Glyphis* sp. exhibit a very slow rate of genetic change, making them unable to adapt to anthropogenic environmental changes.

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LITERATURE CITED

- MARINE PRODUCTS EXPORT DEVELOPMENT AUTHORITY (MPEDA), Govt. of India. 1999. *Indian Fishery Handbook*, pp. 36.
- MITRA, A and BANERJEE, K. 2005. *Living Resources of the Sea : Focus Indian Sundarbans* (Banerjee, S. Ed.). World Wide Fund for Nature-India, WBSO.
- MITRA, A and PAL, S. 2002. *The Oscillating Mangrove Ecosystem and the Indian Sundarbans*. (Banerjee, S and Tampal, F. Ed.). World Wide Fund for Nature-India, WBSO.
- MITRA, A. BANERJEE, K. RAHA, A.K. GHOSH, S. and BHATTACHARYYA. D.P. Status of Shark Community in Coastal West Bengal. *Indian Science Cruiser*, **19** : 15-23.
- MITRA, A. 2000. *Foundation of Environment Science*, Narendra Publishing House, Delhi (India).
- MITRA, A. 2000. *The Northwestern Bay of Bengal and deltaic Sundarbans*. In : *Seas at the Millennium—An environmental evaluation* (Sheppard, C. Ed.). University of Warwick, Coventry, UK, Elsevier Science, **62** : 143-157.

PATTERN OF AVIAN DIVERSITY IN URBAN ENVIRONMENT : A CASE STUDY IN KOLKATA

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ABSTRACT

Our study was aimed towards understanding the pattern of avian community along the urban gradient of Kolkata and their response to fragmentation. During the study we measured diversity index, cumulative species richness, Chao1 species richness, Jackknife1 species richness, Bootstrap species richness, for all bird species and annual avian abundance for the resident bird species during 2004-2006 in 21 different locations situated at different areas along the urban gradient, which were selected for the present study. We also compared avian abundance between different habitat classes. Overall results showed fragment isolation as a significant predictor of species richness. It also showed significant relation to species richness in some of the seasons too. Linear correlation showed that area surveyed per site relate significantly to total birds recorded and to resident birds in some of the seasons too. Regression studies, however, revealed increasing trend in avian richness. Avian abundance for individual resident species, only, showed both positive and negative correlation to the area surveyed. On the basis of comparative studies of the avian abundance for the resident forms, the avian life can be categorized into three basic classes, which results in response to the degree of urbanization. High diversity was noticed in protected areas, wetlands and heterogeneous habitats with moderate periodic disturbances. As we traveled across the urban gradient into the urban core, avian diversity declined sharply, and species which adapted well in these impoverished conditions of urban core showed greater abundance resulting in a probable situation of biotic homogenization.

Keywords : Avian diversity, Urban gradient, Urbanization, Biotic homogenization

1. INTRODUCTION

Progressive urban development results in progressive replacement of native species by non-native forms. With establishment of a city, a number of new features are introduced into the locality suddenly. This in turn regionalizes the natural and the man-made pastures of greenery into isolated patches. Thus, urban development produces full range of manipulations, from slightly altered open-space areas to highly-developed residential and commercial areas (Emlen, 1974; Melles *et al.*, 2003; Blair, 2004). Kolkata, situated along the banks of river Hugli, is no different to this trend. Urban development tends to affect the avian community significantly, and causes a decline

in the diversity compared to any adjacent natural habitat (Emlen, 1974; Bessinger and Osborne, 1982). As a matter of fact, full-gradient urban developments pattern the avian life accordingly, with areas of moderate developments that are subjected to periodic disturbances promoting high avian richness (Blair, 1996). Urban life also enhances dominance of non-native tolerant forms too (Crooks *et al.*, 2004; Blair, 2004). Though avian studies have been conducted in Kolkata since mid-eighteenth century both from the point of view of whole urban gradient as well as individual habitat levels (Roychowdhury, 1984; Mookherjee, 1995; Mookherjee, 1999; Mookherjee and Chatterjee, 1999; Mookherjee, 2004; Ghosh, 2005), majority of these were

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taxonomic reviews or were mere inventorisations. None of them actually investigated how urban developments have affected the overall avian life at the community level. In the light of above reasons, the present study was initiated with the following objectives – (1) assessments of distribution of the avifauna in the different microhabitats of the city and its suburbs; (2) analysis of the avian diversity indices (richness, diversity and abundance); (3) the variety of threats the avian community faces; and (4) development of an integrated strategy for conservation of the avian life.

2. METHODS

2.1. Survey Procedure

The city of Kolkata (area–197.54 km²; lat–22°33'N; long–88°20'E; alt–9 mts) is situated along River Hugli. For the purpose of study we selected 21 sites within the city and its suburbs and conducted our study to assess the overall avian community along the gradient. All these sites were located within the Kolkata Metropolitan Area (KMA) (Anon., 1997). Of these 13 are situated within the core city area 8 are located beyond the core city limits of Kolkata and were regarded as control sites. The study sites vary in size considerably as well as in character and can be categorized into six different major habitat classes (Table 1).

We conducted periodic studies in these habitat fragments from December 2002 to March 2006. We divided the calendar year into four seasons–(1) Winter–December to February; (2) Summer–March to May; (3) Monsoon–June to September; and (4) Post-Monsoon–October and November. During the first thirteen months of the study (December 2002–December 2003) we collected data randomly at different sites to establish avian inventory for each site. From January 2004 onwards we collected data for the analytical studies. We conducted fixed radius point count at each site, taking points with 50 meter and 100 meter radius depending upon habitat size and visibility within the habitat, with some improvisations to suit our study (Hutto *et al.*, 1986). The 50 meter points were situated at a minimum distance of 150 meters

from each other. On the other hand, the 100 meter stations were situated at a distance of at least 250 meters to assure that there is no overlapping of observations.

We collected data at each fragment twice every season. We conducted about 168 surveys per year in these 21 sites. Data collected each day was analyzed and we then elucidated the mean diversity indices, richness indices and abundance per day for a given season at the end of each season. We recorded the birds by sighting and by identifying their calls, and records were counted only if the species occurred within the dimension of the survey points. All the fly-overs that did not have any activity within the survey habitat were recorded as seen at the location but were excluded from analytical studies, except white-rumped vulture (*Gyps bengalensis*) because of the fact that this species is a highly endangered bird and we wanted to include it in our analytical studies. All the avian species were considered for the purpose of analysis to understand the overall avian community along the gradient of urbanization. Surveys were conducted from 7 a. m. to 11 a. m. in the morning as this was the period during which the bird species were more active. During the study we did record some of the birds that are usually nocturnal in habit, like – *Athene brama*, *Ketupa zeylonensis* and *Caprimulgus macrurus*. We did not conduct any night surveys as such. However, whenever we noticed these species while surveying during the day, we included them in our record.

2.2. Data Analysis

We used area covered per site and the fragment isolation as suitable descriptors of patch characters and important predictors of occurrence of different avian species (Crooks *et al.*, 2004). Mean area covered for the 21 fragments is 19.29 hectares (S.D. = 12.88 hectares; ranges= 3.93-50.24 hectares). Mean fragment isolation is 4349.63 m (S.D. =9260.46 m; range = 0-43344.65 m) (Table. 1). All the sites are situated within 48 km of the city.

Data collected during the field surveys were used to calculate Shannon Index

(Magurran, 2004); cumulative species richness; Chao1 species richness; Jackknife1 species richness and Bootstrap species richness (Chao, 2004) at per site per season basis, both for the total species recorded per site and for the resident forms. We also calculated species abundance for the resident species (Verma and Agarwal, 2000). Data relating to species richness were calculated using EstimateS (version 7.5.1, R. K. Colwell, unpublished). Multiple correlations were used to see whether different landscape variables, area surveyed per site and the fragment isolation, were related significantly to species diversity, species richness indices and mean species abundance per site per year, for two years. We used multiple regression models to test whether the landscape variables were significant predictors of the results obtained from diversity studies and abundance data as in multiple correlation study. Linear regression was used to test whether area covered per site was a significant predictor of diversity results. Linear correlation was used to relate the diversity results with the total area covered per site. Relation between the total area surveyed per site and the mean species abundance per site per year for individual species were tested using Spearman's Rank Correlation. Two-tailed t-test was used to test significance of the results for statistical analysis (Misra and Misra, 1983). Results were considered significant when $P < 0.05$ on a two-tailed scale.

We compared the mean abundance of each species of birds to elucidate a comparative ratio of the mean abundance of individual species between the six major habitat classes.

3. RESULTS

3.1. Community level analyses

During the present study we recorded 212 species of birds, in the different study sites. Nine of these species were recorded during the preparation of the inventory only, between December 2002 and December 2003. Hence they were not considered for later analysis. These species are *Anas formosus*, *Anas creca*, *Haliaeetus leucoryphus*, *Porzana fusca*, *Recurvirostra avosetta*, *Tringa erythropus*, *Tringa stagnatilis*, *Tringa*

nebularia and *Calidris ferruginea*. Among the 212 species recorded, 101 birds were resident species. Rest 111 birds were migratory, of which 77 were winter migrants, which includes species like *Phylloscopus coronatus* (Eastern Crowned Warbler) from Chintamani Kar Wildlife Sanctuary that did not have any prior records from Kolkata; 19 were passage migrants; 11 other seasonal migrants; one vagrant and three accidental migrants. Highest number of birds (121 sp.) was recorded at the bheri areas of Nalban of which 65 sp. were residents. The lowest number of birds were recorded at Esplanade and Talapark, 30 species each (Table 1).

The mean seasonal species richness and the diversity indices are significantly lower in the core urban sites. Species richness and species diversity rises significantly in the habitats other than the urban core such as—urban parks and gardens, open spaces, protected areas, wetlands and heterogeneous habitats. As a matter of fact, diversity indices are marginally higher in the heterogeneous habitats. Diversity index, however, showed a downward trend at Santragachi in certain seasons though the species richness was moderately higher (Fig. 1 and Fig. 2). This is attributed to high abundance of few species in respect to others, which in turn reduces the overall diversity of the avian community of the area.

Results of multiple regression studies show that total area surveyed per site and fragment isolation individually act as significant predictors of the different species richness indices, species diversity and species abundance in some of the seasons during 2004-2005 and 2005-2006 ($P < 0.05$). This is applicable for both the total species and for the resident species encountered during the study (Table 2 and Table 3). Multiple correlation studies also suggest that the landscape variables show significant relations to the diversity parameters of total birds and resident birds recorded seasonally during the period of study (Table 2 and Table 3). On the other hand, linear regression studies between resident birds and the total area surveyed per site showed that

Table 1. Geographical details of the habitats studied with total avian species recorded per site.

	Sl.	Study Locality	Latitude (N)	Longitude (E)	Altitude	Area Surveyed per site (Hectare)	Approximate Area of study site (Hectare)	Fragment Isolation (Meter)	Approximate area covered by water bodies (Hectare)	Total Species of Birds Sighted per site	Resident Bird Species Sighted per site
Core Urban Areas	1	Esplanade	22°33'43.25"	88°20'58.36"	7	5.50	16.24	19.2	0.79	39	28
	2	Tala Park	22°26'36.04"	88°22'44.96"	9	15.70	36.08	3691.39	1.60	40	30
	3	ISI Baranagar	22°38'51.68"	88°22'37.51"	8	3.93	2.07	3691.39	0.32	45	39
Urban Parks and Gardens	4	Victoria	22°32'41.78"	88°20'33.60"	10	7.85	21.66	1654.58	4.33	49	43
	5	Rajbhawan	22°34'01.82"	88°20'50.55"	8	7.07	10.77	1921.4	0.06	40	41
	6	Eden Gardens	22°33'53.21"	88°20'27.19"	8	6.28	6.91	443.69	0.64	51	40
	7	AHSI	22°31'41.22"	88°19'59.21"	11	8.64	7.63	2433.81	0.22	58	52
	8	Subhash Sarovar	22°34'06.19"	88°24'04.28"	7	15.70	30.50	1821.91	14.81	46	41
	9	Rabindra Sarovar	22°30'36.05"	88°21'16.08"	8	9.42	68.02	2433.81	28.66	58	46
Open Areas	10	Maidan	22°33'09.88"	88°20'49.04"	6	25.12	94.67	24.38	1.16	39	35
	11	Kalyani University	22°59'17.48"	88°26'57.26"	9	37.68	111.28	43344.65	1.88	73	49
Protected Places	12	Narendrapur	22°25'46.93"	88°24'02.46"	8	4.71	8.16	874.47	0.57	81	60
	13	Botanical Garden	22°33'35.04"	88°17'26.78"	10	37.68	107.93	1520.68	7.33	63	53
	14	Tollygunj Golf Club	22°29'42.59"	88°20'37.47"	8	21.98	39.29	870.58	0.64	48	43
	15	Banabitan	22°35'14.77"	88°25'44.96"	4	21.98	41.61	1370.35	5.34	75	57
Wetlands	16	Nature Park	22°31'25.88"	88°17'33.28"	8	25.12	52.20	8616.29	29.69	73	64
	17	Bheri Areas, Nalban	22°33'57.46"	88°25'31.84"	5	50.24	448.50	0	408.58	121	65
	18	Santragachi	22°34'53.23"	88°16'57.62"	6	25.12	20.16	5821.91	13.78	64	46
	19	Kalyani Jheel	22°58'03.68"	88°26'12.34"	12	15.70	62.55	1121.1	21.56	58	51
Heterogeneous Habitats	20	IIM, Joka	22°26'42.50"	88°17'55.48"	10	31.40	64.40	8209.41	9.62	87	72
	21	Shyamkhola	22°25'24.28"	88°23'37.05"	8	28.26	631.96	1457.3	5.24	96	78

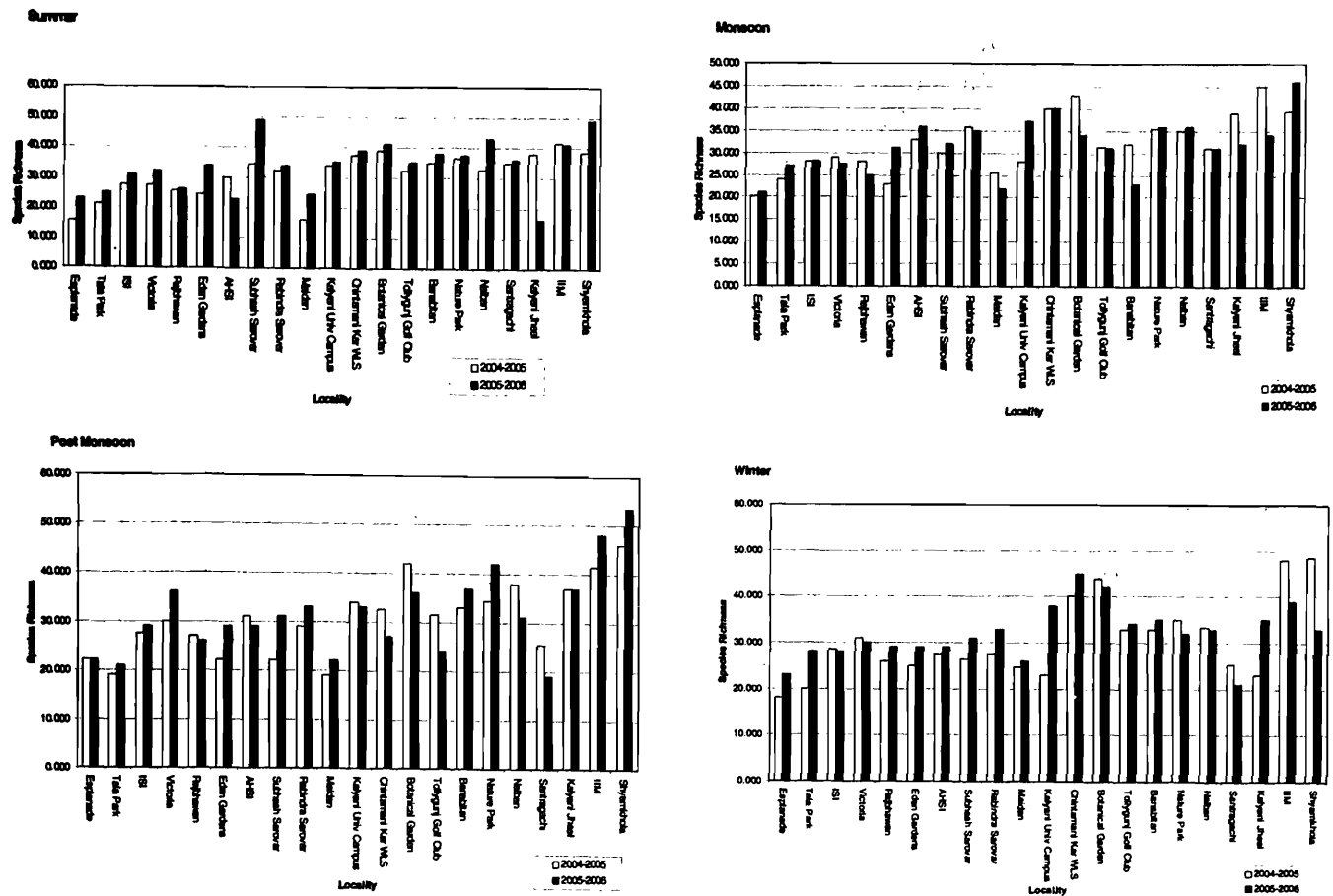


Fig 1. Spatial and temporal mean seasonal species richness of resident birds recorded during the study period

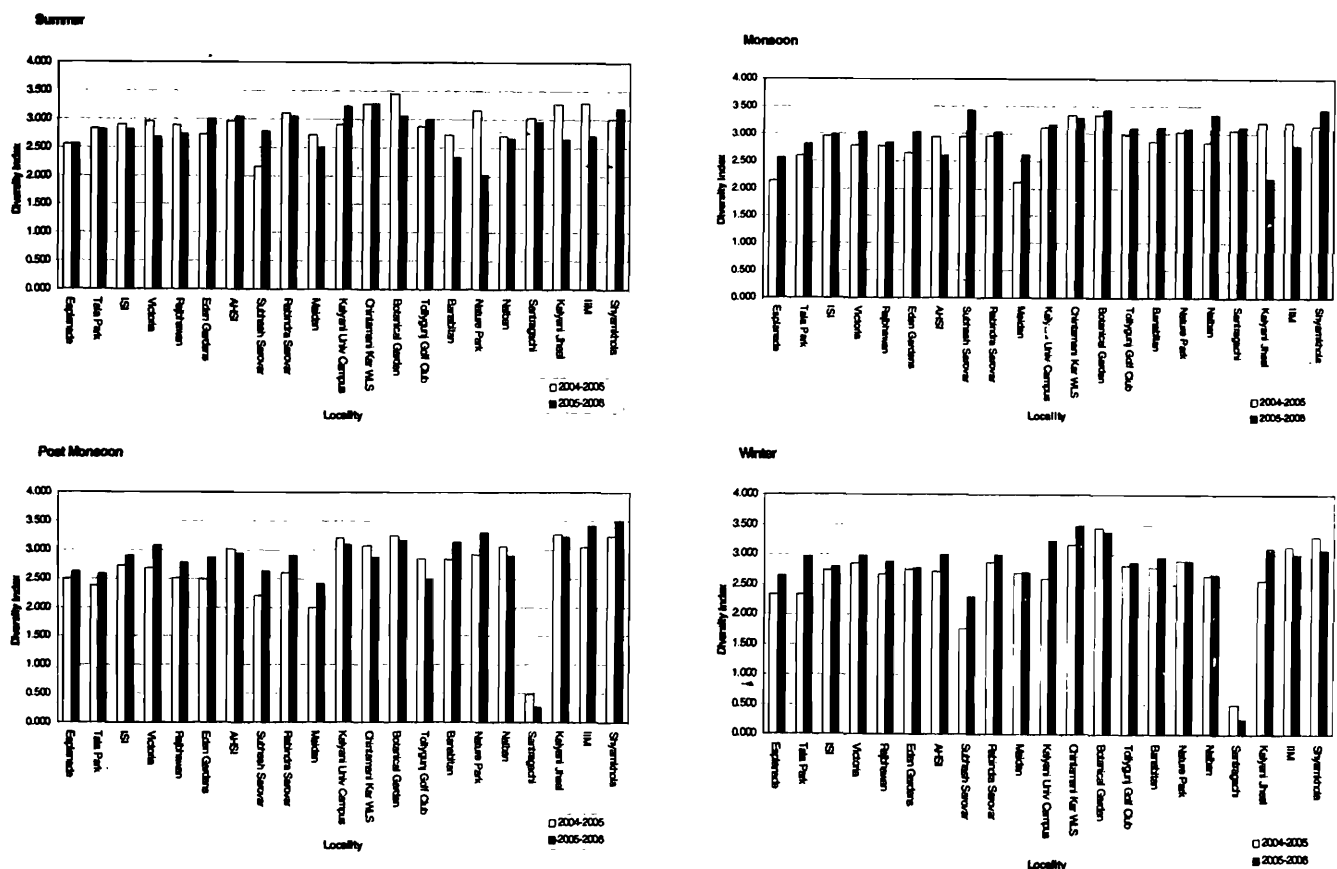


Fig 2. Spatial and temporal mean seasonal species diversity of resident birds recorded during the study period

avian richness indices show a trend of increase with the increasing area. At the same time the landscape variable acts as a significant predictor of the richness indices during post monsoon 2004-2005 ($P < 0.05$). The linear correlation study with the total area surveyed per site show that the species richness indices and the Shannon index relates significantly to the total area surveyed per site in specific seasons only. Relation between area covered per site and Shannon index have been presented in Fig. 3.

3.2. Species level analyses

The correlation studies of the mean annual abundance of individual species and total area surveyed per site reveal that three groups of birds can be segregated on the basis of their relation to the area surveyed per site. One group of birds shows positive relation to the landscape variable in a two tailed scale during 2004-2005 and 2005-2006. Another group of birds show negative significance in any one of the two years during which the study was conducted. Yet another group show negative significance with the area surveyed per site in a two tailed scale during 2004-2005 and 2005-2006. Numbers of birds included in this group are 3, 12 and 34 respectively.

3.3. Habitat level analyses

On the basis of comparisons of the avian abundance, between different habitat classes and on the basis of their response to urbanization, avian species can be categorized into three different classes—urbanization enhanced or urban exploiters, urbanization intermediate and urban sensitive or urban avoiders (Table 4) (Crooks *et al.*, 2004; Blair, 2004). The urban exploiters comprise mainly of cosmopolitan species and were recorded in all the habitat classes. Urbanization intermediate species were found almost all the habitat classes including the core urban sites. However, their abundance was much higher in the habitat fragments other than the urban core, reaching maximum values in the habitats with lesser degree of disturbance. There are 26 birds in this category. The species that avoid the core

urban sites completely have been categorized as urban avoiders. They seem to fail to adapt to the extreme level of urbanization, however, they may occur in the urban parks and gardens.

4. DISCUSSION

Constant urban developments have modified the environments of Kolkata to a great degree. This has regionalized the city habitats accordingly, with areas of moderate development lying towards the periphery along the sprawl end of development. On the other hand, high levels of development occur in the core city limits, which is usually depauperate in natural components. These zones with their variable levels of development and environmental conditions have patterned the avian community of the city according to the resources on offer.

Our study reveals that the urban developments have resulted in reduction in species diversity and species richness in the core areas of developments. This observation is in consensus with some other works too (Emlen, 1974; Bessinger and Osborne, 1982; Blair, 1996; Crooks *et al.*, 2004). This is attributed to the fact that urban developments are associated with introduction of extensive disturbances, like—loss of natural features of the locality, introduction of built-up areas, change in land use patterns, fragmentation, introduction of exotic vegetation components, increased pollution levels, increased noise level and others, in a given area, and its subsequent and constant maintenance over the following periods especially in the urban core. Such disturbances are associated to reduction of bird species in a given area, consequent patterning of avian species along the gradient and progressive replacement of resident faunal forms (Emlen, 1974; Mills *et al.*, 1989; Blair, 1996; Crooks *et al.*, 2004). This does not allow the locality to recover to a condition that occurred in the pre-disturbance conditions (Blair, 1996). This condition results in maintenance of low diversity indices in the core areas of development. Along with maintenance of low diversity indices, high and persistent levels of

Table 2. Standard multiple regression table of effects of area studied per site and habitat isolation on species abundance, species richness (cumulative, Chao 1, Jackknife 1 and Bootstrap) and species diversity for all bird species concerned

		2004–2005				2005–2006			
		β	Intercept	Standard Error	P	β	Intercept	Standard Error	P
Summer	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{a1a2}</i>								
	Area Studied per site	0.76	26.73	7.46	<0.01	0.80	25.80	6.72	>0.10
	Isolation	-0.16			>0.10	-0.06			<0.01
	<i>Chao 1^{b1b2}</i>								
	Area Studied per site	0.72	27.16	13.26	<0.01	0.76	28.98	10.81	<0.01
	Isolation	-0.22			>0.10	-0.13			>0.10
	<i>Shannon Index^{c1c2}</i>								
	Area Studied per site	0.36	2.21	0.29	>0.10	0.08	1.37	0.28	>0.10
Monsoon	Isolation	0.11			<0.01	0.25			<0.01
	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{d1d2}</i>								
	Area Studied per site	0.65	23.95	6.56	>0.10	0.73	24.45	6.89	>0.10
	Isolation	0.10			<0.01	0.03			<0.01
	<i>Chao 1^{e1e2}</i>								
	Area Studied per site	0.50	33.13	7.29	<0.05	0.75	27.14	7.59	<0.01
	Isolation	-0.06			>0.10	-0.05			>0.10
	<i>Shannon Index^{f1f2}</i>								
Post Monsoon	Area Studied per site	0.35	1.31	0.31	<0.10	0.56	2.14	0.28	>0.05
	Isolation	0.24			>0.001	0.10			>0.001
	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{g1g2}</i>								
	Area Studied per site	0.80	25.52	8.10	<0.01	0.49	30.47	9.26	<0.05
	Isolation	-0.07			>0.10	0.01			>0.10
	<i>Chao 1^{h1h2}</i>								
	Area Studied per site	0.68	36.62	10.73	<0.01	0.41	34.64	10.38	>0.05
	Isolation	-0.31			>0.10	0.04			>0.10
	<i>Shannon Indexⁱ¹ⁱ²</i>								
	Area Studied per site	0.24	1.92	0.60	<0.10	0.07	2.57	0.64	<0.10
	Isolation	0.11			>0.001	0.05			>0.001

Table 2. Contd.

		2004–2005				2005–2006			
		β	Intercept	Standard Error	P	β	Intercept	Standard Error	P
Winter	Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness ^{j1j2}								
	Area Studied per site	0.81	25.30	9.71	<0.01	0.81	28.22	6.37	<0.01
	Isolation	-0.31			>0.10	0.19			>0.10
	Chao 1 ^{k1k2}								
	Area Studied per site	0.82	30.95	13.32	>0.01	0.85	31.37	8.15	>0.01
	Isolation	-0.40			<0.10	0.05			<0.10
	Shannon Index ^{l1l2}								
	Area Studied per site	0.19	3.06	0.60	>0.10	0.03	2.01	0.64	<0.10
	Isolation	-0.07			<0.001	0.15			<0.001

^{a1}R² = 0.29; df = 18; P < 0.05; ^{a2}R² = 0.034; df = 18; P < 0.05; ^{b1}R² = 0.26; df = 18; P < 0.05; ^{b2}R² = 0.29; df = 18; P < 0.05; ^{c1}R² = 0.08; df = 18; P < 0.10; ^{c2}R² = 0.04; df = 18; P < 0.10; ^{d1}R² = 0.25; df = 18; P < 0.05; ^{d2}R² = 0.29; df = 18; P < 0.05; ^{e1}R² = 0.12; df = 18; P < 0.10; ^{e2}R² = 0.30; df = 18; P < 0.05; ^{f1}R² = 0.12; df = 18; P > 0.10; ^{f2}R² = 0.18; df = 18; P > 0.05; ^{g1}R² = 0.32; df = 18; P < 0.05; ^{g2}R² = 0.12; df = 18; P > 0.10; ^{h1}R² = 0.24; df = 18; P > 0.05; ^{h2}R² = 0.096; df = 18; P > 0.10; ⁱ¹R² = 0.04; df = 18; P > 0.10; ⁱ²R² = 0.005; df = 18; P > 0.10; ^{j1}R² = 0.34; df = 18; P < 0.05; ^{j2}R² = 0.40; df = 18; P < 0.02; ^{k1}R² = 0.36; df = 18; P < 0.05; ^{k2}R² = 0.39; df = 18; P < 0.02; ^{l1}R² = 0.019; df = 18; P > 0.10; ^{l2}R² = 0.014; df = 18; P > 0.10.

(a1, b1, c1, d1, e1, f1, g1, h1, i1, j1, k1 and l1 in superscript refers to the multiple correlation results obtained during 2004-2005 and a2, b2, c2, d2, e2, f2, g2, h2, i2, j2, k2 and l2 in superscript refers to the multiple correlation results obtained during 2005-2006)

Table 3. Linear multiple regression table of effects of area studied per site and habitat isolation on resident bird species abundance, species richness (cumulative, Chao 1, Jackknife 1 and Bootstrap) and species diversity

		2004–2005				2005–2006			
		β	Intercept	Standard Error	P	β	Intercept	Standard Error	P
Summer	<i>Mean abundance per site^{a1 a2}</i>								
	Area Studied per site	0.19	2.15	0.94	>0.10	0.21	1.08	1.38	>0.10
	Isolation	-0.14			<0.001	0.04			>0.10
	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{b1b2}</i>								
	Area Studied per site	0.59	27.67	6.05	<0.02	0.38	26.78	5.77	>0.10
	Isolation	-0.22			>0.05	0.22			>0.05
	<i>Chao 1^{c1c2}</i>								
Monsoon	Area Studied per site	0.64	28.27	8.95	<0.01	0.48	29.74	7.37	<0.05
	Isolation	-0.26			>0.10	0.17			>0.10
	<i>Shannon Index^{d1d2}</i>								
	Area Studied per site	0.17	2.45	0.29	>0.10	-0.15	0.86	0.3	>0.10
	Isolation	0.07			<0.001	0.33			<0.001
	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{e1e2}</i>								
	Area Studied per site	0.53	24.68	6.67	<0.05	0.63	26.11	7.73	<0.02
Post Monsoon	Isolation	0.11			>0.10	-0.06			>0.10
	<i>Chao 1^{f1f2}</i>								
	Area Studied per site	0.26	33.70	7.39	>0.10	0.63	29.92	7.7	<0.02
	Isolation	0.03			>0.10	-0.13			>0.10
	<i>Shannon Index^{g1g2}</i>								
	Area Studied per site	0.27	1.31	0.31	>0.10	0.5	2.61	0.3	<0.05
	Isolation	0.24			<0.001	0.02			<0.001
Post Monsoon	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{h1h2}</i>								
	Area Studied per site	0.71	22.45	6.48	<0.01	0.42	25.93	8.34	>0.05
	Isolation	0.01			>0.10	0.05			>0.10
	<i>Chao 1ⁱ¹ⁱ²</i>								
	Area Studied per site	0.78	28.50	7.59	<0.01	0.32	28.83	8.91	>0.10
	Isolation	-0.30			>0.05	0.05			>0.10
	<i>Shannon Index^{j1j2}</i>								
Post Monsoon	Area Studied per site	0.17	1.66	0.61	>0.10	0.05	2.28	0.65	>0.10
	Isolation	0.14			<0.001	0.08			<0.001

Table 3. Contd.

		2004–2005				2005–2006			
		β	Intercept	Standard Error	P	β	Intercept	Standard Error	P
Winter	<i>Cumulative Richness, Jackknife 1 Species Richness, Bootstrap Species Richness^{k1k2}</i>								
	Area Studied per site	0.60	24.72	7.70	<0.02	0.35	27.75	5.51	>0.10
	Isolation	-0.32			>0.05	0.2			>0.05
	<i>Chao 1¹¹¹²</i> Chao 1								
	Area Studied per site	0.67	28.73	9.07	<0.01	0.37	29.67	6.25	>0.10
	Isolation	-0.44			<0.05	0.17			>0.10
	<i>Shannon Index^{m1m2}</i>								
	Area Studied per site	0.10	3.18	0.61	>0.10	-0.1	2.11	0.63	>0.10
	Isolation	-0.10			<0.001	0.13			<0.001

^{a1}R² = 0.0004; df = 18; P > 0.10; ^{a2}R² = 0.0009; df = 18; P > 0.10; ^{b1}R² = 0.0324; df = 18; P > 0.05; ^{b2}R² = 0.0169; df = 18; P > 0.10; ^{c1}R² = 0.0441; df = 18; P > 0.05; ^{c2}R² = 0.0256; df = 18; P > 0.10; ^{d1}R² = 0.0004; df = 18; P > 0.10; ^{d2}R² = 0.0036; df = 18; P > 0.10; ^{e1}R² = 0.0324; df = 18; P > 0.05; ^{e2}R² = 0.04; df = 18; P > 0.05; ^{f1}R² = 0.0016; df = 18; P > 0.10; ^{f2}R² = 0.04; df = 18; P > 0.05; ^{g1}R² = 0.0081; df = 18; P > 0.10; ^{g2}R² = 0.0196; df = 18; P > 0.10; ^{h1}R² = 0.0784; df = 18; P < 0.05; ^{h2}R² = 0.01; df = 18; P > 0.10; ⁱ¹R² = 0.0961; df = 18; P < 0.05; ⁱ²R² = 0.0036; df = 18; P > 0.10; ^{j1}R² = 0.0009; df = 18; P > 0.10; ^{j2}R² = 0.0001; df = 18; P > 0.10; ^{k1}R² = 0.0361; df = 18; P > 0.05; ^{k2}R² = 0.0121; df = 18; P > 0.10; ^{l1}R² = 0.0729; df = 18; P > 0.05; ^{l2}R² = 0.0121; df = 18; P > 0.10; ^{m1}R² = 0.0001; df = 18; P > 0.10; ^{m2}R² = 0.0001; df = 18; P = > 0.10.

(^{a1}, ^{b1}, ^{c1}, ^{d1}, ^{e1}, ^{f1}, ^{g1}, ^{h1}, ⁱ¹, ^{j1}, ^{k1}, ^{l1} and ^{m1} in superscript refers to the multiple correlation results obtained during 2004-2005 and ^{a2}, ^{b2}, ^{c2}, ^{d2}, ^{e2}, ^{f2}, ^{g2}, ^{h2}, ⁱ², ^{j2}, ^{k2}, ^{l2} and ^{m2} in superscript refers to the multiple correlation results obtained during 2005-2006)

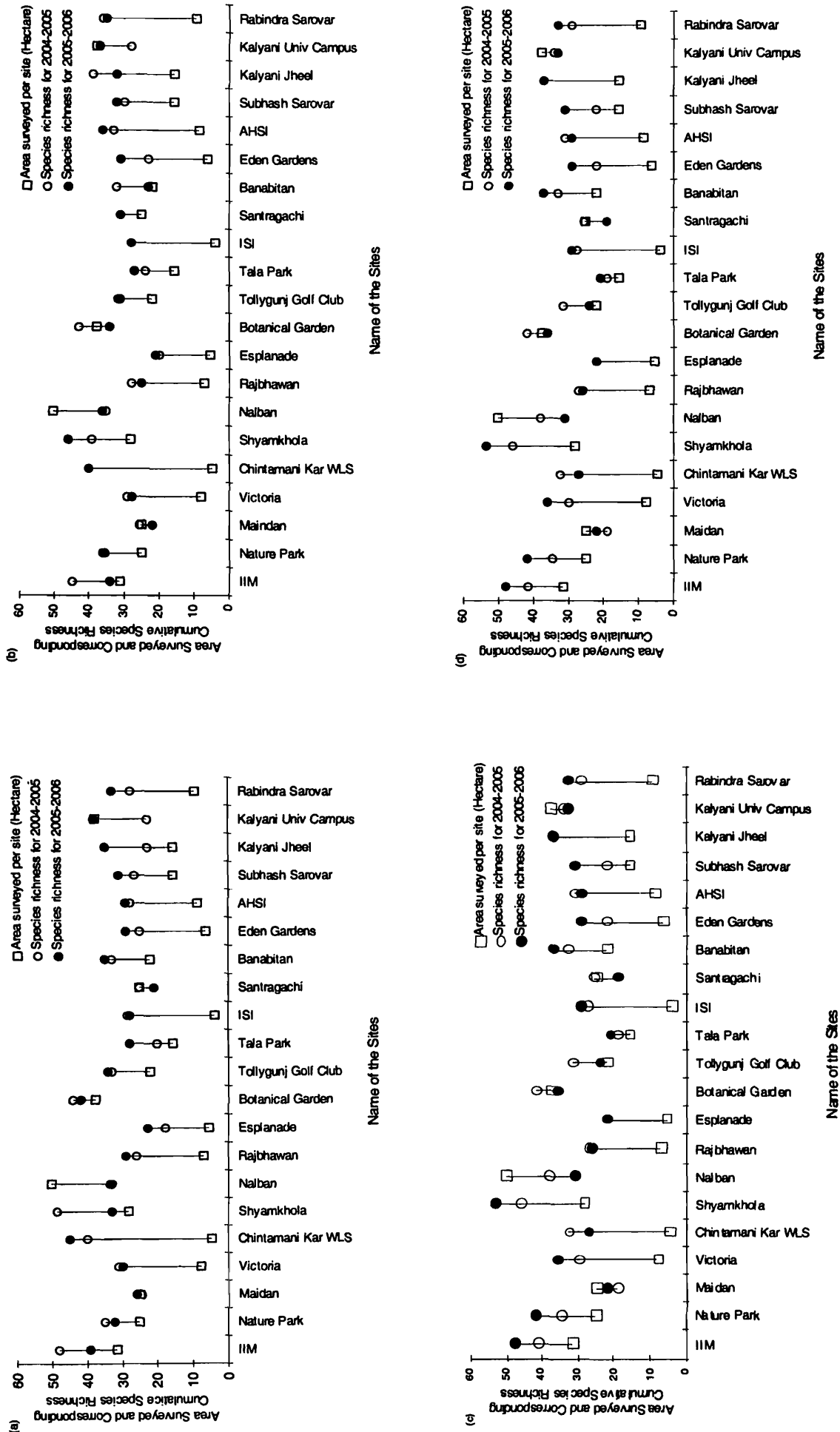


Fig. 3. The relationship between the area covered per site and the species richness per day per season for resident birds at different sites during the years 2004-2005 and 2005-2006-(a) Winter, (b) Monsoon, (c) Summer, and (d) Post Monsoon.

Table 4. Ratios between the mean abundance indices of resident birds in the different habitat classes selected for studies within urban Kolkata and its adjoining areas. Species are categorized as urbanization-enhanced, urbanization-intermediate, urban avoiders and birds recorded in specific habitat types

Species	Ratios															Abundance index
	core urban: parks & gardens	core urban: open areas	core urban: protected areas	core urban: wet-lands	core urban: heterogeneous habitats	parks & gardens: open areas	parks & gardens: protected areas	parks & gardens: wet-lands	parks & gardens: heterogeneous habitats	open areas: protected areas	open areas: wet-lands	open areas: heterogeneous habitat	protected areas: wet-lands	protected areas: heterogeneous habitats	wet-lands: heterogeneous habitats	
Urbanization-enhanced																
<i>Milvus migrans</i> (Boddaert)	1.29	1.20	1.04	1.27	1.32	0.93	0.80	0.99	1.03	0.87	1.06	1.11	1.23	1.28	1.04	
<i>Streptopelia chinensis</i> (Scopoli)	1.10	1.09	0.83	1.06	0.98	0.99	0.75	0.96	0.89	0.76	0.97	0.90	1.28	1.18	0.93	
<i>Psittacula krameri</i> (Scopoli)	1.04	0.85	0.84	1.64	1.35	0.82	0.81	1.58	1.29	0.99	1.92	1.58	1.95	1.60	0.82	
<i>Eudynamis scolopacea</i> (Linnaeus)	1.04	1.14	0.90	1.26	0.95	1.09	0.86	1.21	0.91	0.79	1.10	0.83	1.40	1.06	0.76	
<i>Apus affinis</i> (J. E. Gray)	1.14	1.43	2.01	1.54	1.23	1.26	1.77	1.35	1.08	1.40	1.07	0.86	0.77	0.61	0.80	
<i>Halcyon smyrnensis</i> (Linnaeus)	1.28	1.22	1.09	1.16	0.95	0.95	0.85	0.91	0.74	0.89	0.95	0.78	1.07	0.87	0.82	
<i>Megalaima asiatic</i> (Latham)	1.11	1.24	1.08	1.34	1.07	1.12	0.97	1.21	0.96	0.87	1.08	0.86	1.24	0.99	0.80	
<i>Megalaima haemacephala</i> (P. L. S. Muller)	1.09	1.30	1.24	1.39	1.50	1.19	1.14	1.28	1.38	0.95	1.07	1.16	1.12	1.21	1.08	
<i>Oriolus xanthornus</i> Linnaeus	1.11	1.30	0.94	1.23	1.09	1.17	0.85	1.11	0.98	0.72	0.95	0.84	1.31	1.16	0.89	
<i>Sturnus contra</i> Linnaeus	1.37	1.24	1.19	1.04	1.19	0.91	0.87	0.76	0.87	0.96	0.84	0.95	0.87	0.99	1.14	
<i>Acridotheres fuscus</i> (Wagler)	1.17	1.49	1.25	1.31	1.20	1.27	1.07	1.11	1.02	0.84	0.88	0.80	1.04	0.95	0.92	
<i>Acridotheres tristis</i> (Linnaeus)	1.27	1.11	1.06	1.03	1.19	0.87	0.83	0.81	0.94	0.96	0.93	1.08	0.97	1.13	1.16	
<i>Corvus splendens</i> Vieillot	1.23	1.21	1.10	1.03	1.25	0.98	0.89	0.84	1.02	0.91	0.85	1.04	0.94	1.14	1.22	
<i>Pycnonotus cafer</i> (Linnaeus)	1.09	1.34	0.90	1.03	0.71	1.23	0.83	0.94	0.66	0.67	0.77	0.53	1.14	0.79	0.70	
<i>Copsychus saularis</i> (Linnaeus)	0.94	1.12	1.03	1.22	0.95	1.19	1.09	1.30	1.01	0.92	1.09	0.84	1.19	0.92	0.78	
<i>Nectarinia asiatica</i> (Latham)	1.00	1.10	0.84	1.09	0.71	1.10	0.84	1.09	0.71	0.76	0.99	0.65	1.30	0.85	0.65	
<i>Dinopium benghalense</i> (Linnaeus)	1.25	0.99	0.76	2.25	1.05	0.79	0.61	1.80	0.84	0.77	2.27	1.06	2.95	1.38	0.47	
<i>Dendrocopos macei</i> (Vieillot)	1.14	8.33	1.04	5.00	0.89	7.33	0.92	4.40	0.79	0.13	0.60	0.11	4.80	0.86	0.18	
Urbanization-intermediate																
<i>Dicrurus macrocercus</i> Vieillot	1.37	0.92	0.86	0.84	0.77	0.68	0.63	0.62	0.56	0.93	0.91	0.83	0.98	0.90	0.91	
<i>Sturnus malabaricus</i> (Gmelin)	1.31	0.90	1.40	0.86	0.97	0.69	1.07	0.66	0.74	1.55	0.96	1.08	0.62	0.70	1.12	
<i>Orthotomus sutorius</i> (Pennant)	0.83	1.03	0.77	0.93	0.80	1.25	0.93	1.13	0.96	0.75	0.90	0.77	1.21	1.03	0.85	
<i>Passer domesticus</i> (Linnaeus)	1.18	0.89	1.35	0.86	0.92	0.75	1.14	0.72	0.78	1.52	0.96	1.04	0.63	0.68	1.08	
<i>Columba livia</i> Gmelin	0.90		1.83	0.67	0.71		2.02	0.74	0.79				0.37	0.39	1.07	

Table 4. Contd.

Species	Ratios															Abundance index
	core urban: parks & gardens	core urban: open areas	core urban: protected areas	core urban: wet-lands	core urban: heterogeneous habitats	parks & gardens: open areas	parks & gardens: protected areas	parks & gardens: wet-lands	parks & gardens: heterogeneous habitats	open areas: protected areas	open areas: wet-lands	open areas: heterogeneous habitat	protected areas: wet-lands	protected areas: heterogeneous habitats	wet-lands: heterogeneous habitats	
<i>Centropus sinensis</i> (Stephens)	1.06	0.57	0.33	1.12	0.36	0.54	0.31	1.06	0.34	0.58	1.97	0.63	3.41	1.08	0.32	
<i>Alecdo atthis</i> (Linnaeus)	0.73	2.54	0.69	0.65	1.10	3.46	0.94	0.88	1.50	0.27	0.25	0.43	0.94	1.60	1.70	
<i>Halcyon capensis</i> (Linnaeus)	0.95	0.95	0.63	1.75	0.53	1.00	0.66	1.83	0.56	0.66	1.83	0.56	2.79	0.85	0.30	
<i>Dendrocitta vagabunda</i> (Latham)	0.61	0.52	0.41	0.98	0.43	0.86	0.67	1.62	0.71	0.78	1.89	0.83	2.42	1.07	0.44	
<i>Anastomus oscitans</i> (Boddaert)	0.55	1.57	0.92	0.10	0.24	2.86	1.67	0.18	0.43	0.58	0.06	0.15	0.11	0.26	2.43	
<i>Gyps bengalensis</i> (Gmelin)	0.12	0.05	0.16	0.13	0.26	0.42	1.27	1.05	2.10	3.04	2.50	5.00	0.82	1.65	2.00	
<i>Pycnonotus jocosus</i> (Linnaeus)	0.69		0.70	1.94	1.06		1.02	2.82	1.55				2.76	1.52	0.55	
<i>Phalacrocorax niger</i> (Linnaeus)	0.19		0.72	0.20	0.33		3.76	1.03	1.70				0.27	0.45	1.64	
<i>Ardeola grayii</i> (Sykes)	0.71	0.51	0.47	0.32	0.36	0.72	0.66	0.45	0.51	0.92	0.63	0.71	0.68	0.77	1.13	
<i>Nycticorax nycticorax</i> (Linnaeus)	0.02	1.00	0.40	0.04	0.04	41.25	16.50	1.66	1.82	0.40	0.04	0.04	0.10	0.11	1.10	
<i>Cypsiurus balasiensis</i> (J. E. Gray)	0.48	0.40	0.47	0.27	0.18	0.83	0.99	0.56	0.37	1.19	0.68	0.44	0.57	0.37	0.65	
<i>Corvus macrorhynchos</i> Wagler	0.30	0.14	0.19	0.29	0.22	0.46	0.62	0.96	0.74	1.36	2.09	1.62	1.53	1.19	0.78	
<i>Turdoides striatus</i> (Dumont)	0.47	0.52	0.22	0.64	0.16	1.11	0.46	1.35	0.34	0.41	1.22	0.31	2.96	0.75	0.25	
<i>Treron phoenicoptera</i> (Latham)	0.35		0.34	0.26	0.09		0.96	0.75	0.26				0.78	0.27	0.34	
<i>Nectarinia zeylonica</i> (Linnaeus)	0.12	0.06	0.06	0.12	0.03	0.52	0.49	0.97	0.25	0.94	1.85	0.48	1.97	0.52	0.26	
<i>Egretta garzetta</i> (Linnaeus)	0.10	0.11	1.00	0.04	0.04	1.11	10.50	0.42	0.37	9.50	0.38	0.33	0.04	0.04	0.88	
<i>Streptopelia decaocto</i> (Fridvaldszky)	1.50	0.39	3.00	0.38	0.32	0.26	2.00	0.25	0.21	7.60	0.95	0.81	0.13	0.11	0.85	
<i>Dicaeum erythrorhynchos</i> (Latham)	0.07	0.04	0.02		0.02	0.52	0.34		0.30	0.66		0.58		0.89		
<i>Lonchura punctulata</i> (Linnaeus)	1.33	0.21		0.27	0.01	0.16		0.20	0.01		1.27	0.05			0.04	
<i>Dicrurus aeneus</i> Vieillot			0.24		0.16									0.65		
<i>Zoothera citrina</i> (Latham)			0.15		0.11									0.72		
Urban avoiders																
<i>Bubulcus ibis</i> (Linnaeus)						0.22	0.15	0.15	0.19	0.67	0.69	0.86	1.03	1.28	1.25	
<i>Phalacrocorax fuscicollis</i> Stephens							55.89	1.21	1.35				0.02	0.02	1.12	
<i>Accipter badius</i> (Temminck)						0.14	0.08	0.39	0.10	0.54	2.72	0.72	5.06	1.34	0.26	
<i>Amaurornis phoenicurus</i> (Pennant)							0.34	0.41	0.45				1.23	1.35	1.10	
<i>Psittacula eupatria</i> (Linnaeus)						0.32	0.22	1.11	0.71	0.68	3.50	2.25	5.17	3.32	0.64	
<i>Hierococcyx varius</i> (Vaul)						0.32	0.26	0.66	0.22	0.79	2.03	0.67	2.56	0.85	0.33	

Species	Ratios															Abundance index
	core urban: parks & gardens	core urban: open areas	core urban: protected areas	core urban: wet-lands	core urban: hetero- geneous habitats	parks & gardens: open areas	parks & gardens: protected areas	parks & gardens: wet-lands	parks & gardens: hetero- geneous habitats	open areas: protected areas	open areas: wet-lands	open areas: hetero- geneous habitat	protec- ted areas: wet-lands	protec- ted areas: hetero- geneous habitats	wet- lands: hetero- geneous habitats	
<i>Ardea cinerea</i> Linnaeus							0.33						0.01			
<i>Ardea purpurea</i> Linnaeus								0.08	0.10						1.19	
<i>Casmerodius albus</i> (Linnaeus)						7.00	14.00	0.11	0.14	2.00	0.02	0.02	0.01	0.01	1.31	
<i>Pernis ptilorhyncus</i> (Temminck)							0.04		0.04					1.12		
<i>Metopidius indicus</i> (Latham)							0.04	0.03	0.05				0.60	1.24	2.05	
<i>Athene brama</i> (Temminck)						1.67	0.13	0.45	0.31	0.08	0.27	0.19	3.45	2.38	0.69	
<i>Lanius schach</i> Linnaeus						0.67	0.25	0.31	0.06	0.38	0.46	0.09	1.23	0.23	0.19	
<i>Aegithina tiphia</i> (Linnaeus)													8.50	0.32	0.04	
<i>Cisticola juncidis</i> (Rafinesque)						0.23	1.00	0.12	0.02	4.33	0.50	0.09	0.12	0.02	0.17	
<i>Prinia inornata</i> Sykes						0.08	0.40	0.03	0.01	5.00	0.38	0.14	0.08	0.03	0.37	
<i>Parus major</i> Linnaeus							0.09	0.36	0.06				4.09	0.63	0.15	
<i>Tachybaptus ruficollis</i> (Pallas)													0.19	1.08	5.77	
<i>Mesophoyx intermedia</i> (Wagler)															1.00	
<i>Ixobrychus cinnamomeus</i> (Gmelin)													2.00	0.06	0.03	
<i>Ixobrychus sinensis</i> (Gmelin)													0.38	0.33	0.89	
<i>Dupetor flavicollis</i> (Latham)													3.00	0.67	0.22	
<i>Dendrocygna javanica</i> (Horsefield)													0.01	0.67	68.84	
<i>Nettapus coromandelianus</i> (Gmelin)															27.22	
<i>Spizaetus cirrhatus</i> (Gmelin)														1.00		
<i>Spilornis cheela</i> (Latham)														0.13		
<i>Rallina eurizonoides</i> (Lafresnaye)									0.50							
<i>Porphyrio porphyrio</i> (Linnaeus)															0.79	
<i>Vanellus indicus</i> (Boddaert)											0.14	0.50			3.67	
<i>Psittacula alexandri</i> (Linnaeus)						0.33	4.89			15.00						
<i>Clamator jacobinus</i> (Boddaert)						0.05			0.17			3.17				
<i>Cacomantis merulinus</i> (Scopoli)								0.40	0.10						0.24	
<i>Megalaima lineata</i> (Vieillot)							0.02		0.03					1.20		
<i>Celeus brachyurus</i> (Vieillot)							0.17									

[illegible]

disturbances also promotes species with ability to attain maturity early (Conell, 1978), and showing adaptability to the overall conditions. This is very much prominent in the core urban sites where there is a predominance of these adaptable species. The five urbanization enhanced species and one urbanization intermediate species, such as—*Corvus splendens*, *Sturnus contra*, *Acridotheres tristis*, *Apus affinis*, *Passer domesticus*, and *Milvus migrans*, regarded as primary dominant species, tends to adapt well to the stressed conditions offered by urbanization and utilizes the resources on offer judiciously. In addition to these, there are 20 other sub-dominant species that shows moderate levels of dominance in comparison to the primary dominant birds. These species include *Streptopelia chinensis*, *Psittacula krameri*, *Eudynamis scolopacea*, *Halcyon smyrnensis*, *Megalaima asiatica*, *Megalaima haemacephala*, *Oriolus xanthornus*, *Acridotheres fuscus*, *Pycnonotus cafer*, *Copsychus saularis*, *Nectarinia asiatica*, *Dinopium benghalense*, *Dendrocopos macei*, *Dicrurus macrocercus*, *Sturnus malabaricus*, *Orthotomus sutorius*, *Columba livia*, *Centropus sinensis*, *Halcyon capensis* and *Pycnonotus jocosus*. On the other hand species sensitive to urbanization show higher levels of abundance in the undisturbed and moderately disturbed areas (Table 5). Some of these results show parity with that of Blair (1996), and Crooks *et al.* (2004).

Species diversity and species richness increases progressively in the habitat types other than the urban core, such as—urban parks and gardens, open spaces, urban protected areas, wetlands and reaches maximum in the heterogeneous habitats. Maximum species diversity and species richness in the heterogeneous habitats are attributed to the fact that they have even mosaic of human habitations and substantially diverse floral components, with a balanced mixture of resident and ornamental types. This allows more diverse avian species to utilize the available conditions optimally. Blair (1996) made similar observations too. At the same time, these habitats being situated at areas of moderate levels of developments are also

subjected to moderate levels of disturbances periodically. This is related to the fact that urban development are still in progress at this end of urban gradient. This event can be explained in the light of the 'intermediate disturbance hypothesis' (Conell, 1978; Blair, 1996), which suggests that diversity tends to increase in areas that are disturbed at intermediate spatial and temporal scales.

We also encountered high diversity at wetlands, such as—Nalban and Nature Park (Brace Bridge), and protected areas, such as—Botanical Garden and Chintamani Kar WLS. However, the diversity in these habitats were low compared to that of heterogeneous habitats. This is attributed to the fact that, the periodic disturbances in these habitats are either too regular, as in case of wetlands, or are very low, as in case of the protected places. Such conditions prevent attainment of maximum diversity in these habitats. In addition, high diversity levels in the heterogeneous habitats is also associated with the fact that, since these habitats are situated at the sprawl end of the city they occur at an interphase of high biotic limitations at the rural end and high physical limitations at the urban ends (Blair, 1996). This enables development of an edge habitat promoting high species diversity and richness.

As is evident from the previous sections, urban development introduces large-scale disturbances in a given area. When such disturbances are constant and wide-spread results in the expansion in range of beneficiary species (designated "winners") and subsequently replaces the species which cannot survive these conditions (designated "losers"). This phenomenon is known as biotic homogenization (McKinney and Lockwood, 1999). Such a phenomenon is, probably, in operation within the urban environment of Kolkata. The gradual expansion of the dominant, adaptable species have resulted in regionalization of the range of sensitive birds to specific habitats with suitable habitat components. Thus, there is a trend of progressive extinction of the sensitive species

Table 5. Distribution of resident bird species in different habitat classes with a reflection on the probable loss of species across the urban gradient with increasing levels of development from a less developed habitat class to a highly developed region

Species ^a		Habitat Classes					
		core urban areas	urban parks and gardens	large open areas	protected areas	wetland areas	heterogeneous habitat fragments
Urbanization-enhanced							
Black Kite	<i>Milvus migrans</i> (Boddaert)	+	+	+	+	+	+
Spotted Dove	<i>Streptopelia chinensis</i> (Scopoli)	+	+	+	+	+	+
Rose-ringed Parakeet	<i>Psittacula krameri</i> (Scopoli)	+	+	+	+	+	+
Koel	<i>Eudynamis scolopacea</i> (Linnaeus)	+	+	+	+	+	+
House Swift	<i>Apus affinis</i> (J. E. Gray)	+	+	+	+	+	+
White-breasted Kingfisher	<i>Halcyon smyrnensis</i> (Linnaeus)	+	+	+	+	+	+
Bluethroated Barbet	<i>Megalaima asiatic</i> (Latham)	+	+	+	+	+	+
Crimson-breasted Barbet	<i>Megalaima haemacephala</i> (P. L. S. Muller)	+	+	+	+	+	+
Black-headed Oriole	<i>Oriolus xanthornus</i> Linnaeus	+	+	+	+	+	+
Asian Pied Starling	<i>Sturnus contra</i> Linnaeus	+	+	+	+	+	+
Jungle Myna	<i>Acridotheres fuscus</i> (Wagler)	+	+	+	+	+	+
Common Myna	<i>Acridotheres tristis</i> (Linnaeus)	+	+	+	+	+	+
House Crow	<i>Corvus splendens</i> Vieillot	+	+	+	+	+	+
Red-vented Bulbul	<i>Pycnonotus cafer</i> (Linnaeus)	+	+	+	+	+	+
Oriental Magpie-Robin	<i>Copsychus saularis</i> (Linnaeus)	+	+	+	+	+	+
Purple Sunbird	<i>Nectarinia asiatica</i> (Latham)	+	+	+	+	+	+
Lesser Golden-backed Woodpecker	<i>Dinopium benghalense</i> (Linnaeus)	+	+	+	+	+	+
Fulvous-breasted pied Woodpecker	<i>Dendrocopos macei</i> (Vieillot)	+	+	+	+	+	+
Urbanization-intermediate							
Black Drongo	<i>Dicrurus macrocercus</i> Vieillot	+	+	+	+	+	+
Chestnut-tailed Starling	<i>Sturnus malabaricus</i> (Gmelin)	+	+	+	+	+	+
Common Tailorbird	<i>Orthotomus sutorius</i> (Pennant)	+	+	+	+	+	+
House Sparrow	<i>Passer domesticus</i> (Linnaeus)	+	+	+	+	+	+
Blue Rock Pigeon	<i>Columba livia</i> Gmelin	+	+		+	+	+

Table 5. Contd.

Species*		Habitat Classes					
		core urban areas	urban parks and gardens	large open areas	protected areas	wetland areas	heterogeneous habitat fragments
Coucal	<i>Centropus sinensis</i> (Stephens)	+	+	+	+	+	+
Small Blue Kingfisher	<i>Alecdo atthis</i> (Linnaeus)	+	+	+	+	+	+
Stork-billed Kingfisher	<i>Halcyon capensis</i> (Linnaeus)	+	+	+	+	+	+
Rufous Treepie	<i>Dendrocitta vagabunda</i> (Latham)	+	+	+	+	+	+
Asian Openbill Stork	<i>Anastomus oscitans</i> (Boddaert)	+	+	+	+	+	+
Indian Whitebacked Vulture	<i>Gyps bengalensis</i> (Gmelin)	+	+	+	+	+	+
Red-whiskered Bulbul	<i>Pycnonotus jocosus</i> (Linnaeus)	+	+		+	+	+
Little Cormorant	<i>Phalacrocorax niger</i> (Linnaeus)	+	+		+	+	+
Indian Pond Heron	<i>Ardeola grayii</i> (Sykes)	+	+	+	+	+	+
Night heron	<i>Nycticorax nycticorax</i> (Linnaeus)	+	+	+	+	+	+
Asian Palm-Swift	<i>Cypsiurus balasensis</i> (J. E. Gray)	+	+	+	+	+	+
Large-billed Crow	<i>Corvus macrorhynchos</i> Wagler	+	+	+	+	+	+
Jungle Babbler	<i>Turdoides striatus</i> (Dumont)	+	+	+	+	+	+
Yellow Legged Green Pigeon	<i>Treron phoenicoptera</i> (Latham)	+	+		+	+	+
Purple-rumped Sunbird	<i>Nectarinia zeylonica</i> (Linnaeus)	+	+	+	+	+	+
Little egret	<i>Egretta garzetta</i> (Linnaeus)	+	+	+	+	+	+
Eurasian Collared-Dove	<i>Streptopelia decaocto</i> (Frisvaldszky)	+	+	+	+	+	+
Pale-billed Flowerpecker	<i>Dicaeum erythrorhynchos</i> (Latham)	+	+	+	+		+
Scaly Munia	<i>Lonchura punctulata</i> (Linnaeus)	+	+	+		+	+
Bronze Drongo	<i>Dicrurus aeneus</i> Vieillot	+			+		+
Orange Headed Ground Thrush	<i>Zoothera citrina</i> (Latham)	+			+		+
Urban avoiders							
Cattle egret	<i>Bubulcus ibis</i> (Linnaeus)		+	+	+	+	+
Indian Shag	<i>Phalacrocorax fuscicollis</i> Stephens		+		+	+	+
Shikra	<i>Accipiter badius</i> (Temminck)		+	+	+	+	+
White-breasted waterhen	<i>Amaurornis phoenicurus</i> (Pennant)		+		+	+	+
Alexandrine Parakeet	<i>Psittacula eupatria</i> (Linnaeus)		+	+	+	+	+

Table 5. Contd.

Species ^a		Habitat Classes					
		core urban areas	urban parks and gardens	large open areas	protected areas	wetland areas	heterogeneous habitat fragments
Common hawk cuckoo	<i>Hierococcyx varius</i> (Vaul)		+	+	+	+	+
Grey Heron	<i>Ardea cinerea</i> Linnaeus		+		+	+	
Purple Heron	<i>Ardea purpurea</i> Linnaeus		+			+	+
Large Egret	<i>Casmerodius albus</i> (Linnaeus)		+	+	+	+	+
Honey Buzzard	<i>Pernis ptilorhyncus</i> (Temminck)		+		+		+
Bronze-winged Jacana	<i>Metopidius indicus</i> (Latham)		+		+	+	+
Spotted Owlet	<i>Athene brama</i> (Temminck)		+	+	+	+	+
Black headed Shrike	<i>Lanius schach</i> Linnaeus		+	+	+	+	+
Common Iora	<i>Aegithina tiphia</i> (Linnaeus)				+	+	+
Zitting Cysticola	<i>Cisticola juncidis</i> (Rafinesque)		+	+	+	+	+
Plain Prinia	<i>Prinia inornata</i> Sykes		+	+	+	+	+
Great Tit	<i>Parus major</i> Linnaeus		+		+	+	+
Little Grebe	<i>Tachybaptus ruficollis</i> (Pallas)				+	+	+
Median Egret	<i>Mesophoyx intermedia</i> (Wagler)					+	+
Chestnut Bittern	<i>Ixobrychus cinnamomeus</i> (Gmelin)				+	+	+
Yellow Bittern	<i>Ixobrychus sinensis</i> (Gmelin)				+	+	+
Black Bittern	<i>Dupetor flavicollis</i> (Latham)				+	+	+
Lesser Whistling Teal	<i>Dendrocygna javanica</i> (Horsefield)				+	+	+
Cotton Pigmy Goose	<i>Nettapus coromandelianus</i> (Gmelin)					+	+
Changeable Hawk-Eagle	<i>Spizaetus cirrhatus</i> (Gmelin)				+		+
Creasted Serpent Eagle	<i>Spilornis cheela</i> (Latham)				+		+
Slaty-legged Crake	<i>Rallina eurizonoides</i> (Lafresnaye)		+				+
Purple Moorhen	<i>Porphyrio porphyrio</i> (Linnaeus)					+	+
Red-wattled Lapwing	<i>Vanellus indicus</i> (Boddaert)			+		+	+
Red-Breasted Parakeet	<i>Psittacula alexandri</i> (Linnaeus)		+	+	+		
Pied Crested Cuckoo	<i>Clamator jacobinus</i> (Boddaert)		+	+			+
Rufous-bellied Plaintive Cuckoo	<i>Cacomantis merulinus</i> (Scopoli)		+			+	+

Table 5. Contd.

Species ^a		Habitat Classes					
		core urban areas	urban parks and gardens	large open areas	protected areas	wetland areas	heterogeneous habitat fragments
Lineated Barbet	<i>Megalaima lineata</i> (Vieillot)		+		+		+
Rufous Woodpecker	<i>Celeus brachyurus</i> (Vieillot)		+		+		
Lesser Scaly-bellied Woodpecker	<i>Picus xanthopygaeus</i> (J.E. Gray & G. R. Gray)				+		+
Ashy Woodswallow	<i>Artamus fuscus</i> Vieillot				+		+
White Throated Fantail	<i>Rhipidura albicollis</i> (Vieillot)				+		+
Blacknaped Fly-catcher	<i>Hypothymis azurea</i> (Boddaert)				+		+
Yellow-bellied Prinia	<i>Prinia flaviventris</i> (Delessert)				+	+	+
Striated Grass-Bird	<i>Megalurus palustris</i> Horsfield		+			+	+
Paddy Field Pipit	<i>Anthus rufulus</i> Vieillot			+		+	+
Little Spider-hunter	<i>Arachnothera longirostra</i> (Latham)				+		+
Oriental White Eye	<i>Zosterops palpebrosus</i> (Temminck)				+		+
Baya	<i>Ploceus philippinus</i> (Linnaeus)					+	+
Red Munia	<i>Amandava amandava</i> (Linnaeus)					+	+
White-rumped Munia	<i>Lonchura striata</i> (Linnaeus)			+			+
Black-headed Munia	<i>Lonchura malacca</i> (Linnaeus)					+	+
Only in Specific Habitats							
Darter	<i>Anhinga melanogaster</i> Pennant					+	
Painted Stork	<i>Mycteria leucocephala</i> (Pennant)					+	
Pheasant Tailed Jacana	<i>Hydrophasianus chirurgus</i> (Scopoli)					+	
Brown Fish Owl	<i>Ketupa zeylonensis</i> (Gmelin)				+		
Large-tailed Nightjar	<i>Caprimulgus macrurus</i> Horsfield				+		
Small Minivet	<i>Pericrocotus cinnamomeus</i> (Linnaeus)				+		
Bengal Bushlark	<i>Mirafra assamica</i> Horsfield						+
Asian Paradise-Flycatcher	<i>Terpsiphone paradisi</i> (Linnaeus)						+
Thick-billed Flowerpecker	<i>Dicaeum agile</i> (Tickell)						+
Indian Silverbill	<i>Lonchura malabarica</i> (Linnaeus)						+

^a(Manakadan & Pittie, 2001)

over a greater area along which the disturbance persists. Homogenization, at the same time, is also associated with invasion of species and increase in their abundance, subsequently, in a given area. Invasion may occur naturally (Blair, 2001), as is evident for *Acredothores fuscus* in our case, or it may occur through deliberate introduction locally. Deliberate introduction in respect of Kolkata's environment has occurred for species like *Psittacula alexandri* and *P. eupatria* which have established themselves in the locality with great effect, and they compete with the resident species, *P. krameri*, for food and space. In addition, small-scale killings, trapping and trading of birds in local markets pose serious threats to the avian life in and around Kolkata. Though occasional raids are being conducted by state forest Departments which does put a temporary halt to the trade, it can hardly put an end to the trade totally.

In the light of above observations we would like to suggest that to improve the avian life following things be looked upon to sustain the suitable avian life—

- (i) identification of suitable habitats, for which urban parks and gardens as well as cemeteries are suitable;

- (ii) improvement of the habitat conditions through improving of floral components within the selected habitat to suit avian life;
- (iii) provide legal protection of the avian species; and,
- (iv) promoting awareness among general mass regarding importance of better environmental conditions in protection of suitable animal life.

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LITERATURE CITED

- ANONYMOUS. 1997. Growth of Calcutta Metropolitan Area. Government of India.
- BESSINGER, S. R., and OSBORNE, D. R. 1982. Effects of urbanization on avian community organization. *Condor*, **84** : 75-83.
- BLAIR, R. B. 1996. Land use and avian species diversity along an urban gradient. *Ecological Applications*, **6**(2) : 506-519.
- BLAIR, R. B. 2001. Creating a homogeneous avifauna: Local extinction and invasion along urban gradients in California and Ohio. In J. Murzluff, K. McGowan, and R. Bowman, eds. *Avian Ecology in an Urbanizing World*. Kulwer/Academic Press, : 459-486.
- BLAIR, R. B. 2004. The effects of urban sprawl on birds at multiple levels of biological organization. *Ecology and Society* **9**(5) : 2 [online] URL : <http://www.ecologyandsociety.org/vol9/iss5/art2>.
- CHAO, A. 2004. Species richness estimation. In N. Balakrishnan, C. B. Read, and B. Vidakovic, eds. *Encyclopedia of Statistical Sciences*. Wiley, New York.
- CONNELL, and JOSEPH H. 1978. Diversity in tropical rain forests and coral reefs. *Science*, **199** : 1302-1310.

- CROOKS, KEVIN R., SAUREZ, ANDREW V., BOLGER, and DOUGLAS T. 2004. Avian assemblages along a gradient of urbanization in a highly fragmented landscape. *Biological Conservation*, 115 : 451-462.
- EMLEN, J. T. 1974. A urban bird community in Tucson, Arizona: Derivation, structure, regulation. *The Condor*, 76 : 184-197.
- GHOSH, S. 2005. Urban Biodiversity Study in and around Calcutta. Project Report, Bangabasi College, Kolkata.
- HUTTO, R. L., PLECTSCHET, S. M., and HENDRICKS, P. 1986. A fixed-radius point count method for nonbreeding and breeding season use. *The Auk*, 103 : 593-602.
- MAGURRAN, A. E. 2004. *Measuring Biological Diversity*. Blackwell Publishing, Oxford, UK.
- MANAKADAN, R., and PITTIE, A. 2001. Standardised common and scientific names of birds of the Indian subcontinent. *Buceros*, 6(1) : 1-27.
- McKINNEY, M. L., and LOCKWOOD, J. L. 1999. Biotic homogenization : A few winners replacing many losers in the next mass extinction. *Trends in Ecology and Evolution*, 14(11) : 450-453.
- MELLES, S., GLENN, S., and MARTIN, K. 2003. Urban bird diversity and landscape complexity: Species-environment associations along a multiscale habitat gradient. *Conservation Ecology* 7(1) : 5. [online]. URL: <http://www.consecol.org/vol7/iss1/art5>
- MILLS, G. S., DUNNING, JR., J. B., and BATES, J. M. 1989. Effects of urbanization on breeding bird community structure in southeastern desert habitats. *The Condor*, 91 : 416-428.
- MISRA, B. N., and MISRA, M. K. 1983. *Introductory Practical Biostatistics*. Naya Prakash, Calcutta.
- MOOKHERJEE, K. 1995. *Birds and Trees of Tolly*. Tollygunj Club Ltd., Calcutta.
- MOOKHERJEE, K. 1999. *Midwinter Waterfowl Census in Southern West Bengal, 1990-1997*. Prakriti Samsad, Calcutta.
- MOOKHERJEE, K. 2004. Birds in and around Kolkata. *Naturalist*, 3 : 4-14.
- MOOKHERJEE, K., and CHATTERJEE, S. 1999. *A Guide to the Birds of Salt Lake, Calcutta and Change Detection Study*. Conservator of Forests, Wildlife Circle, West Bengal.
- ROYCHOWDHURY, D. K., 1984. Birds in and around Calcutta Metropolitan Area. *Naturalist*, 1 : 7-16.
- VERMA, P. S., and AGARWAL, V. K. 2000. *Environmental Biology (Principles of Ecology)* S. Chand & Company Ltd., New Delhi.

CHIRONOMID MIDGES OF THE FRESH WATER PONDS OF KOLKATA METROPOLIS

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ABSTRACT

The Chironomidae is a cosmopolitan family of dipteran insects occurring in all zoogeographical regions of the world including Antarctica. The immature stages of most species occur in freshwater, but many terrestrial and marine species are also known. Chironomid midges have been known as pests and have nuisance impact on human health and agriculture for a long time. Chironomid related medical problems are primarily human allergies arising from the larval hemoglobin and epidermis of the adults, causing conjunctivitis, rhinitis, hay fever and or asthma. About 186 species under 67 genera have been found associated with the paddies around the world causing significant damages to the rice and other field crops. In Indian subcontinent, 313 species belonging to 4 subfamilies and 59 genera were reported. The important subfamilies are Diamesinae, Tanypodinae, Orthocladinae and Chironominae. From Kolkata and surrounding areas a total of 9 species belonging to 2 subfamilies and 7 genera were encountered. The most predominant genus was *Chironomus* followed by *Tanytus*.

Keywords : Chironomidae, Diptera, Midges

INTRODUCTION

The Family Chironomidae has a worldwide distribution and is frequently the most abundant group of insects in fresh water. Chironomid, the non biting midges have been known as pests and have nuisance impact on human health and agriculture for a long time. About 186 species under 67 genera have been found associated with the paddies around the world causing significant damages to the paddies and other field crops. Chironomids are considered as indicators of water pollution, acidification and assessment of biodiversity. Studies on the chironomid communities in different ecosystem of India have been made extensively by several workers from time to time (Singh and Kulshrestha, 1975; Kulshrestha, 1979; Chaudhuri *et al.*, 1981, 1983 and 1988, 2001; Chaudhuri and Ghosh, 1986;

Bhattacharyay *et al.*, 1991; Mazumdar *et al.*, 1998; Hazra *et al.*, 2002) The comprehensive studies of rice field Chironomids were made by Chaudhuri, *et al.* (1984), Chaudhuri and Chattopadhyay (1990), Dutta and Chaudhuri (1994). There are four stages in the life cycle of Chironomid such as egg, larva, pupa and adult. The adult stage of Chironomid is rather short, lasting from a few days to several weeks. Seasonal patterns of emergence are closely related to larval development time and this varies considerably from one species to other. The present work was undertaken to explore the diversity of Chironomids from some freshwater ponds of Kolkata metropolis.

MATERIAL AND METHODS

Adults were collected during the period of December, 2005 and November, 2006 by

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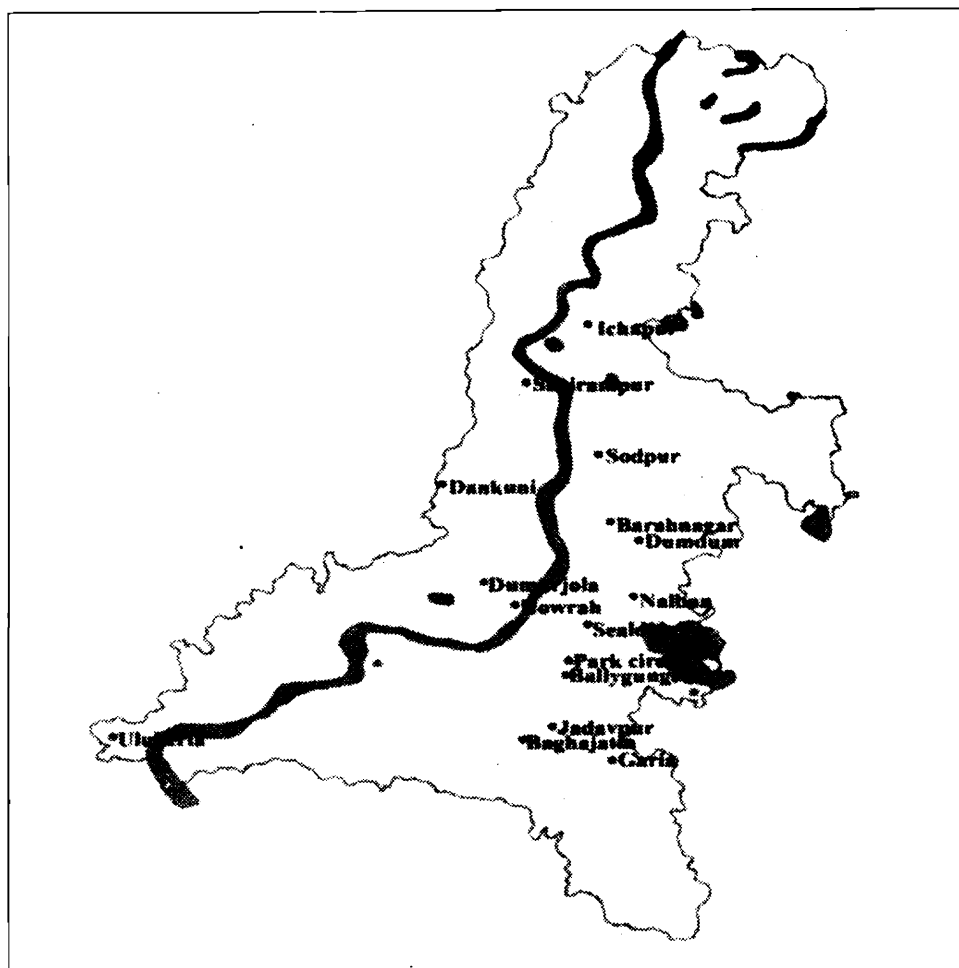


Fig. 1. Sites of Collection

sweeping with insect net and larvae were collected from the bottom mud in fresh water pond with the help of sampler. Larvae were collected and reared in the laboratory in plastic tray containing tap water and a bottom layer of autoclaved mud. The cultures were aerated with pump and the water was changed every alternate day. The phenol-balsam technique as used by Chaudhuri and Guha (1987) was followed for microslide preparation of larvae, pupae and adults.

RESULT AND DISCUSSION

In Indian subcontinent, 313 species belonging to 4 subfamilies and 59 genera were reported. The important subfamilies are Diamesinae, Tanypodinae, Orthocladinae and Chironominae. A total of 9 species belonging to 2 subfamilies and 7 genera (Table 1) were identified from fresh water habitat in Kolkata.

Chironomus circumdatus (Kieffer) (Fig. 2)

Tendipes circumdatus Kieffer, 1916. Annls Hist. Nat. Mus. Natn. Hungarici., 14 : 110.

Material examined : 3♂, Ballygunge, June 2006.



Fig. 2. *Chironomus circumdatus* (Kieffer)

Table-1. List of chironomid species reported from fresh water habitat of Kolkata metropolis

Family	Sub-family	Tribe	Species
Chironomidae	Chironominae	Chironomini	<i>Chironomus circumdatus</i> (Kieffer)
			<i>Chironomus striatipennis</i> Kieffer
			<i>Glyptotendipes verrucosus</i> (Kieffer)
			<i>Kiefferulus barbatitarsis</i> (Kieffer)
			<i>Polypedilum nudiceps</i> Chaudhuri, Guha & Das Gupta
			<i>Stictochironomus obscurus</i> (Guha & Chaudhuri)
		Tanytarsini	<i>Tanytarsus fuscimarginalis</i> Chaudhuri, Guha & Ghosh
	Tanypodinae	Tanypodini	<i>Tanypus bilobatus</i> (Kieffer)
			<i>Tanypus lucidus</i> Chaudhuri, Das & Debnath

Differential diagnosis : 1. Blunt anal point, with 5-7 basolateral setae. 2. Gonocoxite with 10-13 setae. 3. Gonostylus with 6 setae on inner apical margin and 3-4 setae on outer margin. 4. Superior volsella curved with 5 setae at base. 5. Inferior volsella straight with 14-18 incurved setae near apex.

***Chironomus striatipennis* Kieffer**
(Fig. 3)

Chironomus striatipennis Kieffer, 1910. Mem. Ind. Mus., 2 : 236.

Material examined : 1 larvae, 3♀ and 4♂, Patuli, August 2006.

Differential diagnosis : 1. Long curved anal point with 4-8 basolateral setae. 2. Gonocoxite with 24 setae, 3. Gonostylus wider in the middle with 6 setae at its inner apical margin. 4. Superior volsella curved with 6-10 setae at

base. 5. Inferior volsella long curved with 14-18 incurved setae near apex.

***Glyptotendipes verrucosus* (Kieffer)**
(Fig 4)

Chironomus verrucosus Kieffer, 1911b Rec. Indian Mus., 6 : 140.

Glyptotendipes verrucosus (Kieffer) : Sublette & Sublette, 1973. Univ. Press, Hawaii, 1 : 404.

Material examined : 1 pupae and 1♂, Uluberia, Feb. 2006.

Differential diagnosis : 1. Hypophygium with tubular anal point having dilated apex. 2. Gonostylus moderately bent inward and blunt. 3. Superior volsella hook like and with 6-8 setae at its base. 4. Inferior volsella stout and digitiform with 32-34 incurved apical setae.



Fig. 3. *Chironomus striatipennis* Kieffer



Fig. 4. *Glyptotendipes verrucosus* (Kieffer)

***Kiefferulus barbatitarsis* (Kieffer)**
(Fig 5)

Chironomus barbatitarsis Kieffer, 1911b. *Rec. Indian Mus.*, 6 : 154.

Kiefferulus barbatitarsis (Kieffer) : Chaudhuri & Ghosh, 1986. *Syst. Ent.*, 11 : 227.

Material examined : 2 larvae, 1 pupae, 2 ♀ and 4 ♂, Jagrasisar, May 2006.

Differential diagnosis : 1. Anal point well developed; tongue like with about 20 small setae basally. 2. Gonocoxite well developed with 16-18 long setae. 3. Gonostylus widest proximally, narrowed apically, with 24-26 setae along inner margin.



Fig. 5. *Kiefferulus barbatitarsis* (Kieffer)

***Polypedilum nudiceps* Chaudhuri, Guha & Das Gupta**
(Fig. 6)

Polypedilum nudiceps Chaudhuri, Guha & Das Gupta, 1981. *Tijdschr. Ent.*, 124 : 133.



Fig. 6. *Polypedilum nudiceps* Chaudhuri, Guha & Das Gupta

Material examined : 1 ♂, Uluberia, December 2005.

Differential diagnosis : 1. Anal point long, pointed with 7-8 small setae at each basal margin. 2. Gonocoxite short with 6 setae, 3. Gonostylus long, little bent inward.

***Stictochironomus obscurus* (Guha & Chaudhuri)**
(Fig 7)

Pentapedilum obscurus Guha & Chaudhuri, 1983. *J. Bombay Nat. Hist. Soc.*, 79(3) : 673.

Stictochironomus obscurus (Guha & Chaudhuri): Chaudhuri & Chattopadhyay, 1990. *Tijdschr. Ent.*, 133(2) : 165.

Material examined : 2 larvae, 1 pupae, 1 ♀ and 3 ♂, Patuli, November 2006

Differential diagnosis : 1. Anal point long, strong distally narrowed. 2. Superior volsella narrowly digitiform, curved sometimes distally hooked. 3. Inferior volsella long narrow and curved.



Fig. 7. *Stictochironomus obscurus* (Guha & Chaudhuri)

***Tanytarsus fuscimarginalis* Chaudhuri, Guha & Ghosh**
(Fig. 8)

Tanytarsus fuscimarginalis Chaudhuri, Guha & Ghosh, 1984. *Oriental Ins.*, 18 : 33.

Material examined : 1 ♂, Dumdum, February 2006

Differential diagnosis : 1. Anal point stout with 5-7 spinulae in a row. 2. Gonocoxite with 5

setae. 3. Gonostylus long and attenuated at tip, bearing 7-10 setae over it.

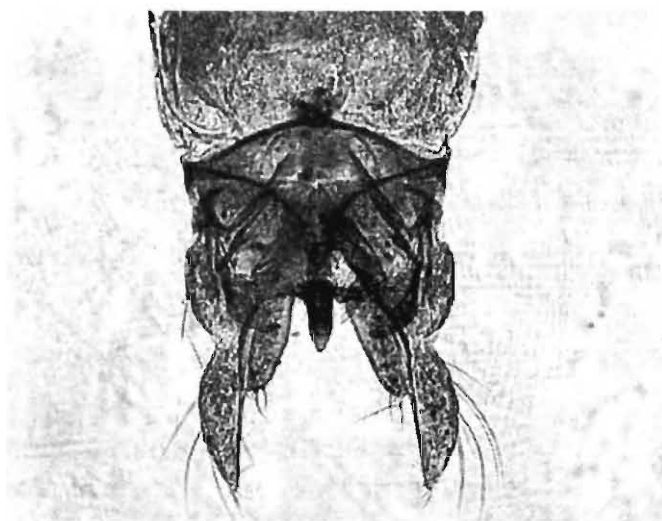


Fig. 8. *Tanytarsus fuscimarginalis* Chaudhuri, Guha & Ghosh

Tanypus bilobatus (Kieffer)
(Fig 9)

Procladius bilobatus Kieffer, 1913b. Rec. Indian Mus., 9 : 155.

Tanypus bilobatus (Kieffer) : Chaudhuri, Nandi & Ghosh, 1983. Arch.Hydrobiol., 97(1) : 123.

Material examined : 4♂, Jagrasisar, May 2006

Differential diagnosis : 1. Gonocoxite robust with a prominent median notch and 12-16 long setae along outer margin. 2. Gonostylus folded inward devoid of setae and a prominent bifurcated tooth at apex.



Fig. 9. *Tanypus bilobatus* (Kieffer)

Tanypus lucidus Chaudhuri,
Das & Debnath
(Fig. 10)

Tanypus lucidus Chaudhuri, Das & Debnath, 1988. Polskie Pismo Ent., 55 : 103.

Material examined : 2♂, Dumurjola, December 2005

Differential diagnosis : 1. Gonocoxite evenly curved with 10-12 long setae along outer margin. 2. Gonostylus relatively feeble and folded inward with tooth at apex. 3. Anal point triangular.

From the above, in subfamily Chironominae, the genus *Chironomus*, *Glyptotendipes*, *Kiefferulus*, *Polypedilum*, *Stictochironomus*, and *Tanytarsus* and in subfamily Tanypodinae, only the genus *Tanypus* were identified. The most predominant genus was *Chironomus* followed by *Tanypus*.



Fig. 10. *Tanypus lucidus* Chaudhuri, Das & Debnath

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LITERATURE CITED

- BHATTACHARYAY, S., ALI, A. and CHAUDHURI, P.K. 1991. Orthoclads of tribe Orthocladini from India. *Beitr. Ent.*, **41** : 333-359.
- CHAUDHURI, P.K. and CHATTOPADHYAY, S. 1990. Chironomid of the rice paddy areas of West Bengal, India (Diptera : Chironomidae). *Tijdschr. Ent.*, **133**(2) : 149-195.
- CHAUDHURI, P.K., DAS, S.K. and DEBNATH, R.K. 1988. Studies of the Indian Tanypodinae (Diptera : Chironomidae), genus *Tanypus* Meigen. *Polskie Pismo Ent.*, **55** : 99-109.
- CHAUDHURI, P.K. and GHOSH, M. 1986. Two Indian species of *Kiefferulus* Goetghebuer (Diptera : Chironomidae). *Systematic Entomology*, **11** : 277-292.
- CHAUDHURI, P.K. and GUHA, D.K. 1987. A conspectus of the Chironomid Midges (Diptera : Chironomidae) of India and Bhutan. *Ent. Scand. Suppl.*, **29** : 23-33.
- CHAUDHURI, P.K., GUHA, D.K. and DASGUPTA, S.K. 1981. Taxonomic studies of Chironominae (Diptera : Chironomidae) from India. The genus *Polypedilum* (Kieffer). *Tijdschrift Voor Entomologie*, **124** : 111-147.
- CHAUDHURI, P.K., GUHA, D.K. and GHOSH, M. 1984. Tanytarsini (Diptera : Chironomidae) from India. *Oriental Ins.*, **18** : 31-41.
- CHAUDHURI, P.K., NANDI, S.K., and GHOSH, M. 1983. Postembryonic stages of *Tanypus bilobatus* (Kieffer) n. comb. (Diptera : Chironomidae) with a note on its biology. *Archiv für Hydrobiologie, Stuttgart*, **97** : 122-133.
- CHAUDHURI, P.K., HAZRA, N. and ALFRED, J.R.B. 2001. A Checklist of Chironomid midges (Diptera : Chironomidae) of the Indian subcontinent. *Oriental Ins.*, **35** : 335-372.
- DUTTA, T.K. and CHAUDHURI, P.K. 1994. A new species of *Glyptotendipes* Kieffer from India. *J. Bombay nat. Hist. Soc.*, **93** : 435-438.
- HAZRA, N., SAHA, G.K. and CHAUDHURI, P.K. 2002. Records of Orthoclad species from the Darjeeling-Sikkim Himalayas of India (Diptera : Chironomidae) with notes on ecology. *Hydrobiologia*, **474**(1) : 41-55.
- KULSHRESTHA, A.K. 1979. First record of the genus *Pentapedilum* Kieffer from India. *Oriental Ins.*, **13**(3-4) : 303-306.
- MAZUMDAR, A., CHAUDHURI, P.K. and HAZRA, N. 1998. Additions to *Tanytarsus* species from Mangrove ecosystem of West Bengal, India (Diptera : Chironomidae). *Oriental Ins.*, **32** : 219-238.
- SINGH, S. and KULSHRESTHA, A.K. 1975. Three new species of *Tanytarsus* (Diptera : Chironomidae). *Oriental Ins.*, **9**(4) : 419-424.

REPORT ON STORED PRODUCT MITES COLLECTED FROM SOME AREAS OF HOOGHLY DISTRICT AND KOLKATA

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ABSTRACT

The present paper reports the results of preliminary observations made during January-March, 2007 on diversity of mite fauna collected from different types of stored products from some areas of Hooghly district and Kolkata. A total of 15 samples from 5 major habitats like, seed, pulses, cereals, dry fish and farinaceous products were screened. The collected mite fauna belonged to 15 species under 10 genera and 6 families covering all the 3 major orders like, Astigmata, Mesostigmata and Prostigmata. Out of these, there were 6 species under 5 genera, the occurrence of which in stored products were earlier unknown in West Bengal. Among these, the mites belonging to the family Acaridae were grain-feeders, those belonging to Uropodidae were fungivorous, the members of the family Cheyletidae and Ascidae were predators while the rest like, Raphignathidae and Glycyphagidae were free-living or of accidental occurrence. Among injurious mites, the members of the family Acaridae were the most dominant and among predatory mites, those belonging to family Cheyletidae were most prevalent. The occurrence of others was rather scarce. This paper lists the mite species collected from stored products of different habitats, discusses their nature of damage, food habits, distribution and provides collection data, etc.

Keywords : Seeds, cereals, pulses, dry fish, farinaceous product, habitat, mites.

INTRODUCTION

Mites infesting stored grains are of double importance. Firstly, they feed on grain contents damaging the grains in such a way so that they become useless for human consumption as well as for germination. Secondly, they increase the humidity of granaries which, in turn, invites the fungal growth making the grain totally or partially unmarketable. Hence, the mites infesting various types of grains have received the attention of entomologists and acarologists and a fairly good amount of work has been done from different parts of India like, Uttar Pradesh (Girish *et al.*, 1971, 1973; Lal *et al.*, 1973; Maurya and Jamil, 1981; Maurya *et al.*, 1983), Haryana (Mathur, 1979; Mathur and Mathur, 1983; Kumud, 1987; Mathur and Minocha, 1989), Punjab (Kapil and Bhanot, 1973), Bihar

(Nahar and Gupta, 1980), South India (Nangia and ChannaBasavanna, 1989). However, very little information is available from West Bengal and excepting Gupta *et al.* (1991) nothing else is known from this state. Hence, an investigation has been undertaken to find out the diversity of mite fauna infesting different types of grains and other stored products like, stored seeds, pulses and cereals, wheat flour, dry fish and farinaceous products, etc. and a preliminary result of that study is reported herein.

MATERIAL AND METHODS

The samples of stored products were collected during January-March 2007 from different places of Hooghly district and Kolkata. Some of the samples were examined under stereo-binocular microscope to collect the mite

specimens with the help of fine brush moistened with ethyl alcohol. In some cases, the collected stored product samples were put into Tullgren's Apparatus and mites were extracted by heat desiccation method. The mites were mounted in Heinze's medium and were studied and identified under research microscope.

RESULTS AND DISCUSSION

The present paper reports a total of 15 species belonging to 6 families, 10 genera under 3 orders (Table 1). The habitats and localities from where those were collected, the nature of damage and key for their identification are given in the table 1.

Table 1. List of stored product mites with their habitats, nature of association and damage done, if any.

I. Order ASTIGMATA

Family	Species	Habitat	Nature of Association	Nature of Damage	Remarks
Acaridae	<i>Acarus gracilis</i> Hughes	Bengal gram seed	Grain feeder	Made holes on grain surface, had eaten away the endosperm, grains turned blackened and shriveled, population was very high	This is the first record of this species from West Bengal
	<i>Acarus siro</i> L.	Groundnut, Suji, Wheat flour	Grain feeder	Made holes on nut surface, the severely damaged seeds became powdery. Population was very high	
	<i>Lardoglyphus kono</i> i (Sasa and Asanuma)	Dry fish	Feeder of dry fish	Dry fishes due to feeding by this mite turned powdery. The flesh portion was completely eaten away	This is the first record of this species from West Bengal.
	<i>Suidasia medanensis</i> Oudemans	Groundnut, Wheat flour	Grain feeder	Made holes on nut and fed on grain contents making the grains powdery. In wheat flour the infestation of this mite made the flour crumpled	
	<i>Suidasia nesbitti</i> Hughes	Groundnut, Watermelon seed	Grain feeder	Made holes on seeds, fed on grain content making the grain powdery	This is the first record of this species from West Bengal
	<i>Tyrolichus casei</i> Oudemans	Bread	Fungal association	This mite was seen amidst fungal mycellia grown on bread surface. The bread was almost 20 days old. Population was low.	This is the first record of this species from West Bengal

Table 1. *Contd.*

Family	Species	Habitat	Nature of Association	Nature of Damage	Remarks
Glycyp-hagidae	<i>Glyciphagus domesticus</i> (De Geer)	Bengal gram seed	Fungal feeder	Found associated with mould grown on seeds. Population was very high	
	<i>Lepidoglyphus destructor</i> Schrank	Bengal gram seed	Fungal feeder	No damage done	

II. Order MESOSTIGMATA

Ascidae	<i>Blattisocius tarsalis</i> (Berlese)	Suji, bread	Associated with <i>Acarus siro</i>	Predated upon <i>Acarus siro</i> . Population was very low	
Uropodidae	<i>Fusciropoda marginata</i> C.L.Koch	Ground nut	Fungal feeder	Fed on fungal mycellia	

III. Order PROSTIGMATA

Cheyletidae	<i>Cheyletus aversor</i> Rohdendorf	Watermelon seed, Cake-dust, Dry fish	Associated with Acarid mites	Probably fed upon <i>S. nesbitti</i> and <i>L. kono</i>	This is the first record of this species from West Bengal.
	<i>Cheyletus fortis</i> Oudemans	Seeds of Bengal gram	Associated with Acarid mites	Probably fed upon <i>S. nesbitti</i> and <i>L. kono</i>	This is the first record of this species from West Bengal.
	<i>Cheyletus</i> sp. nr. <i>fortis</i>	Seeds of Bengal gram	Associated with Acarid mites	Probably fed upon <i>S. nesbitti</i> and <i>L. kono</i>	
	<i>Cheyletus malaccensis</i> Oudemans	Ground nut	Associated with Acarid mites	This was found abundant in the sample. Known as effective predator of Acarid mites.	
Raphignathidae	<i>Raphignathus</i> sp.	Seeds of Bengal gram	Fungal association	Accidental occurrence, its role in the sample is uncertain. Population was very low.	This is the first report in stored products in India.

Among the species reported here, the population of *Acarus siro* on groundnut and *Lardoglyphus kono* on dry fish was very high and every sample was found infested with this mite. The occurrence of *Suidasia medanensis* on

groundnut, *Blattisocius tarsalis* on suji, *Cheyletus aversor* on seeds of watermelon and *Glyciphagus domesticus* on Bengal gram were earlier unknown. Earlier, Gupta *et al.* (1991) reported 25 species from West Bengal, of those *Acarus*

siro, *Cheyletus malaccensis*, *Raphignathus* sp., *Fuscuropoda marginata*, *Blattisocius tarsalis* and *Glycyphagus domesticus*, which are reported here, were found common with every sample. The species forming new records from West Bengal are *Acarus gracilis*, *Lardoglyphus kono*i, *Tyrolichus casei*, *Suidasia nesbitti*, *Cheyletus aversor* and *Cheyletus fortis*.

Key to the orders, families, genera and species of stored product mites from West Bengal

1. Pedipalpal apodeme represented by a tined seta situated near the inner basal angle of the tarsus, stigmata situated dorsal to coxae II-IV and usually with elongated peritremes, tritosternum usually with lacinia
..... *Mesostigmata*, 3
 - Apotele completely absent on pedipulp, stigmata never situated near dorsal to coxae II-IV 2
2. Ambulacrum of legs comprising of a median claw with a prominent pretarsus or an associated membranous pad or a stalked sucker like organ, chelicerae chelate, trichobothria never present on idiosoma, stigmata and tracheae absent
..... *Astigmata*, 4
 - Ambulacra of legs not as above, chelicerae chelate or variously modified into piercing stylets or hook-like organ, idiosoma often with trichobothria, a respiratory system usually present *
 - * Propodosoma trichobothria when present usually without conspicuous stigmata, chelicerae rarely chelate, dentate, pedipalp often with thumb-claw complex by tibia and tarsus, tracheae when present open by a paired stigmata between chelicerae or on dorsal surface of propodosoma and often with associated peritreme, usually weakly sclerotized. *Prostigmata*, 12
3. Hypostomal setae 2 and 3 forming a transverse row posterior to hypostomal setae I. Tritosternum usually removed from coxae I, no leg grooves *Gamasina*, *
- * Adults with 5 pairs of setae in J series arising from the posterior region of the dorsal shield, corniculi not forked distally *Ascidae*, **
- ** Peritreme reaching to about the posterior margin of coxae II, fixed digit of chelicera very short, without teeth, *pilus dentilis* relatively long *Blattisocius tarsalis*
- Hypostomal setae 1,2 and 3 in linear series. Tritosternum usually partially or completely covered by the enlarged, flattened coxae I. Leg grooves present
..... *Uropodina*, *
- * Metapodal plates present, female genital shield often with anterior projection
..... *Fuscuropoda*, **
- ** Idiosoma tapering towards posterior end, pulvili of legs I are three fold, those of legs II-IV-5 fold, second pair of legs bear stouter spines *Fuscuropoda marginata*
4. Propodosoma and hysterosoma may or may not be separated by a suture. Dorsal setae foliate or bilaterally pectinate *
- * Skin tough, granular, scale-like or densely striated, dorsal body setae pectinate or fan-like, free living *Glycyphagidae*, 5
- Propodosoma and hysterosoma separated by a suture, skin smooth, scale-like or wrinkled, some dorsal body setae long and whip like *Acaridae*, 6
5. With a subtarsal scale and without a crista metopica *Lepidoglyphus*, *
- * Sigma on genu 2 not thickened in either sex, in female the posterior pair of genital setae arises behind the posterior edge of the genital opening
..... *Lepidoglyphus destructor*
- without a subtarsal scale, usually with crista metopica. *Glycyphagus*, *
- * Setae vi inserted almost in the middle of the crista metopica, d_2 arising at the level of d_3 *Glycyphagus domesticus*
6. One genu 1, solenidia sigma 1 at least 3 times longer than sigma 2 and tarsal setae

- long and slender, male with strong ventral spur on femur I..... *Acarus*, 7
- Sigma 1 less than 3 times length of sigma 2, or if 3 times longer, then some tarsal setae spine like, male femur I normal 8
7. Dorsal seta d_2 not more than 2 times length of d_1 *Acarus siro*
- Dorsal seta d_2 4-5 times longer than d_1 *Acarus gracilis*
8. Female with bifid claws on all legs, males always heteromorphic with the 3rd leg ending in 2 conspicuous processes *Lardoglyphus*, *
- * Setae d_4 almost equal in length to d_3 , leg I and II of male with undivided claws. *Lardoglyphus kono*
 - Female without bifid claws, homomorphic males usually found, though heteromorphic ones also occur 9
9. Both hysterosomal setae d_1 , L_2 short, equal in length..... *Tyrolichus*, *
- * Setae la 4-6 times longer than d_1 *Tyrolichus casei*
 - Setae d_1 only short seta on the hysterosoma 10
10. Seta he conspicuously longer than hi , males with no anal suckers *Suidasia nesbitti*
- Setae he about the same length as hi , large flat anal sucker present in male *Suidasia medanensis*
11. Cheliceral bases closely fused with gnathosoma and without indication of suture, peritreme usually M shaped may be present in gnathosoma *
- * Palp with strong claw, thumb short, may or may not have comb-like and sickle like setae, tarsi II, III and IV usually with claws and empodia Cheyletidae, *
 - * Dorsal idiosoma setae simple, lanceolate, never fan shaped *Cheyletus*, 12
 - Cheliceral bases fused with each other but not with gnathosoma, suture conspicuous, peritreme present in interior position of propodosoma *
 - * Chelicera form a stylophore, coxae II and III contiguous Raphignathidae *Raphignathus* sp.
12. Palp claw with large basal tooth *Cheyletus fortis*
- Palp claw with more than one basal tooth 13
13. Inner comb of palp tarsus with 30 teeth, peritreme 6 segments *Cheyletus aversor*
- Inner comb of palp tarsus with 24 teeth, peritreme 4-5 segments *Cheyletus malaccensis*

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LITERATURE CITED

- GIRISH, G., GOYEL, R. K. and KRISHNAMURTHY, K., 1971. Occurrences of *Acaropsis docta*, Berlese (Prostigmata : Cheyletidae) on *Trogoderma granarium* Everts and *Rhizopertha dominica* Fab. at Hapur (U.P.) *Bull. Grain Tech.*, 9 : 83-85.
- GIRISH, G., GOYEL, R. K. and KRISHNAMURTHY, K., 1973. Studies on Indian mites Part-II Association of *Cheyletus malaccensis* Oud. (Cheyletidae : Prostigmata) with *Trogoderma granarium* Everts, *Bruchus chinensis* Linn. And *Tribolium castaneum*. *Bull. Grain Tech.*, 11(2) : 110-120.
- GUPTA, ARUN, GUPTA, S.K. and BANERJEE, S. 1991. A report on mites infesting stored grain in West Bengal. *Bull. Grain Tech.*, 29 : 47-49.

- KAPIL, R. P. and BHANOT, J. P. 1973., Feeding behavior of the predatory mite *Acaropsis docta* Berlese. *J. Stored Product Res.*, 9 : 1-16.
- KUMUD, 1987. Analysis of the interactions between some stored product mites and storage fungi in a micro-cosm. Ph. D. thesis. Haryana Agri. University.
- LAL, L., KATYAR, O. P., SINGH, J. and MUKHERJEE, S.P., 1973. A new host of *Tyrophagus putrescentiae* (Schränk) (Tyroglyphidae : Acarina) at Varanasi. *Bull. Grain Tech.*, 11 : 69-70.
- MATHUR, S. 1979. A new record of *Tyroborus lini* Oudemans (Acaridae : Astigmata) from India. *Acar. Newsl.*, 9 : 3.
- MATHUR, R. B. and MATHUR, S. 1983. Mites associated with stored grain product in Haryana, India. *Indian J. Acar.*, 7(2) : 44-52.
- MATHUR, R. B. and MINOCHA, A. 1989. Influence of natural food density on cannibalism in *Acaropsis solliers* (Prostigmata : Cheyletidae). In : *Progress in Acarology* (Eds. Channa Basavanna, G. P. and Viraktamath, C. A.), Oxford IBH, New Delhi, 2 : 255-258.
- MAURYA, K. R. and JAMIL, Z., 1981. A survey of storage acari in Lucknow. *Bull. Mem.*, 6(2) : 97-122.
- MAURYA, K. R., JAMIL, Z. and DEY, B. 1983. Mite infestation pattern in various stored products in Lucknow (India). *Bull. Mem.*, 7(2) : 116-120.
- NAHAR, S. C. and GUPTA, S.K. 1980. Preliminary report on stored grain mites of Bihar. *Bull. Grain Tech.*, 18 : 130-134.
- NANGIA, N. and CHANNA BASAVANNA, G.P. 1989. Acarines associated with stored products in Karnataka, India. In : *Progress in Acarology* (Eds. Channa Basavanna, G.P. and Viraktamath, C. A.), 2 : 241-248.

DIVERSITY AND DOMINANCE OF MIGRATORY WATERBIRDS IN SIX WETLANDS OF SOUTHERN WEST BENGAL, INDIA

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ABSTRACT

Several wetlands in the southern West Bengal serve as important roosting grounds for migratory avifauna. The present survey was undertaken to study the composition, diversity and dominance of several trans-Himalayan migratory, resident-migrant and resident aquatic avifauna in Nalban Bheri (Kolkata), Santragachi Jheel (Howrah), Saheb Badh (Purulia), Bakreshwar Barrage (Birbhum), Tilpara Barrage (Birbhum) and the wetlands inside Ballavpur Wildlife Sanctuary (Birbhum). Of all the wetlands studied, population of migratory waterbirds was highest in Ballavpur Wildlife Sanctuary (11,362). However, maximum number of migratory (including both migratory and resident-migrant) species and resident species were recorded from Tilpara Barrage (21 species and 12 species respectively). Major migratory aquatic avifaunal species are Lesser Whistling Duck (*Dendrocygna javanica*), Northern Pintail (*Anas acuta*) and Gadwall (*Anas strepera*). It is interesting to note that where the total number of waterfowl is very high, one or two species usually predominate. This is supported by the fact that the diversity index of the Tilpara Barrage is highest (0.998) and the dominance index is lowest (0.178). On the contrary, the dominance index of the Santragachi Jheel is highest (0.94) and the diversity index is lowest (0.073) of all the sites studied. This result reflects the idea that the dominance and diversity of a particular study area are inversely related to each other.

Keywords : Migratory water birds, wetlands, southern West Bengal.

INTRODUCTION

Several wetlands in the southern West Bengal serve as important roosting grounds for migratory avifauna. The present survey was undertaken to study the composition, diversity and dominance of several migratory (both trans-Himalayan and locally migrant) and resident aquatic avifauna in six wetlands situated at the southern part of West Bengal that are known to be the roosting grounds for the migratory waterbirds.

STUDY SITE AND METHODOLOGY

During the course of present study, waterfowl census was conducted in the

following wetlands of southern West Bengal, namely, Nalban Bheri (Kolkata) [henceforth NB], Santragachi Jheel (Howrah) [henceforth SJ], Saheb Badh (Purulia) [henceforth SB], Bakreshwar Barrage (Birbhum) [henceforth BB], Tilpara Barrage (Birbhum) [henceforth TB] and the wetlands inside Ballavpur Wildlife Sanctuary (Birbhum) [henceforth BWLS] [Fig. 1]. In the region under study, migration generally completes at the end of December and during last week of December and first week of January the total population of migratory waterfowl reaches its peak (Mazumdar *et al.*, 2005). Therefore, the present survey was conducted during January, 2006 when the wetlands are expected to show

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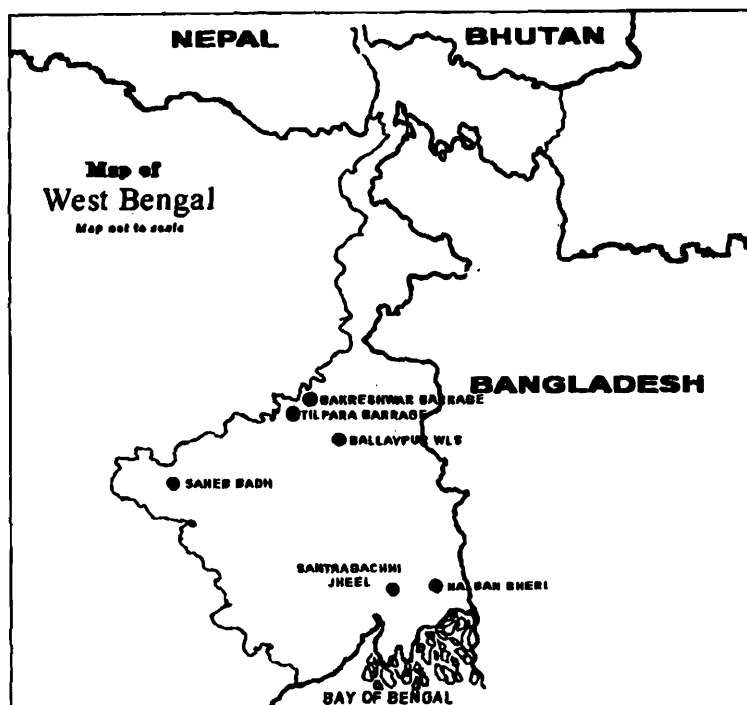


Fig. 1. Location of the study sites in West Bengal

maximum aggregation of the migratory waterfowls.

In all the study sites, 'total count' methodology was followed and the waterbirds were counted using binoculars and telescopes. All the waterbirds present in the waterbodies were counted and species and the number of individuals were recorded. The large waterbodies were divided into imaginary blocks and the waterbirds in each block was counted in succession on the same visit. Species Diversity Index and Species Dominance Index were obtained following Shannon Weiner's Diversity Index and Simpson's Dominance Index respectively.

RESULTS AND DISCUSSION

Present observation revealed that in southern West Bengal the major migratory aquatic avifaunal species are Lesser Whistling Duck (*Dendrocygna javanica*), Northern Pintail (*Anas acuta*) and Gadwall (*Anas strepera*) comprising 64.5%, 15.7% and 4.1% respectively of the total population of migratory waterfowls counted in all the sites. Lesser Whistling Duck (*Dendrocygna javanica*) was observed to be the most predominant species at SJ, SB and BWLS contributing to 96.9%, 74.8% and 57.0%

respectively of the total migratory waterbirds at each site. Of all the wetlands studied, population of migratory waterbirds was highest in BWLS (11,362) followed by SJ (9,789), SB (3,228), BB (1,876), TB (1,430) and NB (1,105). Maximum diversity of wetland birds was recorded at TB (33 species) followed by BWLS (27 species), SB (26 species), NB (25 species), BB (21 species) and SJ (16 species). However, maximum number of migratory (including both migratory and resident migrant) species was recorded at TB (21 species) followed by NB (19 species), SB and BWLS (16 species each), BB (15 species) and SJ (9 species). Among the sites studied, TB showed highest species diversity of trans-Himalayan wetland birds (10 species) as well as resident species (12 species). Maximum number of resident-migrant species is recorded at NB (12 species.) followed by TB (11 species), SB (8 species), BB and BWLS (7 species each) and SJ (4 species) [Table 1 & 2, Fig 2].

It is interesting to note that in the sites where the total number of waterfowl is very high, one or two species usually predominate. In the present study, dominance index of SJ and SB is 0.94 and 0.572 respectively and the dominant species is Lesser Whistling Duck (*Dendrocygna javanica*) [Table 1]. In BWLS, Lesser Whistling Duck (*Dendrocygna javanica*) and Northern

Table 1. Status of wetland birds in different study area of southern West Bengal

	Nalban Bheri (=NB)	Santragachi Jheel (=SJ)	Saheb badh (=SB)	Bakreshwar Barrage (=BB)	Tilpara Barrage (=TB)	Ballavpur WLS (=BWLS)
Total number of migratory waterfowl	1,105	9,789	3,328	1,876	1,430	11,362
Migratory species	7	5	8	8	10	9
Resident-migrant species	12	4	8	7	11	7
Resident species	6	7	10	5	12	11
Vagrant species	0	0	0	1	0	0
Shannon Weiner's Diversity Index	0.805	0.073	0.464	0.724	0.998	0.399
Simpson's Dominance Index	0.199	0.940	0.572	0.250	0.178	0.430

Table 2. Comparison of the wetland birds and wetland-associated birds encountered in the six study sites :

Species	Status (Ali, 1996)	NB	SJ	SB	BB	TB	BWLS
Waterbirds							
Little Grebe <i>Tachybaptus ruficollis</i>	R	0	0	✓	✓	0	✓
Great Crested Grebe <i>Podiceps cristatus</i>	M	0	0	0	✓	✓	0
Little Cormorant <i>Phalacrocorax niger</i>	RM	✓	✓	✓	✓	✓	✓
Indian Cormorant <i>Phalacrocorax fuscicollis</i>	RM	✓	✓	✓	0	0	0
Great Cormorant <i>Phalacrocorax carbo</i>	RM	✓	0	✓	✓	✓	0
Darter <i>Anhinga melanogaster</i>	RM	0	0	0	0	0	✓
Little Egret <i>Egretta garzetta</i>	R	0	0	0	✓	✓	✓
Great Egret <i>Casmerodius albus</i>	R	0	0	0	0	✓	0
Cattle Egret <i>Bubulcus ibis</i>	R	✓	✓	✓	✓	✓	✓
Indian Pond Heron <i>Ardeola grayii</i>	R	✓	✓	✓	0	✓	✓
Grey Heron <i>Ardea cinerea</i>	RM	✓	0	0	0	0	0
Yellow Bittern <i>Ixobrychus sinensis</i>	RM	✓	0	0	0	0	0
Fulvous Whistling-Duck <i>Dendrocygna bicolor</i>	RM	0	✓	✓	0	0	0
Lesser Whistling-Duck <i>Dendrocygna javanica</i>	R	0	✓	✓	0	✓	✓
Greylag Goose <i>Anser anser</i>	M	0	0	0	✓	✓	✓
Bar-headed Goose <i>Anser indicus</i>	RM	0	0	0	✓	✓	0
Ruddy Shelduck <i>Tadorna ferruginea</i>	RM	0	0	0	✓	✓	0
Cotton Pygmy-goose <i>Nettapus coromandelianus</i>	R	0	✓	✓	0	✓	✓
Gadwall <i>Anas strepera</i>	M	✓	✓	✓	✓	✓	✓
Falcated Duck <i>Anas falcata</i>	V	0	0	0	✓	0	0
Eurasian Wigeon <i>Anas penelope</i>	M	0	0	0	✓	✓	✓

Table 2. Contd.

Species	Status (Ali, 1996)	NB	SJ	SB	BB	TB	BWLS
Northern Shoveler <i>Anas clypeata</i>	M	✓	✓	✓	✓	✓	✓
Northern Pintail <i>Anas acuta</i>	M	0	✓	✓	✓	✓	✓
Garganey <i>Anas querquedula</i>	M	✓	0	✓	0	0	0
Common Teal <i>Anas crecca</i>	M	0	0	✓	0	0	✓
Red-crested Pochard <i>Rhodonessa rufina</i>	M	0	0	✓	✓	✓	✓
Common Pochard <i>Aythya ferina</i>	M	0	0	✓	0	0	0
Ferruginous Pochard <i>Aythya nyroca</i>	RM	0	✓	✓	0	✓	✓
Tufted Duck <i>Aythya fuligula</i>	M	0	0	✓	✓	✓	✓
White Breasted Waterhen <i>Amaurornis phoenicurus</i>	R	✓	0	✓	0	0	0
Common Coot <i>Fulica atra</i>	RM	0	0	✓	✓	0	✓
Purple Swampphen <i>Porphyrio porphyrio</i>	R	0	0	✓	0	✓	✓
Common Moorhen <i>Gallinula chloropus</i>	R	✓	✓	✓	0	✓	✓
Pheasant tailed Jacana <i>Hydrophasianus chirurgus</i>	R	0	0	0	0	✓	✓
Bronze Winged Jacana <i>Metopidius indicus</i>	R	0	✓	✓	0	✓	✓
Little Ringed Plover <i>Charadrius dubius</i>	RM	✓	0	0	0	0	0
Red-wattled Lapwing <i>Vanellus indicus</i>	R	0	0	0	0	✓	0
Grey-headed Lapwing <i>Vanellus cinereus</i>	M	0	0	0	0	✓	0
Pintail Snipe <i>Gallinago stenura</i>	M	✓	✓	0	0	0	0
Swinhoe's Snipe <i>Gallinago megala</i>	M	✓	✓	0	0	0	0
Common Redshank <i>Tringa totanus</i>	RM	0	0	0	✓	✓	0
Green Sandpiper <i>Tringa ochropus</i>	M	✓	0	0	0	✓	0
Wood Sandpiper <i>Tringa glareola</i>	M	✓	0	0	0	0	0
Common Sandpiper <i>Actitis hypoleucos</i>	RM	✓	0	0	0	✓	0
Wetland-associated species							
Eurasian Marsh Harrier <i>Circus aeruginosus</i>	M	0	0	0	0	0	✓
Pied Harrier <i>Circus melanoleucos</i>	RM	0	0	0	0	✓	0
Greater Spotted Eagle <i>Aquila clanga</i>	RM	0	0	0	0	0	✓
Asian Openbill <i>Anastomus oscitans</i>	R	0	0	0	✓	✓	0
Wooly-necked Stork <i>Ciconia episcopus</i>	RM	0	0	0	0	0	✓
Stork billed Kingfisher <i>Halcyon capensis</i>	R	0	0	0	0	0	✓
White Throated Kingfisher <i>Halcyon smyrnensis</i>	R	✓	✓	✓	0	0	0
Common Kingfisher <i>Alcedo atthis</i>	RM	✓	0	✓	0	0	0
Pied Kingfisher <i>Ceryle rudius</i>	R	✓	0	0	0	0	0
Barn Swallow <i>Hirundo rustica</i>	RM	✓	0	0	✓	✓	0
White-browed Wagtail <i>Motacilla maderaspatensis</i>	R	0	0	0	✓	0	0
White Wagtail <i>Motacilla alba</i>	RM	✓	0	✓	0	✓	✓
Citrine Wagtail <i>Motacilla citreola</i>	RM	✓	0	0	0	0	0
Yellow Wagtail <i>Motacilla flava</i>	RM	✓	0	0	0	✓	0

M = Migrant; RM = Resident Migrant; V = Vagrant;

✓ = Recorded; 0 = Not recorded

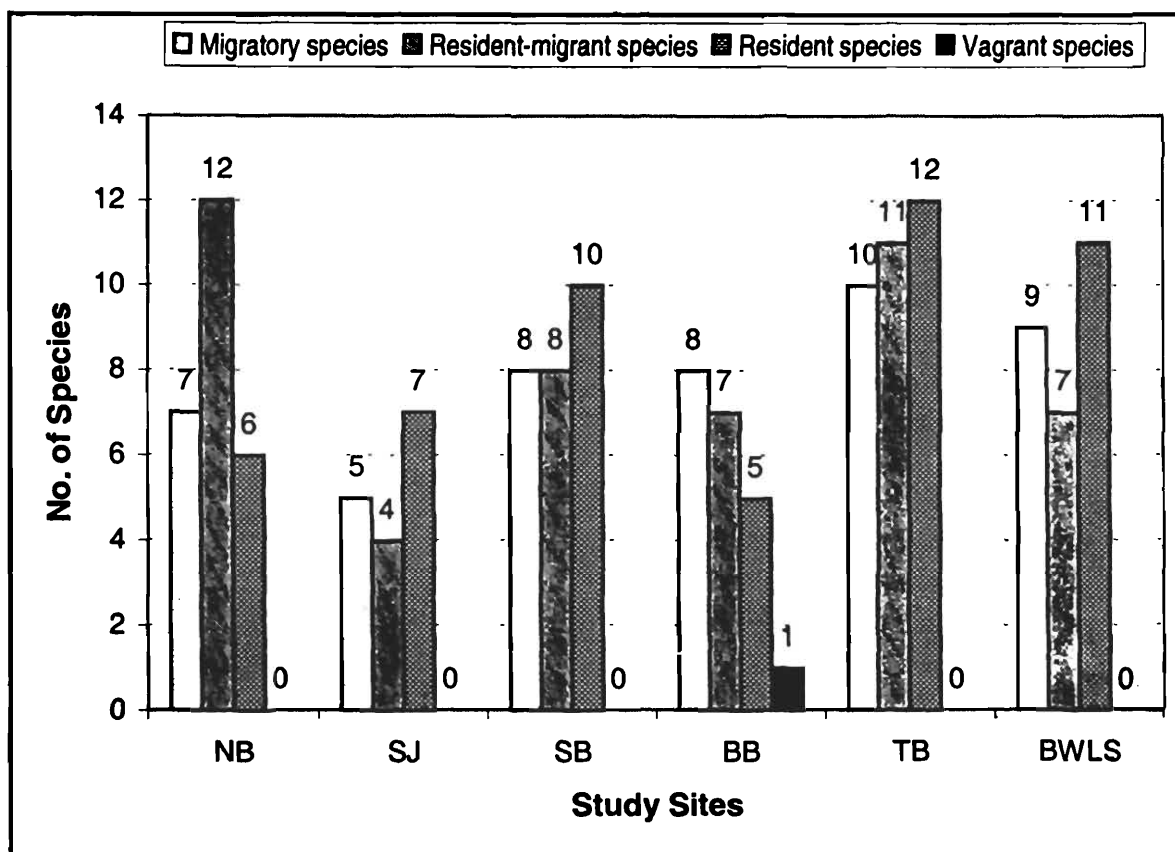


Fig. 2. Comparison of the migratory, resident-migrant and resident species of wetland birds in the study sites

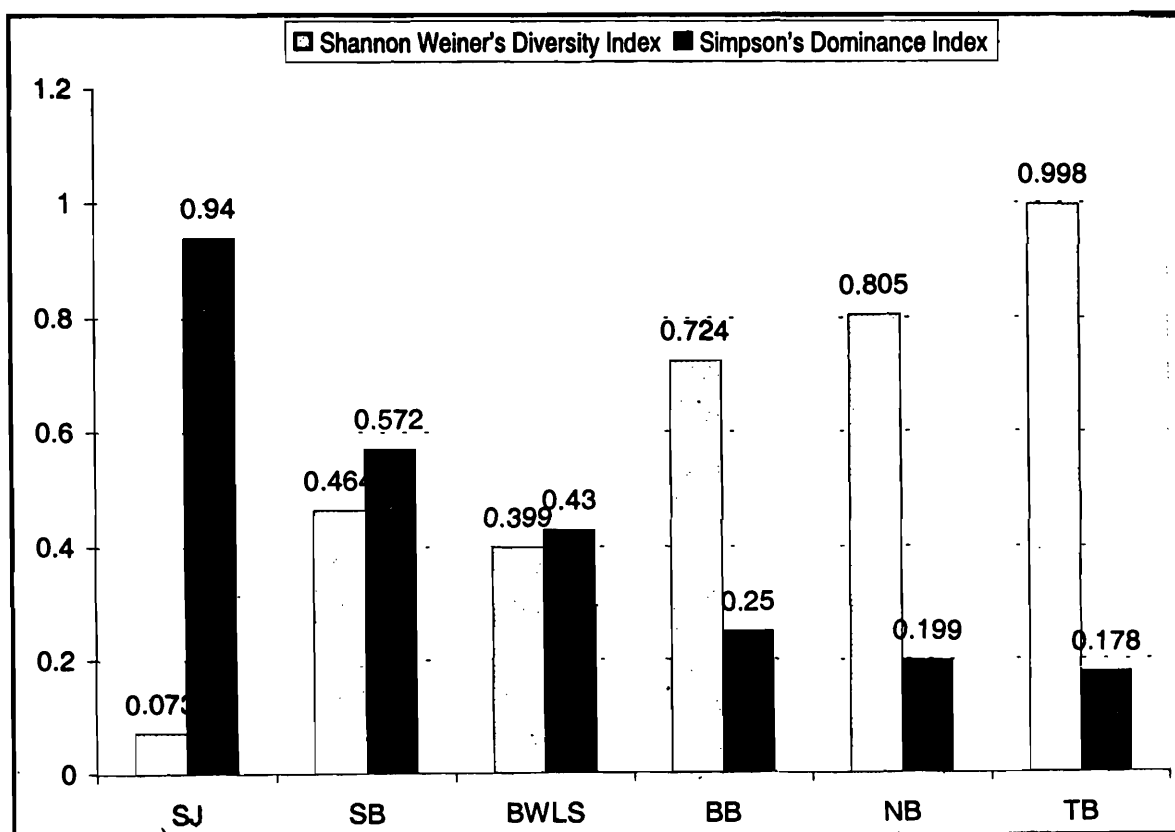


Fig. 3. Comparison of the Dominance and Diversity Indices of the study sites

Pintail (*Anas acuta*) contribute to a significant portion of the population present and the dominance index of this site is 0.43, [Table 1, Fig. 2]. On the contrary, in TB total number of individual waterbird is much lesser as compared to BWLS, SJ or even SB, yet maximum number of trans-Himalayan migratory, resident species and second largest number of resident-migrant aquatic avifaunal species was found in this site. As expected, one or two species do not dominate this site and the site shows high diversity and low dominance of the waterfowl species. This is supported by the fact that the diversity index of the TB is highest (0.998) and the dominance index is lowest (0.178) of all the sites studied. In terms of diversity of waterfowl, TB is followed by NB (0.805), BB (0.724), SB (0.464), waterbodies of BWLS (0.399) and SJ (0.073). SJ, on the other hand, had maximum dominance index of 0.94 that is followed by SB (0.572), BWLS (0.43), BB (0.25), NB (0.199) and TB (0.178) [Table 1].

From the present observation it can be said that all these sites serve as good wintering ground for a good number of migratory and locally migrant avifaunal species. This result reflects the idea that the dominance and

diversity of a particular study site are inversely related to each other [Fig 3]. In the study site where the dominance index is high showing values more than 0.5 in communities, one or two species contribute quite significantly. On the contrary, in the study area where the dominance index is low and one or two species do not dominate, the diversity increases as all the species are more or less evenly distributed. However, additional observations at these sites at other times of the year and over different years are needed to provide a deeper insight into the value of these wetlands to waterbirds.

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LITERATURE CITED

- ALI, S. 1996. *The Book of Indian Birds*. (12th Revised edition). New Delhi. Oxford University Press.
- ANON. 1998. *Wetlands and Waterbirds of West Bengal*. Nature Environment & Wildlife Society.
- GRIMMET, R., INSKIPP, C. and INSKIPP, T. 1999. *Pocket Guide to the Birds of Indian Subcontinent*. New Delhi. Oxford University Press.
- MANAKADAN, R. and PITTIE, A. 2001. "Standardized common and scientific names of the birds of the Indian subcontinent". *Buceros*, 6(1) : 1-37.
- MAZUMDAR, S., GHOSH, P. and SAHA, G.K. 2005. "Diversity and behaviour of waterfowl in Santragachi Jheel, West Bengal, India during winter season" *Indian Birds* Vol. 1 No. 3 (May-June 2005) : 68-69
- SONOBE, K. and USUI, S. (EDS). 1993. *A field guide to the waterbirds of Asia*. Tokyo. Wild Bird Society of Japan.

DIVERSITY OF PISCAN FAUNA IN NORTH BENGAL DISTRICTS

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ABSTRACT

Freshwater fishes are the most diverse group of India's vertebrates with minimum of 600 species. National Bureau of Fish Genetic Resources (NBFGGR), Lucknow in 1992 had identified nine endemic fishes from north east region of India as most threatened. These are *Ompok pabda*, *Ompok pabo*, *Labeo dyocheilus*, *Semiplotus semiplotus*, *Olyra longicaudata*, *Psilorhynchus homaloptera*, *Noemacheilus elongatus*, *Balitora brucei* and *Barbus dukai*. In the six districts of North Bengal namely Darjeeling, Jalpaiguri, Coochbihar, Maldah, North and South Dinajpur remarkable fish diversity is seen. In North Bengal hill stream species of fish comprise the fish fauna of the river Tista and its tributaries. Over 125 species of fish have so far been recorded from this area. But recent studies reveal that a remarkable number of fish species have become endangered in North Bengal districts. Name of the fishes which have become endangered in all the six districts of North Bengal are—*Tor putitora* (Golden Himalayan Mahaseer), *Tor tor* (Red finned Mahaseer), *Barilius sp* (Boroli), *Nandus nandus* (Nados), *Ompok pabda* and *Ompok pabo* (Pabda). The major drawback in this regard is the lack of effectful surveys on fish species. The destruction of the habitat (ecology) of hill stream especially in the river Tista during the flood of 1968, coupled with destructive methods of fishing in the deep pools in course of the river are the main cause of declination of hill stream fish fauna in the state. Measures should be taken to avoid further destruction.

Key words : Endemic fishes, endangered, fish diversity, declination.

INTRODUCTION

One of the global crisis at present point of time is rampant loss of the World's Biological Wealth. The Biodiversity Convention of Rio de Janeiro in June 1992 was thus articulated to help growing global concern for saving and sharing the genetic wealth of our planet. Thus conservation of biodiversity and the effective use of such diversity in enhancing ecologically sustainable advances in crop and animal productivity have been accorded prominence in the global, political, and economical agenda for the present decade. There exists report on the existence of more than 24,600 finfish species throughout the world (Groobridge, 1992). Freshwater fishes are the most diverse group of India's vertebrates with minimum of 600

species (Talwar and Jhingran, 1991). Based on the recent conservation assessment, 88 species in Western Ghat streams and 82 species in Eastern Himalayas are in threatened category and of the threatened species nearly 25-30% is highly endemic to their geographic realms.

National Bureau of Fish Genetic Resources (NBFGGR), Lucknow in 1992 had identified nine endemic fishes from northeast region of India as most threatened. These are *Ompok pabda*, *Ompok pabo*, *Labeo dyocheilus*, *Semiplotus semiplotus*, *Olyra longicaudata*, *Psilorhynchus homaloptera*, *Noemacheilus elongatus*, *Balitora brucei* and *Barbus dukai*. Sinha (1994) has listed 13 species as threatened from North East. In the six districts of North Bengal namely Darjeeling, Jalpaiguri, Coochbihar, Malda,

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North and South Dinajpur remarkable fish diversity is seen.

Considering the importance of the biodiversity study of the fish present work has been undertaken to consider the present scenario of the ichthyofaunal distribution in North Bengal districts in contrast to existing survey reports on biodiversity status of fish species.

METHODOLOGY

i. Methods of Survey

a. Literature Survey

Extensive literature survey was done on the line of research to receive the data of the fish population of North Bengal Districts which comprises six districts like Uttar Dinajpur, South Dinajpur, Malda, Coochbihar, Darjeeling and Jalpaiguri. Literature survey was done with the help of the following libraries—Zoological Survey of India, Kolkata; Asiatic Society, Kolkata; National Library, Kolkata; Library of Bengal Natural History Museum (BNHM), Darjeeling; Departmental Library of the Dept. of Zoology, University of Calcutta etc.

b. Museum Survey

Bengal Natural History Museum, Darjeeling was established in 1903. The museum has a collection of over 4300 specimen. This Natural History Museum packs in its folds a rich collection of fauna found in the Himalayas and in Bengal. This unique museum also has a good collection of fishes. Probably all of them were collected from North Bengal. These specimens may provide ample clues about the previous fish population of North Bengal.

c. Market / Field Survey

In North Bengal hill stream species of fish comprise the fish fauna of the river Tista and its tributaries. Market survey was done in the six districts of North Bengal and extensive field survey was done by random collection of fishes from Siliguri and Darjeeling area.

ii. Area Covered for the Present Study : (Fig. 1)

Malda :

Out of 23 major wetlands in West Bengal 11 are situated in Malda district. River Ganga lies on the border of the district and other rivers are Mahananda, Kalindi, Purnabhaha and Pagla.

Dinajpur Districts (North and South)

The main rivers of the districts are Mahananda and Nagar. Other important tributaries/streams are Kulik, Sui, Gamsi, Chitamati, Dak, Sudhani, Cheredhar etc. Atrayi is one of the major river of South Dinajpur.

Coochbihar

Major rivers of Coochbihar are Tista, Jaldhaka and Sankosh. Other rivers are Buri Tista, Sutunga, Gidhari, Dudhuya, Dolang, Torsha, Kaljani, Raidak etc.

Jalpaiguri

This district is full of rivers. Tista is the largest and important river and other important rivers are Chel, Dharala, Jaldhaka, Dudua, Torsha, Kaljani, Raidak, Sankosh.

Darjeeling

Every rivulets of the district flows to the two main rivers Tista and Mahananda. The rivers are Mechi, Balasona, Manjadhara and Changnala, Rangtangnala, Pancholen river, Mahanadi, Tista, Ranjonala, Reangnala, Chelnala, Bara rangeet, Jaldhaka etc.

RESULT AND DISCUSSION

From various references over 125 species of fish have so far been recorded from this area (Shaw and Shebbeare, 1937; Day, 1878; Sen, 1992; Talwar and Jhingran, 1991, Jayaram, 1999). Among them 75 major species are listed here. (Table 1).

Total number of fresh water fish species which are displayed in Bengal Natural History

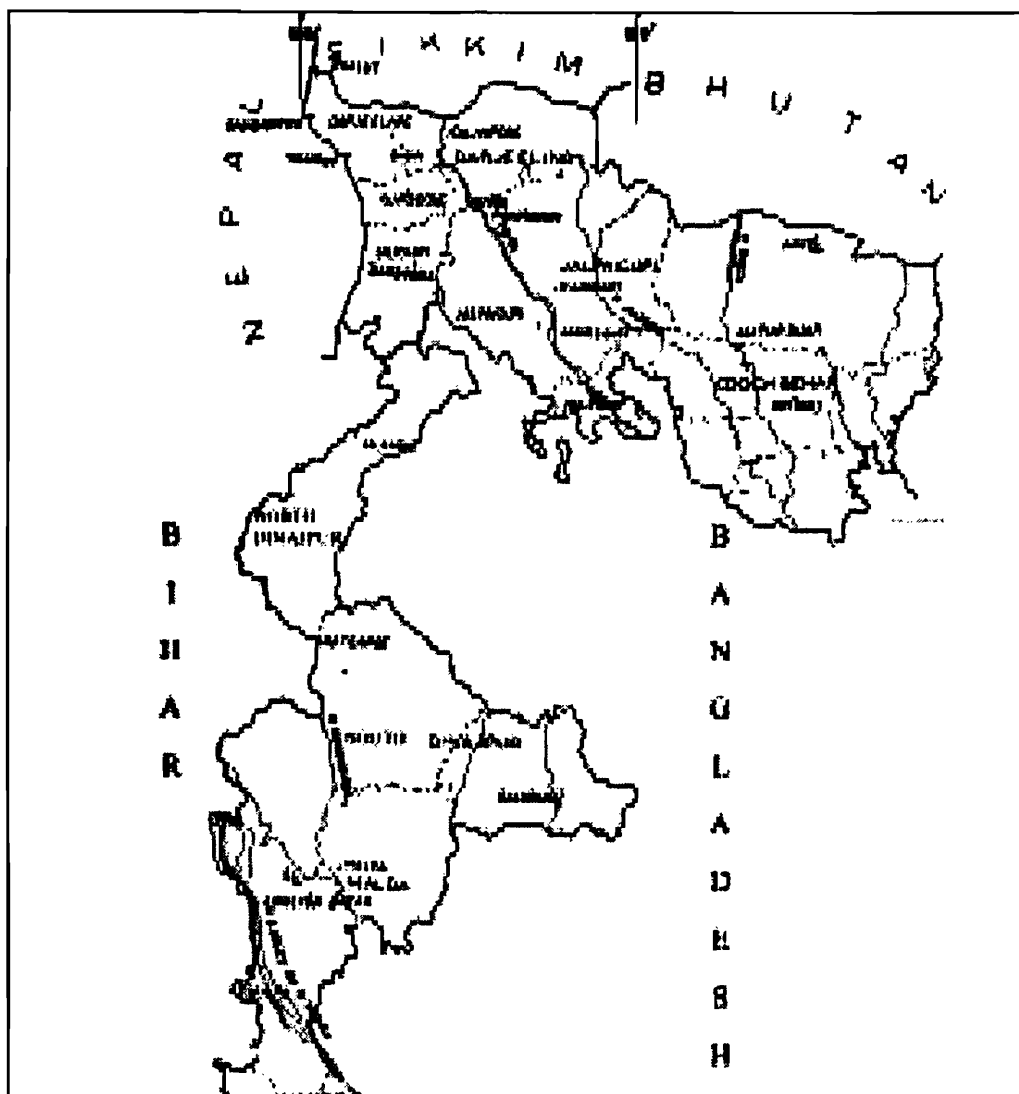


Fig. 1. Map showing rivers of North Bengal

Museum is 52. But these are not the exact reflection of the fish fauna of North Bengal. These specimen only provide the information about the freshwater fishes of North Bengal which were collected in the early phase of 20th century. But it can be said that many of them may have become endangered in present years and some are in threatened category. Among the fish specimen of BNHM, Darjeeling *Barilius vagra* and *Nandus nandus* may have become endangered in the north Bengal districts (According to Dept. of Fisheries, Govt. of West Bengal, April, 2005 and Report, Aquatech Popularisation Society, 2002). (Table 2 and 3).

From the recent references and market and field survey it can be noticed that some freshwater fish species may have become endangered in all the six districts of north Bengal likewise *Ompok pabda*, *Ompok pabo*,

Nandus nandus, *Rita rita*, *Olyra kempi*, *Xenentodon cancila*, *Esomus danricus*. A list was thus prepared to confirm the present status of the fishes of north Bengal. 18 common species of fishes were studied and their present status are given in the present study (Table 4).

From the above list we can find that although some species which are referred as endangered in the report of Aquatech popularisation society, 2002 are more or less abundant in North Bengal Districts such as *Notopterus notopterus*. *Raiamas bola* is abundant in South Dinajpur and Maldah. *Badis badis*, *Barilius vagra* and *Barilius barna* are also abundant in Uttar Dinajpur, South Dinajpur and Maldah. Which is not supporting the work of previous worker (Report of Aquatech Popularisation Society, 2002).

Table 1. Major Fish species of North Bengal

Sl. No.	Scientific Name	Local Name
1	<i>Oreinus molesworthii</i>	Asla (Nepalese), Moui (Lepcha)
2	<i>Schizothorax progastus</i>	Asla (Nepalese)
3	<i>Chela bacaila</i>	Chela (Bengali), Chilwa (Hindi)
4	<i>Laubuca laubuca</i>	
5	<i>Barilius barna</i>	Bhola (Bengali), Puti or Fakatar (Nepalese)
6	<i>Barilius bendelensis</i>	Joia (Bengali), Elengi (Mechi), Na-pagli (Rabha), Guder (Nepalese)
7	<i>Barilius(raiamas) bola</i>	Bhola (Bengali), Bhola (Nepalese), Nalaida (Mechi)
8	<i>Barilius shacra</i>	Koksa (Bengali), Na-born (Mechi)
9	<i>Barilius vagra</i>	Koksa (Bengali), Na-born (Mechi)
10	<i>Danio aequipinnatus</i>	Chebli (Bengali), Bhiti (Nepalese)
11	<i>Danio dangila</i>	Nipati (Bengali), Laupati (Mechi)
12	<i>Danio devario</i>	Bans-pata (Bengali), Laupati (Mechi)
13	<i>Danio rerio</i>	Anju (Bengali)
14	<i>Esomus danricus</i>	Dadhikha (Bengali), Danrika (Lower Bengal), Daranki (Rabha)
15	<i>Rasbora daniconius</i>	Dadhikha (Bengali), Danrika (Lower Bengal), Daranki (Rabha)
16	<i>Amblypharyngodon mola</i>	Mowa or mowka (Bengali-local), Mowrala (Southern Bengal), Elenga (Rabha)
17	<i>Aspidoparia jaya</i>	—
18	<i>Aspidoparia morar</i>	—
19	<i>Barbus chagunio</i>	Utta (Hindi), Dauka (Mechi)
20	<i>Barbus conchoni</i>	Kanchan-puti (Bengali)
21	<i>Barbus dukai</i>	Bhorkol or Buluk (Bengali), Katli (Nepalese), Mirpunja (Nepalese)
22	<i>Barbus phutunio</i>	Phutuni-punti (Bengali)
23	<i>Tor putitora</i>	Mahaseer or Mahasol (Bengali), Sor-maccha or Saar (Nepalese)
24	<i>Barbus sarana</i>	Kurti (Bengali), Sarana-punti (Lower Bengal), Na-Charan (Rabha)
25	<i>Barbus stigma</i>	Punti (Bengali), Puti-Krei (Mechi)
26	<i>Barbus ticto</i>	Tita-punti
27	<i>Barbus titas</i>	Punti (Bengali), Na-pitikri (Mechi), Na-Nishen (Rabha)
28	<i>Cirrhinus reba</i>	Kharkebata or Raig (Bengali), Rewa (Hindi), Na-bhangna (Mechi)
29	<i>Crossocheilus latia</i>	Gauma (Hindi)
30	<i>Garra gotyla</i>	Ghor-poia (Bengali), Budena (Nepalese), Momut (Lepcha), Chiltuka (Mechi)
31	<i>Labeo bata</i>	Bhangna (Bengali), Bhangna-bata (Lower Bengal), Lengsa (Mechi)

Table 1. Contd.

Sl. No.	Scientific Name	Local Name
32	<i>Labeo boga</i>	—
33	<i>Labeo dero</i>	Kursa or Katalkusi (Bengali), Gurdi or Goddi (Nepalese), Phunketia (Mechi)
34	<i>Labeo gonius</i>	Kurchi or Goni (Bengali)
35	<i>Rohtee cotio</i>	Mauwa (Bengali), Gurda (Hindi)
36	<i>Semiplotus semiplotus</i>	Badangi (Bengali), Chepti (Nepalese), Darangni (Mechi)
37	<i>Psilorhynchus balitora</i>	Ttari (Hindi)
38	<i>Psilorhynchus sucatio</i>	—
39	<i>Balitora brucei</i>	Tita-Kabri (Nepalese)
40	<i>Aborychthys elongatus</i>	—
41	<i>Acanthopthalmus pangia</i>	Pangya (Bengali)
42	<i>Botia dario</i>	Balabotia (Mechi)
43	<i>Lepidocephalichthys annandalei</i>	Poia (Bengali)
44	<i>Lepidocephalichthys guntea</i>	Poia (Bengali), Gunte (South Bengal), Na-mucha or Na-Machon (Rabha)
45	<i>Noemachilus beavani</i>	—
46	<i>Noemachilus botia</i>	Natwa (Hindi)
47	<i>Noemacheilus corica</i>	Khorika (Bengali)
48	<i>Noemachilus devdevi</i>	—
49	<i>Noemacheilus rupicola</i>	—
50	<i>Noemacheilus savona</i>	—
51	<i>Noemachilus scaturigina</i>	—
52	<i>Noemachilus shebbearei</i>	—
53	<i>Semiplotus gongota</i>	Ghor-poia (Bengali), Mushra (Mechi)
54	<i>Ompok pabda</i>	Pabda (Bengali), Tapugulinda (Mechi)
55	<i>Silurus cochinchinensis</i>	—
56	<i>Chaca chaca</i>	Chega (Bengali), Gageb (Mechi), Chega- bakau (Rabha)
57	<i>Mystus cavasius</i>	Tengra (Bengali)
58	<i>Mystus seenghala</i>	Air (Bengali), Ari or Pogal (Hindi)
59	<i>Mystus vittatus</i>	Tengra (Bengali), Na-tingna (Mechi), Tengana (Rabha)
60	<i>Olyra kempfi</i>	Bot-singhi (Bengali), Tara-ranji (Mechi)
61	<i>Bagarius bagarius</i>	Bagha-ar (Bengali), Gaunch (Hindi)
62	<i>Erethistes elongatus</i>	Bot-tangra (Bengali), Na-taram (Rabha)
63	<i>Erethistes hara</i>	Kutakanti or kurkati (Bengali), Rkheb (Mechi), Na-palthong (Rabha)
64	<i>Euchiloglanis hodgarti</i>	Titkabri (Nepalese)
65	<i>Glyptothorax telchitta</i>	—
66	<i>Laguvia shawi</i>	—
67	<i>Pseudecheneis sulcatus</i>	Kabri (Nepalese)

Table 1. Contd.

Sl. No.	Scientific Name	Local Name
68	<i>Xenentodon cancila</i>	Kankle or Kakhya (Bengali), Thona (In the Terai), Kawa (Hindi), Kankila (Rabha)
69	<i>Dorychthys deocata</i>	—
70	<i>Ambassis nama</i>	Chanda (Bengali), Nama-Chanda (Lower Bengal)
71	<i>Badis badis</i>	Bot-Koi (Bengali), Bhedo or bheda (lower Bengal)
72	<i>Ctenops nobilis</i>	—
73	<i>Glossogobius giuris</i>	Bhalia (Bengali), Beley (Southern Bengal), Bhal-Chata (Rabha), Bvhula (Hindi)
74	<i>Nandus nandus</i>	Dudhurkhal (Bengali), Nandus (Lower Bengal), Thota or Na-tika (Mehi)
75	<i>Trichogaster fasciatus</i>	Chopra, Khalisa, Chel (Bengali), Na-prap (Rabha)

Table 2. Names of the Displayed Fish Specimen in Bengal Natural History Museum, Darjeeling

1. <i>Ophicephalus amphibious</i> .	27. <i>Mystus cavasius</i> .
2. <i>Mystus seenghola</i> .	28. <i>Barbus putitora</i>
3. <i>Ctenops nobilis</i> .	29. <i>Cirrhina mrigala</i> .
4. <i>Ambassis noma</i> .	30. <i>Ophiocephalous amphibolous</i> .
5. <i>Barilius vagra</i> .	31. <i>Ophiocephalous merulius</i> .
6. <i>Barbus comhonius</i> .	32. <i>Clarius batrachus</i> .
7. <i>Phyncobdella aculeata</i> .	33. <i>Nandus nandus</i> .
8. <i>Trichogaster fasciatus</i> .	34. <i>Labeo nandina</i> .
9. <i>Danio equipinnatus</i> .	35. <i>Barbus sarana</i> .
10. <i>Labeo nandina</i> .	36. <i>Heteropneustus fossilis</i> .
11. <i>Mastacembalus pancalus</i> .	37. <i>Mastacambelus armatus</i> .
12. <i>Ophicephalus striatus</i>	38. <i>Schizothorax progastus</i> .
13. <i>Amphipnous cuchia</i> .	39. <i>Barilius tileo</i> (Hamilton).
14. <i>Catla catla</i> .	40. <i>Chaca chaca</i> .
15. <i>Begarius begarius</i> .(Hamilton)	41. <i>Challichrous pabda</i> .
16. <i>Nemachelius lobia</i> .	42. <i>Siser rhabdophorus</i> .
17. <i>Gossochelus lobia</i> .	43. <i>Glyptothorax lineatus</i> .(Day).
18. <i>Tetodon cutcutia</i> .	44. <i>Somiloptas gongota</i> .
19. <i>Homaloptera brucei</i> .	45. <i>Xenotodon cancila</i> .(Hamilton).
20. <i>Notopterus notopterus</i> .	46. <i>Puntnis chola</i> .(Hamilton).
21. <i>Barilius bendelisis</i> .	47. <i>Aspidoparia morar</i> .
22. <i>Darychthys deocata</i> (Hamilton)	48. <i>Pseudotropins murius</i> .
23. <i>Channa orientalis</i>	49. <i>Garra gotyla</i> .
24. <i>Laubuca laubuca</i> .	50. <i>Gassochelus latia</i> .
25. <i>Glyptothorax horai</i> .	51. <i>Basilus tileo</i> .
26. <i>Barbus liasochelius</i> .	52. <i>Labeo dora</i> .

Table 3. Endangered/threatened fish species of North Bengal (Report, Aquatech Popularisation Society, 2002)

Critically Endangered	Endangered	Vulnerable	Near Threatened
<i>Labeo gonius</i>	<i>Labeo pangusia</i>	<i>Schizothoraichthys progastus</i>	<i>Mystus cavasius</i>
<i>Nandus nandus</i>	<i>Labeo dero</i>	<i>Danio dangila</i>	<i>Labeo bata</i>
<i>Aplocheilichthys panchax</i>	<i>Tor tor</i>	<i>Garra gotyla</i>	
<i>Tor putitora</i>	<i>Barilius barna</i>	<i>Chaca chaca</i>	
<i>Badis badis</i>	<i>Raiamas bola</i>	<i>Balitora brucei</i>	
<i>Cyprinion semiplotum</i>	<i>Barilius vagra</i>	<i>Botia dario</i>	
	<i>Neolissocheilus hexagonalepis</i>	<i>Mystus vittatus</i>	
	<i>Danio devario</i>	<i>Ailia coilia</i>	
	<i>Olyra kempfi</i>	<i>Rita rita</i>	
	<i>Esomus danricus</i>	<i>Gududsia chapra</i>	
	<i>Puntius sarana</i>	<i>Amblypharyngodon mola</i>	
	<i>Labeo calbasu</i>		
	<i>Ompok pabda</i>		
	<i>Ompok pabo</i>		
	<i>Bagarius bagarius</i>		
	<i>Notopterus notopterus</i>		
	<i>Amphipnous cuchia</i>		
	<i>Mastacembelus armatus</i>		
	<i>Xenotodon cancila</i>		
	<i>Rhinomugil corsula</i>		
	<i>Batasio batasio</i>		

Table 4. List of Probable Endangered Fish Species in North Bengal Districts

Sl. No.	Scientific name of the fishes	Districts					
		Darjeeling	Jalpaiguri	Coochbihar	North Dinajpur	South Dinajpur	Maldah
1	<i>Tor putitora</i>	—	—	—	—	—	+
2	<i>Badis badis</i>	—	—	—	+	+	+
3	<i>Labeo pangusia</i>	—	—	—	—	—	+
4	<i>Tor tor</i>	—	—	—	—	+	+
5	<i>Barilius barna</i>	—	—	—	+	+	+
6	<i>Barilius vagra</i>	—	—	—	+	+	+
7	<i>Raiamas bola</i>	—	—	—	—	+	+
8	<i>Balitora brucei</i>	—	—	—	—	—	—
9	<i>Garra gotyla</i>	—	—	—	+	+	+
10	<i>Ompok pabda</i>	—	—	—	—	—	—
11	<i>Ompok pabo</i>	—	—	—	—	—	—

Table 4. Contd.

Sl. No.	Scientific name of the fishes	Districts					
		Darjeeling	Jalpaiguri	Coochbihar	North Dinajpur	South Dinajpur	Maldah
12	<i>Nandus nandus</i>	–	–	–	–	–	–
13	<i>Rita rita</i>	–	–	–	–	–	–
14	<i>Olyra kempi</i>	–	–	–	–	–	–
15	<i>Xenentodon cancila</i>	–	–	–	–	–	–
16	<i>Notopterus notopterus</i>	+	+	+	–	–	–
17	<i>Gudusia chapra</i>	+	+	+	–	–	+
18	<i>Esomus danricus</i>	–	–	–	–	–	–

Abundant + Endangered –

Reviewing the previous work and thorough investigation during the project work a significant decline of fish fauna in North Bengal districts is noticed and main reasons for disappearance of these valuable fish fauna may be due to indiscriminate over exploitation of different species from different rivers of North Bengal. During extensive fishing in breeding season a loss of spawning fish is also occurred which is one of the major cause for loss of future population. Destruction of breeding ground in the river Tista has occurred due to the consecutive flood which is one of the major causes behind the declination of fish fauna in North Bengal.

Deforestation has given rise enormous soil erosion. As a result landslides and flood has become regular incident which causes a severe change in ecological condition of habitat causing destruction of fish population either through their migration or mortality.

During the survey it was revealed that in North Bengal districts *Nandus nandus* is practically extinct from natural water after dreadful attack of EUDS in 1968 (Report. Aquatech Popularisation Society, 2002).

Survey of rivers of North Bengal proves a severe contamination of pollutants and discharged chemicals from different source

point through direct or indirect inlets (Sengupta, 1978).

Fish conservation attitude has been changed internationally and several initiatives have come (Williams and Miller, 1990) with captive breeding and rearing of rare fish.

Conservation status of India's freshwater fishes, especially in rainforest streams in Western Ghat and Himalayas is poor. Despite the discovery of several new species to date, the rate of increase of pressure on this fauna is high that extinction may be expected even before discovery.

From the present study following measures are suggested for conservation of enriched fish fauna of North Bengal. Immediately different inletting points in different rivers should be closed or scientifically regulated, use of chemical pesticides should be banned in agricultural fields and rational use of less harmful pesticides should be recommended as early as possible, natural breeding ground of several fish species should be restored immediately. Furthermore, awareness among local inhabitants about the value of fish and importance of their conservation is the most primary need to save rivers and their valuable fish fauna of North Bengal.

LITERATURE CITED

- DAY, F. 1878. *The Fishes of India* : being a Natural History of the Fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon. Reproduced in 1958. London, William Dowson and Sons.
- GROOBRIDGE, B. 1992. *Global biodiversity* : status of the earth's living resources. World Conservation Monitoring Centre. London. Chapman & Hall. : 576-578.
- JAYARAM, K. C. 1999. *The Freshwater Fishes of the Indian Region*. Delhi, Narendra Publishing House.
- REPORT. 2002. Study of Diminishing trend in Species Diversity of Fish in West Bengal for evolving Conservation strategies. *Aquatech Popularisation Society*. Kolkata, : 106.
- SEN, T. K. 1992. *Fauna of West Bengal Freshwater Fishes*. Calcutta. Zoological Survey of India.
- SENGUPTA, R. 1978. Status of pisciculture in the hill areas of Darjeeling. *Fisheries Education Bull. CIFE*.
- SHAW, G.E. and SHEBBEARE, E. O. 1937. The fishes of Northern Bengal. *J. roy. Asiat. Soc. Beng. Sci.* Calcutta, 3.
- SINHA, M. 1994. Threatened Coldwater Fishes of North Eastern Region of India. In : *Threatened fishes of India* (Eds. P.V. Dehadrai, P. Das and S.R. Verma), Natcon Publication, 4 : 173-176.
- TALWAR, P. K. and JHINGRAN, A. G. 1991. *Inland Fishes*. Vol-1, 2, Oxford & Publishing Co. Pvt. Ltd. 1062p.
- WILLIAMS, J. E and MILLER, R. R. 1990. Conservation status of the North American fish fauna in fresh water. *J. Fish Biol.* 37 : 79-85.

DIVERSITY OF INSECT COMMUNITY IN FRESH WATER WETLANDS OF WEST BENGAL, INDIA

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ABSTRACT

Wetlands offer ample micro-niches to diverse insect groups, which provide significant support to the aquatic food web in this particular ecosystem. Study of diversity, distribution and density of entomofauna in freshwater wetlands of West Bengal particularly in southern district of the state which revealed a total of 120 species of insects belonging to 5 major orders and 21 families, occurring in this special ecosystem. The population density of the order Ephemeroptera is highest in premonsoon period, where as orders Odonata, Coleoptera and Diptera remain highest during post monsoon. The only order Hemiptera actually did not showed any definite seasonal fluctuation. The data on diversity and seasonal occurrence revealed that the coleopteran diversity is highest while Ephemeropterans were lowest. Of the total species present in terms of density Diptera was highest (0.24–516/m²) and lowest Ephemeroptera (0–9.18/m²). The distribution in four microhabitats shows the existence of maximum number of families in weedy area, along with aquatic vegetation and muddy areas near the edge of the wetlands.

Keywords : Insect diversity, freshwater wetland.

INTRODUCTION

Wetlands are among the most important ecosystems on Earth. They function as the downstream receivers of water and waste from both natural and human sources. They have been called “Biological supermarkets” because of the extensive food chain and rich biodiversity that they support. The shallow depth of freshwater wetlands supports suitable growth of macrophytes and offers ample micro-niches to diverse insect groups. From the economic point of view the aquatic insects of freshwater wetlands are important for their significant role in aquaculture (Jhingran, 1997) and serve as a reliable indicator of water quality. The aquatic insects provide significant support to the aquatic food web in wetland ecosystem and are responsible for the sustenance of cultivable fishes and other wildlife (Singh and Ray, 1991). Their composition, abundance and distribution provide an index of the ecosystem emphasizing

on the trophic structure, water quality and eutrophication of the eco-system (Wiederholm, 1980 and Lang, 1985).

In India, so far investigations have been made on the diversity, both qualitative and quantitative aspects of freshwater aquatic life specially macroinvertebrates by Hora (1933); Govind (1969); Munawar (1970); Gupta (1981; 1983); Gupta and Pant (1986); Roy *et al.* (1988); Kulshrestha *et al.* (1988) and Singh and Roy (1991). But less attention has been paid on the study of insects of wetlands of West Bengal except Datta and Sarangi (1980); Mitra & Kumar (1988); De (1990); Bhattacharya and Gupta (1991), Ghosh and Chattopadhyay (1990; 1994) and Nandi *et al.* (1993); Bhattacharya (1998); Pal *et al.* (1998). Hence, the present study has been taken on the species composition, diversity and abundance of aquatic insect of freshwater wetlands of West Bengal. Besides their faunal account other ecological information

particularly of habitat preference of these insects were also studied. The entire study was conducted in seven districts of West Bengal viz. Kolkata, North 24 Parganas, South 24 Parganas, Nadia, Hoogly, Purba Midnapur and Paschim Midnapur.

MATERIAL AND METHODS

Surveys were made in lakes and ponds and other wetlands areas at every fortnight intervals. For collecting the specimens net (0.5m²) made of nylon cloth (75-80 mesh/cm²), D-Shaped hauling net and a metal box type of sampler (20×20×40 cm³) were used.

Qualitative studies were made to explore the faunal diversity of these wetlands. Quantitative studies were done using the metal box type sampler. The collected materials were assorted after filtering through standard sieve no.40. The insect specimens were preserved in 70 percent alcohol or mounted in dry condition for laboratory studies. Total surveys were conducted during the year 1998 to 2000, with special emphasis was given in Premonsoon, Monsoon and Postmonsoon periods.

RESULTS AND DISCUSSION

Bhattacharya and Gupta (1991) recorded altogether 99 species from wetlands of West Bengal. Further 21 species is added from the study of earlier mentioned wetlands of West Bengal. Thus it makes a total 120 species of insects so far known from West Bengal. Only 5 orders viz. Ephemeroptera, Odonata, Hemiptera, Coleoptera, and Diptera were represented as wetland inhabiting insects. Out of these, Coleoptera comprising the largest number of 55 species belonging to 4 families followed by Hemipterans representing 39 species of 9 families. The Odonates and Dipterans are represented by 14 and 9 species respectively, distributed under 3 and 4 families, respectively and the Ephemeroptera has so far been recorded by only 3 species under one family. A total of 120 species were distributed under 5 orders, 69 genera and 21 families.

The qualitative study revealed the insects of

total 120 species Ephemeroptera 8.71%; Odonata 18.66%; Hemiptera 33.39%; Coleoptera 28.87%; Diptera 10.37%, respectively. (Table-1).

There is considerable seasonal variations in abundance and percentage composition with maximum population in post monsoon (October-January) and minimum in monsoon (June-September) for Coleoptera, Diptera and Odonata, while maximum in pre-monsoon (February-May) and minimum in monsoon for Ephemeroptera, but Hemiptera have no striking seasonal fluctuations. (Table-2). The order wise analysis revealed that Ephemeroptera represented by only 3 species with the density (no/m²) fluctuating between 0-9.18/m² (0-0.27%), but increasing pre-monsoon period. Odonata comprises a total of 14 species. Where *Rhyothemis variegata*, *Brachythemis contaminata*, *Trithemis pallidinervis* and *Ischuura senegalensis* are most dominant. The abundance of Odonates was maximum in post-monsoon, and minimum in monsoon. Odonate density varied from 1.2-12.09/m² (0.05%-0.27%). Hemipterans are represented by 39 species of where *Diplonychus annulatum*, *Ranatra sordidula*, *Anisops sardia*, *Limnogonus nitius* and *Micronecta scutellaris* are most dominant. Their density varied from 3.21-18.63 (0.15%-0.59%), showing no particular trend in seasonal fluctuations. Coleoptera comprising of a total of 55 species of where *Amphiops pedestris*, *Hydrocoptus subvittulus*, *Laccophilus anticotus*, *Enochrus escuriens*, *Sternolophus rufipes*, *Amphiops pedestris* and *Canthydrus laetabilis* are most dominant. Coleoptera density varied from 0.52-25.51/m² (0.01%-0.42%). Among the 9 dipteran species, Chironomid larvae were recorded as abundant. Its number was observed maximum in post monsoon and minimum in monsoon. The population density varied from 0.24-516/m² (0.03%-11.12%).

Table-3 represents the distribution of the freshwater wetland inhabiting insect's families in four microhabitats, namely, weedy areas, limnatic or open water at certain depth, surface film and muddy bottom or muddy areas near the edges of wetlands. The quantitative analysis of the insects of the study site indicates that

Table-1. Qualitative collection of insect' species from different districts of West Bengal

	Kolkata	24 PGS(N)	24 PGS(S)	Nadia	Hoogly	Midnapur (purba)	Midnapur (pachim)
Class INSECTS							
Order EPHEMEROPTERA							
Family BAETIDAE							
1. <i>Coleon bengalense</i> Kimminsi	–	+	+	–	+	+	++
2. <i>Coleon kimminsi</i> Hubbard	+	+	+	+	–	–	+
3. <i>Coleon bicolor</i> Kimminsi	–	+	+	+	+	–	–
Order ODONATA							
Family LIBELLULIDAE							
1. <i>Brachythemis contaminata</i> Fabricius	++	+++	++	++	+++	+++	++
2. <i>Crocothemis servilia</i> Drury	++	+	+	+	–	–	–
3. <i>Diplacodes trivialis</i> Rambur	+	+	+	+	+	+	++
4. <i>Neurothemis tullia</i> Drury	+	+	+	+	+	+	++
5. <i>Orthetrum sobina</i> Drury	–	–	–	+	++	++	++
6. <i>Potomarcha obscura</i> Rambur	–	–	–	–	++	+	+
7. <i>Rhyothemis variegata</i> Linnaeus	++	++	++	+		+++	+
8. <i>Trithemis pallidinervis</i> Kirby	+++	++	++	+	++	++	++
9. <i>Zyxomma petiolatum</i> Rambur	++	–	–	+	+	+	+
Family COENAGRIONIDAE							
10. <i>Agriocnemis pygmaea</i> Rambur	+	–	–	+	++	++	+
11. <i>Ceriagrion coromandelianum</i> Fabricius	+	+	+	+	+	+	+
12. <i>Ischnura senegalensis</i> Rambur	++	++	++	++	++	++	–
Family GOMPHIDAE							
13. <i>Ictinogoamphus rapax</i> Rambur	–	–	–	+	+	+	++
14. <i>Mesogomphus lineatus</i> Selys	–	–	–	–	++	+	++
Order HEMIPTERA							
Family BELOSTOMATIDAE							
1. <i>Belostoma indica</i> Distant	–	–	–	+	+	–	+
2. <i>Diplonychus rusticum</i> Fabricius	+	+	+	++	++	+	+
3. <i>Diplonychus molestum</i> Duf.	+	+	+	+	–	–	–
4. <i>Diplonychus annulatum</i> Fabricius	+++	+++	++	+++	+++	+++	+++
Family GERRIDAE							
5. <i>Limnogonus fossarum</i> Fabricius	+	++	++	+	+	++	++
6. <i>Limnogonus nitidus</i> Mayr	+++	++	+++	++	++	+++	++
7. <i>Limnogonus parvulus</i> Stal	+	+	+	+	+	+	+
8. <i>Limnogonus</i> sp.	+	+	+	–	+	+	+
9. <i>Neogerris parvula</i> Stal	+++	++	+	+	–	+	–
10. <i>Rhagadotarsus kraepelini</i> Breddin	–	+	+	–	+	+	+
Family HYDROMETRIDAE							
11. <i>Hydrometra</i> sp.	+	+	+	+	–	–	+
12. <i>Hydrometra vittata</i> Stal	++	++	++	++	++	++	++
Family NEPIDAE							
13. <i>Laccotrephes griseus</i> Guerin	+	++	++	++	+	+	+

Table-1. Contd.

	Kolkata	24 PGS(N)	24 PGS(S)	Nadia	Hoogly	Midnapur (purba)	Midnapur (pachim)
14. <i>Laccotrephes rubber</i> Linnaeus	+	+	+	-	+	-	-
15. <i>Nepa apiculata</i> Uhler	-	+	-	-	+	+	+
16. <i>Ranatra sordidula</i> Dohrn	+++	+++	++	+++	+++	+++	++
17. <i>Ranatra filiformia</i> Fabricius	++	++	++	++	++	++	+
18. <i>Ranatra elongate</i> Fabricius	+	+	+	-	+	+	+
Family NOTONECTIDAE							
19. <i>Anisops breddini</i> Krikadly	+	+++	+++	++	+++	+++	+
20. <i>Anisops bouvieri</i> Krikadly	+	+	+	+	+	+	+
21. <i>Anisops sardea</i> Henrich & Shaffer	++	+++	++	++	+++	+++	+++
22. <i>Anisops batilliformis</i> Lundblad	+	+	+	+	+	+	+
23. <i>Anisops pieberi</i> Krikadly	-	-	+	+	++	++	+
24. <i>Nychia</i> sp.	++	+	+++	+	+	+	+
Family PLEIDAE							
25. <i>Plea frontalis</i> Fieb.	+++	++	++	+	+	+	+
26. <i>Plea</i> sp.	+	+	+	-	-	-	-
Family VELIDAE							
27. <i>Microvelia vittigera</i> Sharp	++	+	+	+	++	++	++
28. <i>Microvelia albomaculata</i> Distant	+	+	+	++	+	-	-
29. <i>Microvelia diluta</i> Distant	-	-	-	+	+	+	+
Family CORIXIDAE							
30. <i>Corixa hieroglyphica</i> Duf.	++	+	+	+	+	-	-
31. <i>Corixa promontoria</i> Distant	-	-	+	-	+	+	+
32. <i>Micronecta haliplodes</i> Horvath	++	+	+	+	+	+	+
33. <i>Micronecta scutellaris</i> Stal	+++++	+++	+++	++	++	+++	++
34. <i>Micronecta striata</i> Distant	++	+	++	++	++	+	+
35. <i>Micronecta siva</i> Kirk	-	-	-	+	+	+	+
36. <i>Micronecta merops</i> Distant	+	-	-	+	+	+	+
37. <i>Micronecta proba</i> Distant	-	-	+	-	+	+	+
38. <i>Synaptonecta</i> sp.	+	-	-	+	+	+	+
Family MESOVELLIDAE							
39. <i>Mesovelia</i> sp.	++	++	+	-	++	+	+
Order COLEOPTERA							
Family DYTISCIDAE							
1. <i>Clypeodytes</i> sp.	+	-	-	+	+	+	+
2. <i>Canthydrus laetabilis</i> Walker	+++	++	++	++	+++	+++	+++
3. <i>Canthydrus luctuosus</i> Aube	++	+	++	+	++	++	++
4. <i>Canthydrus morsbachi</i> Walker	-	+	+	+	+	+	+
5. <i>Canthydrus</i> sp.	-	-	-	+	+	+	+
6. <i>Cybister limbatus</i> Fabricius	-	-	-	+	+	+	+
7. <i>Cybister confusus</i> Sharp	-	-	+	+	-	+	+
8. <i>Cybister tripunctatus</i> Sharp	+	+	+	+	+	+	+
9. <i>Cybister regulosus</i> Redt.	-	-	+	-	+	+	+

Table-1. Contd.

	Kolkata	24 PGS(N)	24 PGS(S)	Nadia	Hoogly	Midnapur (purba)	Midnapur (pachim)
10. <i>Dytiscus</i> sp.	+	+	+	+	-	-	-
11. <i>Eretes sticticus</i> Linnaeus	-	+	+	+	+	+	+
12. <i>Guignotus flammulatus</i> Sharp	+	++	++	+	++	++	+
13. <i>Guignotus pendjabensis</i> Guignot	+++	++	+	+	+	+	+
14. <i>Guignotus</i> sp.	+	+	+	+	-	-	-
15. <i>Hydraticus fabricii</i> Macleay	+	+	+	+	-	-	-
16. <i>Hydrovatus bonvouloiri</i> Sharp	+	++	++	+	+	+	+
17. <i>Hydrovatus confertus</i> Sharp	++	-	+	++	+	++	++
18. <i>Hydrocoptus subvittulus</i> Mot.	++	++	+++	+++	+++	+++	+
19. <i>Hydaticus Luezonicus</i> Abeu	-	-	+	+	+	+	++
20. <i>Hydaticus ricini</i> Macley	++	+	+	-	+	+	++
21. <i>Hydroporina</i> sp.	-	-	-	+	+	+	++
22. <i>Hyphydrus renardi</i> Severin	+++	+	+	-	-	+	+
23. <i>Hyphidrus indicus</i> Sharp	+	-	+	+	+	+	+
24. <i>Laccophilus anticatus</i> Sharp	-	-	-	+	++	++	++
25. <i>Laccophilus parvulus</i> Aube	++	+	-	+	-	-	-
26. <i>Laccophilus anticatus</i> Sharp	+++	+	++	++	++	+	+
27. <i>Laccophilus chinensis</i> Boh.	-	-	+	+	++	-	-
28. <i>Sandracottus festivus</i> Illinger	-	-	-	+	+	+	+
29. <i>Uvarus quadrilineatus</i> Zimmermann	++	+	+	+	+	+	+
Family HYDROPHILIDAE							
30. <i>Amphiops pedestris</i> Sharp	+++	++++	+++	+++	+++	++	++
31. <i>Amphiops</i> sp.	+++	++	++	++	+	++	++
32. <i>Berosus indicus</i> Mots	++	+	+	-	+	-	-
33. <i>Berosus putchellus</i> Macley	-	-	-	-	+	+	+
34. <i>Coelostoma</i> sp.	-	-	+	+	-	-	-
35. <i>Clivina</i> sp.	-	-	-	-	+	+	+
36. <i>Enocrus escuriens</i> Walker	++	++	++	++	+++	+++	+++
37. <i>Enocrus</i> sp.	-	-	-	+	+	-	-
38. <i>Globeria</i> sp.	-	-	+	+	-	-	-
39. <i>Hydrophilus indicus</i> Bedel	++	+	-	+	-	+	+
40. <i>Hydrophilus olivaceus</i> Fabricius	-	+	+	+	-	+	+
41. <i>Hydraena</i> sp.	+	+	-	-	-	-	-
42. <i>Helochaes anchoralis</i> Sharp	++	+	+	-	+	+	+
43. <i>Helochaes crenatus</i> Sharp	-	+	-	+	-	+	+
44. <i>Helochaes</i> sp.	-	-	+	-	+	+	+
45. <i>Laceobius</i> sp.	-	-	-	+	+	+	+
46. <i>Regimbartia attenuate</i> Fabricius	++	+	+	-	+	-	-
47. <i>Regimbartia attenuate</i> Fabricius	-	+	+	+	-	-	-
48. <i>Sternolophus rufipes</i> Fabricius	++	++	+++	+++	+++	+++	++
49. <i>Uloma</i> sp.	-	+	+	-	-	+	+

Table-1. Contd.

	Kolkata	24 PGS(N)	24 PGS(S)	Nadia	Hoogly	Midnapur (purba)	Midnapur (pachim)
Family HALIPLIDAE							
50. <i>Haliphus angustifrons</i> Fabricius	++	+	+	+	–	+	+
51. <i>Haliphus pulchellus</i> Fabricius	–	–	+	–	++	+	+
Family GYRINIDAE							
52. <i>Dineutes unidentatus</i> Fabricius	++	++	++	++	+	+	+
53. <i>Dineutes spinosus</i> Fabricius	+	+	+	+	++	++	++
54. <i>Dineutes</i> sp.	+	+	–	–	+	+	+
55. <i>Orectochilus productus</i> Wied	++	+	+	+	++	+	+
Order DIPTERA							
Family CHIRONOMIDAE							
1. <i>Chironomus circumdatus</i> Kieffer	++++	+++	+++	+++	++	++	+
2. <i>Chironomus</i> sp.	++	+++	+++	+	+	++	+
3. <i>Tanytarsus</i> sp.	++	++	–	+	+	+	+
4. <i>Monopelopia</i> sp.	–	–	–	–	–	+	+
Family CULICIDAE							
5. <i>Aedes</i> sp.	+	+	+	+	+	–	–
6. <i>Anopheles</i> sp.	++	++	++	+	++	+	+
7. <i>Culex</i> sp.	+	+	+	+	+	+	+
Family STRATIOMYIDAE							
8. <i>Odontomyia</i> sp.	+	+	+	–	+	+	+
Family EPIDRIDAE							
9. <i>Brachydeutera longipes</i> Hendl	–	–	–	+	+	+	++
Total (120 species)							

over 26% of the total insect species occur in association with aquatic weeds. Occurrence of insect families in the diverse microhabitat reveals that maximum insect families occupy the weedy areas where they are found in trashes tangles of the aquatic vegetation. Little over 14% are restricted on the surface film of water bodies; over 13% and 12% of the total species occupy the limnatic and muddy areas, respectively.

It appears that the macrophytes provide suitable food and shelter for insects. (Mc. Lachlan, 1975; Soszka, 1975). At the same time the soft clay soil with decaying leaves and other organic matter in the bottom soil influences the growth and propagation of various benthic animals (Bose and Lakra, 1994). Bose and Lakra *op. cit.* also reported that the maximum number of most of the species of organism in aquatic

ecosystem occurred after rain, which also corroborates our finding. During pre-monsoon insects population showed a decreasing trend due to their reduced rate of multiplication. Majority of the insects group except Odonate showed least population in monsoon probably because of frequent and heavy rainfall between June and September. Heavy rainfall and high water discharge displace or destroy the microhabitats of these insects; causing a drastic reduction in their number.

Loden (1974) suggested that chironomid larvae can be used as pollution indicator. Mahadevan and Krishnaswamy (1984) have argued that relatively high population size *Chironomus* sp. is the best biological indicator of pollution. In the present investigation similar features were observed particularly in North 24 Parganas, South 24 Parganas and Kolkata than

Table-2. Seasonal abundance (Number/m²) and percentage (%) Distribution of different Groups in different districts.

Insect Group	Kolkata			24Parganas (North)			24Parganas (South)			Nadia			Hoogly			Midnapur (Purba)			Midnapur (Paschim)		
	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post
Diptera	222.0(8.12%)	44.4(2.08%)	516(11.12%)	115.72(4.46%)	7.5(0.13%)	488.4(10.22%)	109.03(0.41%)	5.24(0.06%)	386.98(8.78%)	4.89(0.12%)	2.46(0.09%)	12.76(0.23%)	15(0.42%)	1.24(0.03%)	123.12(4.81%)	18.32(0.38%)	14.89(0.31%)	56.37(1.12%)	57(1.13%)	12.12(0.03%)	117.7(3.12%)
	10.09(8.12%)	6.22(0.26%)	11.39(0.24%)	3.52(0.62%)	0.52(0.001%)	7.55(0.18%)	19.16(0.4%)	9.87(0.25%)	21.31(0.59%)	13.48(0.48%)	7.86(0.23%)	18.87(0.41%)	11.89(0.27%)	6.22(0.24%)	14.87(0.29%)	5.89(0.08%)	1.22(0.02%)	7.45(0.13%)	10.11(0.31%)	8.47(0.19%)	10.56(0.24%)
	8.78(0.21%)	11.21(0.35%)	18.12(0.31%)	9.04(0.22%)	16.43(0.3%)	18.63(0.38%)	11.02(0.31%)	10.41(0.26%)	16.5(0.33%)	15.27(0.32%)	11.12(0.31%)	17.56(0.37%)	7.23(0.18%)	9.51(0.26%)	11.09(0.32%)	10.23(0.24%)	16.37(0.47%)	18.56(0.59%)	15.31(0.31%)	9.87(0.23%)	17.89(0.37%)
Coleoptera	2.31(0.08%)	1.2(0.05%)	5.8(0.12%)	9.74(0.24%)	7.09(0.14%)	12.09(0.27%)	8.29(0.23%)	7.21(0.14%)	10.28(0.26%)	7.86(0.11%)	5.26(0.12%)	11.23(0.32%)	8.26(0.23%)	5.89(0.13%)	9.87(0.23%)	5.67(0.12%)	3.07(0.12%)	10.32(0.23%)	6.59(0.15%)	4.56(0.13%)	9.87(0.25%)
	1.12(0.04%)	0.34(0.01%)	0.89(0.02%)	0.89(0.02%)	0.26(0.005)	0.76(0.02%)	0.76(0.02%)	0.28(0.005%)	0.58(0.01%)	9.18(0.26%)	—	0.61(0.002%)	6.35(0.21%)	—	0.02(0.002%)	7.86(0.13%)	—	0.01(0.02%)	5.67(0.18%)	—	0.03(0.002%)
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ephemeroptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Pre. — Premonsoon; Mon. — Monsoon; Post. — Postmonsoon

Table-3. Distribution of Insect families in four microhabitats of freshwater wetlands of West Bengal

Weedy areas/along with aquatic vegetation		Bottom mud or muddy areas near the edge		Limnatic or open water at certain depth		Surface film of water	
Order	Families	Order	Families	Order	Families	Order	Families
Hemiptera	Belostomatidae Pleidae Nepidae Hydrometridae Microvelidae Mesovelidae	Hemiptera	Nepidae	Hemiptera	Corixidae Nepidae Pleidae Notonectidae	Hemiptera	Gerridae Hydrometridea Microvelidae Mesovelidae
Coleoptera	Dytiscidae Hydrophilidae Curculionidae	Coleoptera	Hydrophilidae	Coleoptera	Belostomatidae Dytiscidae Hydrophilidae Sperchelidae	Coleoptera	Gyrinidae
Odonata	Aeshnidae Coenagrionidae	Orthoptera	Gryllotalpidae				
Ephemeroptera	Bactidae						
Diptera	Heleidae	Diptera	Chironomidae Muscidae Culicidae			Diptera	
		Odonata	Libelulidae Tabanidae			Culicidae Stratiomyidae	

other district wetlands, possibly due to the fact that water pollution is relatively higher in wetlands of the said districts.

Thus, from the present investigation it is revealed that the insect diversity become highest in post monsoon and lowest in monsoon season. The insect abundance is presumable directly related to the seasonal appearances and disappearances of macro-vegetation of wetland

and also with the nature of water, bottom soil and rain.

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LITERATURE CITED

- BHATTACHARYA, D.K. and GUPTA, B. 1991. Fresh Water Wetland Inhabiting Insects of West Bengal. *Environment & Ecology*, 9(4) : 995-998.
- BOSE, S.K. and LAKRA, M.P. 1994. Studies on the Macro zoo-benthos of two fresh water ponds of Ranchi. *J. Freshwat. Biol.*, 6(2) : 135-142.
- BHATTACHARYA, D.K. 1998. Insect Fauna Associated with Large Water hyacinth in Fresh Water Wetlands of West Bengal. *Proceedings of the National Seminar on Environmental Biology*, Viswa Bharati University, April 03-05, 1998 : 145-148.
- DATTA, N. C. and SARANGI, N. 1980. Preliminary study on the macro benthos of a brackish water bheri at Taldi, West Bengal. *J. Inland. Fish. Soc. India*, 12 : 81-88.
- DE, M. 1990. Biological and taxonomic studies on aquatic beetles of wetlands of Calcutta metropolitan district. pp 287-289. In : G.K. Manna and B.B. Jana, editors. *Impacts of environment on animals and aquaculture*. Kalyani. Univ. India.
- GHOSH, A.K. and CHATTOPADHYAY, S. 1990. Biological resources of Brace Bridge Wetlands. *Indian J. Landscape System & Ecological Studies*, 13(2) : 189-207.
- GHOSH, A.K. and CHATTOPADHYAY, S. 1994. Biological resources of periurban wetlands : Santragachi Jheel, Howrah district, West Bengal. *Indian J. Landscape System & Ecological Studies*, 17(1) : 1-7.
- GOVIND, B.V. 1969. Bottom fauna and macro vegetation in the Tungabhadra reservoir and their role in the food chain of fish communities. In : Seminar on "Ecology and Fisheries of Freshwater Reservoirs", sponsored by ICAR at CIFRI, Barrackpore, 27-29, Nov. 1969; 99-128.
- GUPTA, P. K. 1981. An ecological study of the macrobenthic communities in Kumaun Lakes. *Ph. D. Thesis*, Kumaun University, Nainital, : 303.
- GUPTA, P. K. 1983. Macro benthos of lake Nainital with particular reference to pollution, water, air and soil pollution. *International rev. Ges. Hydrobiol*, 19(1) : 3097-405.
- GUPTA, P.K and PANT, M.C. 1986. Analysis of the inshore macrozoobenthic community in lake Nainital, U.P. India. *International rev. Ges. Hydrobiol*, 71(1) : 115-125.
- HORA, S. L. 1933. Animal in brackish water at uttarbhag, lower Bengal, *Curr. Sci.*, 1 : 12-38.
- JHINGRAN, V.G. 1997. Fish and Fisheries of India. *Hindustan Publishing Corporation (India) Delhi*, 3rd Ed. (Corrected reprint) pp. XXiii + 728.
- KULSHRESTHA, S.K., ADHOLIA. U.N., BHATNAGAR. A., KHAN A.A. and SAXENA. M. 1988. Past, present and future of Bhopal lakes. *Proc. Nat. sym. Dept. of Zoology. Motilal Vigyan Mahavidyalaya, Bhopal, India*, i-v; 1-257.

- LANG, C. 1985. The Oligochaete community of the sub-litoral as indicator of lake Geneva eutrophication. *Arch. Hydrobiol.*, **103** : 325-340
- LODEN, M.S. 1974. Predation of Chironomid (Diptera) larvae on oligochaetes. *Limnol and Oceanogr.* **19** : 156
- MITRA, K. and KUMAR, K. 1988. Common insects of fresh water ponds and their control. *Central inland capture fish. Res. Inst., Barrackpore, Bull.* **54**, PP. 12-38.
- MAHADEVAN, A. and KRISHNASWAMY, K. 1984. Chironomid larval populations size an index of pollution in river Vaigai. *Poll. Res.*, **3** : 35-38
- MC LACHLAN, A. J. 1975. The role of aquatic macrophytes in the recovery of the benthic fauna of a tropical lake after a dry phase. *Limnol. Oceanogr.*, **20** : 54-63.
- MUNAWAR, M. 1970. Limnological studies on freshwater ponds of Hyderabad, India; *The Biotype. Hydrobiol.*, **35**(1) : 127-162.
- NANDI, N.C., DAS, S. R., BHUNIYA, S. and DASGUPTA, J.M. 1993. Wetland Faunal Resources of West Bengal. 1. North and South 24-parganas District. *Rec. zool. Surv.. India, Occ. paper No.* **150** : 1-50.
- PAL, S., DEY, S.R., BHATTACHARYA, D.K., DAS, S.K. and NANDI, N. C. 1998. Macrophyte preference and insects diversity of freshwater wetlands in Southeastern Bengal. *Proceedings of the National Seminar on Environmental Biology*, April, 3-5, 1998, Viswa Bharati University, 165-169.
- ROY, S. P., KUMAR, V. and PATHAK, H. S. 1988. Faunestic composition of aquatic insects of eastern Bihar with notes on their some aspects of ecology. *Rec. Zool. Surv. India*, **85**(1) : 88-95.
- SINGH, J.P., and ROY, S.P. 1991. Seasonal changes in the standing crop of some macro invertebrate population of the Kavar lake, Begusarai (Bihar), *J. Freshwater Boil.*, **3**(1) : 59-64.
- SOSZKA, G.J. 1975. The invertebrates on submerged macrophytes in three-masurian lakes. *Ecol. Pol.*, **23**(3) : 371-391.
- WIEDERHOLM, T. 1980. Use of benthos in LakeMonitoring. *J. Water. Poll. Cont. Fed.*, **52** : 537-547.

DIVERSITY OF HIGH ALTITUDE ACRIDIDS

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ABSTRACT

A comparative study of the diversity in acridids at different altitude of the Darjeeling hills is presented in this paper. A total number of 21 species of grasshoppers were found in five study areas at different altitudes. Six species of grasshoppers were available in Darjeeling town, nine species of grasshoppers were available in the Happy Valley Tea Estate and eight species were found in the fallowland of Lebong. Three species of grasshoppers were available in the Bannockburn fallowland area whereas, nineteen species were found in the Singla tea garden area. Moreover, the study revealed that the species diversity was higher at altitude below 2000ft (700 m.). This variations in the diversity of acridids may due to altitudinal differences in the study area.

Keywords : Diversity, acridid, highaltitude, species.

INTRODUCTION

The study of diversity of acridid population is still in its infancy. There is a great need for in depth research on the quantitative aspect of acridids Uvarov (1933) from his study on the ecology of Moroccan locust in Iraq and Syria concluded that even within the restricted zone the locust did not occur everywhere but only slopes of some hill ranges with hard soils and scanty but characteristic vegetation harbours a rich population of locust. Clark (1966) worked on *Phaulacridium vittatum* of East Australia and concluded that persistence of populations under conditions of limited food could be attributed to the poor discrimination between favourable plants and those unfavourable for development or survival. Roonwal (1981) observed that the changes in the growth and condition of the vegetation affect the population of these insects. Nath and Haldar (2005) showed that pollution had a significant role in population fluctuation of *Oedalus abruptus*. But the study of diversity of acridids at different altitudes of Darjeeling

hill region was not done so far. In view of the existing lacunae, such study on the acridids is presented in this communication.

MATERIALS AND METHODS

Acridids for this study were collected from five study areas at different altitudes of Darjeeling hill namely, Darjeeling town (2075 m.), Happy Valley tea estate (1920 m.) Lebong fallowland (1675.7 m.), Bannockburn wet fallowland (1218.7 m.) and Singla abandoned tea estate (600 m.).

An insect net of conventional design (dia.30 cm.) has been employed to sample the grasshoppers. The technique adopted was a slight modification of the method followed by Benfill & Brusven (1973). This technique was also adopted by Nath and Haldar (1998), where the quadrat method was employed to sample population of acridid and collections were done by sweeping in unit time. Each of the five areas has been divided into three plots of 5 m² for collection of insects. A fortnightly collection has

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been made from all these plots, taking 10 minutes for collection in each of the plots. Therefore, the total collection time for each site was 30 minutes. Collections were made in the morning between 8.30 and 9.30 a.m. The collected material from each plot were narcotized separately in killing bottles and transferred to polythene bags for transport to the laboratory for further study. Temperature and humidity were recorded by thermometer and hygrometer respectively.

Shannon index is used to compare species diversity in different habitats.

RESULTS AND DISCUSSION

The study showed that six species of grasshopper viz. *Atractomorpha crenulata* (Fab.), *Trilophidia annulata* (Thunb.), *Ceracris nigricornis* (Bolv.), *Oxya velox* (Fabr.), *Phleoba antennata* Brun. and *Locusta* spp. were available in Darjeeling town (Table-1).

Happy valley, which is situated beside Darjeeling town, contains *Atractomorpha crenulata* (Fab.), *Catantop pinguis innotabilis* (Walk), *Phleoba panteli* Boliv., *P. infumata*, *P. antennata* Brun., *Trilophidia annulata* (Thunb.), *Ceracris nigricornis* (Bolv.), *Oxya velox* (Fabr.), *Spathosternum p. prasiniparum* (Walk).

Lebong fallowland is situated near Darjeeling town. The study in this area revealed that *Atractomorpha crenulata* (Fabr.), *Catantop pinguis innotabilis* (Walk.), *P. panteli* Boliv., *P. infumata*, *P. antennata* Brun., *Ceracris nigricornis* (Bolv.), *O. velox* (Fabr.), *Spathosternum p. prasiniparum* (Walk.), i.e. eight species of grasshoppers were available.

The collection site near Bannockburn is situated by the side of a deep forest and it is a wet fellowland area. Three species of grasshoppers namely, *Ceracris nigricornis* (Bolv.), *Oxya velox* (Fabr.) and *Atractomorpha crenulata* (Fabr.) were available in this area.

Singla is an area where many abandoned tea gardens and agricultural fields are present. Nineteen different species of grasshoppers were available in that area. These include *Phleoba*

panteli Bolv., *Catantop pinguis innotabilis* (Walk.) *P. infumata*, *P. antennata* Brun., *Trilophidia annulata* (Thunb.), *Oxya velox* (Fabr.), *Xenocatantop humilis humilis* (Serv.), *Hieroglyphus banian* (Fabr.), *Stenocatantop splendens* (Th.), *Condocris rosea* (de Geer), *Locusta* spp., *Choroedocus robustus* (Serv.), *Coptecra* spp., *Eyprepocnemis alacris impicta* (Uvarov), *Aulacobothrus luteipes* (Walk), *Heteracris pulcher* (Bol.), *Peripolus pedarius* (Stal) and *Spathosternum p. prasiniparum* (Walk).

Studies on the diversity of acridids in five different habitats revealed that availability of grasshoppers depends upon altitude which on the other hand affect the environmental conditions of these collection sites. The temperature of Darjeeling town and Happy Valley T.E. ranges between below 0°C and 22°C and humidity is 30% to 70%. During winter snow fall is very common. Temperature of Lebong and Bannockburn usually does not go below 0°C. Moreover, in Singla temperature ranges between 15° C and 35°C and humidity 40% to 85%.

C. nigricornis and *A. crenulata* were absent in Singla, but were available in other four habitats. *T. annulata* was available in all the sites except Lebong and Bannockburn. The vegetational patterns were different in all the five sites and that was probably due to differences in climatological factors prevailing at different altitudes. Gyllenberg (1974) revealed that the size of the grasshopper population was regulated mainly by abiotic factors. Sampling plots at lower altitude (Singla) were inhabited by highest diversity of taxa. In comparison, the plots of other areas yielded lower diversity of taxa.

The presence of *O. velox* in all the five study sites indicated its adaptability to wide variations in environmental condition. On the other hand *C. nigricornis* which was available near wetland such as Bannockburn, also available in Darjeeling town, Happy Valley and Lebong but absent in Singla, which indicated that this species preferred lower temperature. *A. crenulata* was restricted above 700 m. altitude. Whereas, *C. pinguis innotabilis*, *P. panteli*,

Table-1. Occurrence of Grasshoppers at different altitudes of Darjeeling hill

Name of the Grasshoppers	Darjeeling town	Happy Valley	Lebong fallowland	Bannockburn fallowland	Singla
<i>Atractomorpha crenulata</i> (Fab.)	+	+	+	+	-
<i>Catantop pinguis innotabilis</i> (Walk)	-	+	+	-	+
<i>Phleoba panteli</i> Bolv.	-	+	+	-	+
<i>P. infumata</i>	-	+	+	-	+
<i>P. antennata</i> Brun.	+	+	+	-	+
<i>Trilophidia annulata</i> (Thunb.)	+	+	-	-	+
<i>Oxya velox</i> (Fabr.)	+	+	+	+	+
<i>Xenocatantop humilis humilis</i> (Serv.)	-	-	-	-	+
<i>Hieroglyphus banian</i> (Fabr.)	-	-	-	-	+
<i>Stenocatantop splendens</i> (Th.)	-	-	-	-	+
<i>Condoctris rosea</i> (de Geer)	-	-	-	-	+
<i>Locusta</i> spp.	+	-	-	-	+
<i>Choroedocus robustus</i> (Serv.)	-	-	-	-	+
<i>Coptecra</i> spp.	-	-	-	-	+
<i>Eyprepocnemis alacris impicta</i> (Uvarov)	-	-	-	-	+
<i>Aulacobothrus luteipes</i> (Walk.)	-	-	-	-	+
<i>Heteracris pulcher</i> (Bol.)	-	-	-	-	+
<i>Peripolus pedarius</i> (Stal.)	-	-	-	-	+
<i>Ceracris nigricornis</i> (Walk.)	+	+	+	+	-
<i>Spathosternum p. prasiniparum</i> (Walk.)	-	+	+	-	+

+ present - absent.

Table 2. Diversity indices of species at different habitats.

Darjeeling	Happy Valley T.E.	Lebong Fallow land	Bannockburn Fallowland	Singla
0.98	1.916	1.629	0.973	2.178

P. infumata, *P. antennata*, *T. annulata* were available in various altitudes indicating their adaptability to wide variations of temperature and humidity. This observation is similar to that of Vestal (1913) who reported the variation in grasshopper species diversity depending on physical conditions of environment.

The diversity indices, as determined by Shannon method, showed little variation between the values of Happy Valley T.E. ($H = 1.916$) and Lebong fallowland ($H = 1.629$) (Table-2). This may be due to occurrence of nearly same number of species in both the sites

(nine in Happy Valley and eight in Lebong). Bannockburn showed the lowest diversity index ($H = 0.973$) and the next higher index ($H = 0.98$) was recorded at Darjeeling. In contrast, acridids fauna at Singla showed the highest diversity index value ($H = 2.178$), where the highest number of species (19) were encountered. The possible important reasons for supporting a diverse fauna by Singla than

other study areas are low altitude, relatively higher temperature and humidity.

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LITARATURE CITED

- BENFILL, J. C. and BRUSVEN M. A. 1973. Food habits and ecology of grasshoppers in the Seven Devils Mountains and Salmon river breaks of Idaho. *Malandaria*, **21** : 1-33.
- CLARK, D.P. 1966. A population study of *Phaulacridium vittatum*. *Aus. J. Zool.*, **15** : 799-872.
- GYLLENBERG, G. 1974. A simulation model for testing the dynamics of grasshopper population. *Ecology*, **55**(3) : 645-650.
- NATH, S. and HALDAR, P. 1998. Population dynamics of the grasshopper, *Acrida exaltata* (Walker) in the arid zone of West Bengal. *J. Interacad.*, **2** : 67-70.
- NATH, S. and HALDAR, P. 2005. Effect of heavy metals on population dynamics of an acridid, *Oedaleus abruptus*. *J. Environ. & Sociobiol.*, **2** : 67-70.
- ROONWAL, M.L. 1981. Field bioecology and morphology of central Indian grasshoppers (Acridoidea) with notes on a swimming species. *Proc. Zool. Soc. Cal.*, **32** : 87-106.
- UVAROV, B. P. 1933. Biology of the Moroccan locust in Iraq and Syria and the prevention of its out breaks. *Bull. Ent. Res.*, **24** : 407-420.
- VESTAL, A. G. 1913. Local distribution of grasshoppers in relation to plant associations. *Biol. Bull. Woods. Hole (Mass.)*, **25** : 141-180.

BIODIVERSITY STATUS OF FRESH WATER FISHES OF NORTH EASTERN HIMALAYA WITH SPECIAL REFERENCE TO THREATS AND CONSERVATION MEASURES

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ABSTRACT

The fishery resources of the North Eastern Himalaya Region fall within the all three types of climate, i.e. tropical, sub-tropical and temperate and represent a strong biodiversity. Based on modification of different parts of the body as adaptation to various adverse environmental conditions, fishes are true hill stream forms, semi-torrential forms, migratory forms and plain water forms. Altogether a total of 274 fish species have been recorded from the diverse fresh water bodies which belongs to 114 genera under 37 families and 10 orders. Among them 269 species are food fish, 250 potential ornamental fish, 48 cultivable fish and 9 sport fish. Out of the total 274 diversified fish species of the NE region, highest number of fish species have been recorded from Assam (206), followed by Meghalaya (175), Arunachal Pradesh (172), Manipur (150), Tripura (141), Mizoram (97), Nagaland (73) and Sikkim (30). The biodiversity statuses of 274 fishes were assessed following IUCN criteria. Among them 9 are exotic. Of the total 265 indigenous species, 10 are Critically Endangered (CR), 28 are Endangered (EN), 54 are Vulnerable (VU), 48 are Lower Risk Near Threatened (LRnt), 08 are Lower Risk Least Concern (LRlc), 04 are Data Deficient (DD) and 122 are Not Evaluated (NE). An appraisal on various biodiversity threats in the water bodies of eight states of North Eastern Himalayan region have been made such as unethical exploitation by using prohibited fishing methods, small meshed gears, chemical and herbal poisoning, dynamiting, habitat destruction and alteration by river water abstraction, by construction of dams, diversion of streams for irrigational purpose, pollution, sand mining, clandestine introduction of exotic and alien species in to the natural waters etc. This paper also discusses the management strategies to be implemented for the conservation of freshwater fish diversity in the region through conservation of habitat and conservation of fish stocks.

Keywords : Fish, diversity, North Eastern India, conservation.

INTRODUCTION

The North Eastern Himalayan Region of India comprising of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura is gifted with vast aquatic resources in the form of rivers, streams, lakes, reservoirs, floodplain wetlands, ponds and large areas under rice-fish culture system. The region lies between 21.50° to 29.50° North latitude and

85.50° to 97.50° East longitude and is bounded on the north by China and Bhutan, on the west by Bangladesh and on the east by Burma and covers an elevation from 15 to 5000 m from the sea level. The rivers Brahmaputra, Barak and Teesta form the principal drainage of North East India with its numerous tributaries flowing through the different states along with myriads of rivulets and lentic water bodies. About 70% of the area in these States being hilly region, the

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distribution of majority of the fish species is expected to belong to the hill region. North East India is considered as one of the hot spots of freshwater fish biodiversity in the world (Kottelat and Whitten, 1996). The region shares its fish fauna predominantly with that of the Indo-Gangetic fauna and to a small extent with the Burmese and South China fish fauna (Yadava and Chandra, 1994). Review of literature indicates that there has been a wide variation in the number of fishes reported from this region ranging from 129 to 274 (Yadava and Chandra, 1994; Ghosh and Lipton, 1982; Sinha, 1994; Sen, 2000; Mahapatra *et al.*, 2004a).

In the present paper, an attempt has been made to illustrate the status of diversified fish species available in different states of the region along with their conservation status.

MATERIALS AND METHODS

In the present study, random rapid field surveys were conducted during 2000-2005 in different states of the region. Observation of different fish species was made at important fish assembling centres. The information regarding their occurrence was collected from local fishermen as well as from fish vendors.

The fish species with respect to their commercial utilization as cultivable, food, sport and ornamental were evaluated based on some specific criteria. Consumer preference and market demand were the criteria used for deciding the food value of fishes. The food fishes that showed adequate growth in unit time were brought under cultivable category. The sport fishes were demarcated based on the preference shown by the anglers. The ornamental fishes were categorised based on the criteria like colouration, body shapes, banding patterns, finnages, suckers, transparent body and preying habits.

The conservation status of each species was assigned based on the evaluation of 329 species made in the CAMP report (1998). The nomenclature followed in this paper is after Jayaram (1999).

RESULTS AND DISCUSSION

The up to date inventory of the fish species of NEH region records 274 fish species which belonged to 114 genera under 37 families and 10 orders. This includes 265 indigenous and 9 exotic fish species. The 9 exotic fish species have already well adapted with the environment and the present author has recorded the established breeding population of some of the species like *Cyprinus carpio*, *Oreochromis mossambicus*, *O. niloticus* and *Clarius gariepinus* from different water bodies of the region. Of the approximately 806 species inhabiting freshwater of India (Talwar and Jhingran, 1991), NEH region represents 34%. Majority of the 274 species belong to Cypriniformes (148), followed by Siluriformes (76), Perciformes (33), Clupeiformes (07), Anguilliformes (03), Synbranchiformes (02), Osteoglossiformes (02), Cyprinodontiformes (01), Syngnathiformes (01), and Tetraodontiformes (01).

It is revealed from the study that local people consume almost all the species (99.27%) except *Aplocheilichthys panchax* and *Chaca chaca* in some locality. A total of nine species (3.28%) were identified as major sport fish of the region. The important cold water sport fishes of the region are mahseers (*Tor putitora*, *T. tor*, *T. chelyoides*, *Neolissocheilus hexagonolepis* and *N. hexastichus*) and Indian trout (*Barilius bola*). As many as 48 fish species (17.52%) of the region have been considered as cultivable fish. Two hundred and fifty five fish species (91.24%) have been found to have potential ornamental value. The important ornamental fishes like *Puntius shalynius*, *Danio dangila*, *Badis badis burmanicus*, *Acanthocobitis botia*, *Chaca chaca*, *Schistura beavani*, *Psilorhynchus sucatio* and *Hara hara* are largely unknown among the local masses. For these native fish species, there is immense scope for development of ornamental fisheries (Dutta, 2000; Ghosh *et al.*, 2002; Mahapatra *et al.*, 2003a, 2003b, 2003c, 2004b, 2005, 2007a; Nair, 2004; Sarmah *et al.* 2004; Vinod *et al.*, 2006).

Out of the total 274 diversified fish species of the NE region, highest number of fish species have been recorded from Assam (206), followed by Meghalaya (175), Arunachal Pradesh (172),

Manipur (150), Tripura (141), Mizoram (97), Nagaland (73) and Sikkim (30). But, in relation to total number of fish species available and the number of fish species having ornamental value, the highest percentage was recorded in Nagaland (97.26%), followed by Sikkim (96.67%), Arunachal Pradesh (95.93%), Mizoram (93.81%), Manipur (92.67%), Meghalaya (90.86%), Assam (90.78%) and Tripura (73.05%).

Biodiversity threats in the form of diverse types of human interventions are the main reason for the alarming decline of fish populations in most of the rivers of NE region. The various types of destructive fishing activities practiced along the river systems of North Eastern Himalayan regions are as follows :

1. Use of small meshed fishing gears kills the fry and fingerlings, thus leading to a drastic reduction in population of the most of the fishes especially those who are already under threatened category.
2. Fishing using chemical and herbal poisons also a major threat of the natural fishery.
3. Dynamiting is very rampant in all rivers, reservoirs and streams as a device for harvesting of fishes.
4. The habitat destruction of fishes is another major reason for the declining biodiversity of fishes in North Eastern States. Habitat loss has taken place due to the following reasons like Construction of dams, Deforestation, Agricultural practices in river bed, Water abstraction, Sand mining, Sewage and industrial effluents.
5. Indiscriminate fishing of the brood and juveniles.
6. Over fishing of some selected fish especially for ornamental fish trade. These species are exploited beyond the sustainable levels, thus leading to their endangerment in most of their place of inhabitation.
7. Introduction of exotic species in to the natural waters of has resulted in the competition for food and space between the exotic and indigenous fish. The exotic species like common carp, *Cyprinus carpio*; Tilapia (*Oreochromis*

mossambicus) and African cat fish (*Clarias gariepinus*) has established their breeding populations.

8. The outbreak of EUS in 1988 and its recurrence now at varied intensities are another major threat faced by the indigenous fishes of the NEH region.

Conservation status of fishes have shown that out of total 265 indigenous species, 10 are Critically Endangered (CR), 28 are Endangered (EN), 54 are Vulnerable (VU), 48 are Lower Risk Near Threatened (LRnt), 08 are Lower Risk Least Concern (LRlc), 04 are Data Deficient (DD) and 122 are Not Evaluated (NE). The diversified fish species along with their conservation status have been presented in table 1.

Though there is an ample scope for fisheries development in the region, interestingly most of the field has been left unattended so far in real perspectives. The ICAR Research Complex has initiated research activity in various fields and has already developed or refined some technologies like composite fish culture in hills, paddy-cum-fish culture, cage-fish culture and running water fish culture (Nayak and Mandal, 1988, 1989a, 1989b). Breeding technology of some fish species have been refined under mid hill altitudinal condition and for some fish species have been developed (Das and Kalita, 2003; Mahapatra *et al.*, 2007 b, Mahapatra *et al.*, 2007 c).

For proper and sustained utilization of high altitude aquatic resources for enhancing fish production and income, there is a need to impart adequate training, education and extension to the local masses with regard to the development of aquaculture using local species, ornamental fishery and sport fishery. Following suggestions will be conducive to the sustainability of fishery of the region as well as to conserve the freshwater fish biodiversity of NEH from endangerment.

- 1) With proper education and technical guidance local fisher folk can be organized and trained to sustainable exploit these diversified fishery in which sufficient tracts of their natural habitat including their breeding grounds are conserved.

Table 1. Diversified Fish Species of North East and Their Conservation Status.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
1.	<i>Aborichthys elongatus</i> (Hora)		+				-	-
2.	<i>Aborichthys garoensis</i> Hora	+						-
3.	<i>Aborichthys kempfi</i> Chaudhuri			+			-	-
4.	<i>Aborichthys tikaderi</i> Barman		+			-	-	-
5.	<i>Acanthocobitis botia</i> (Hamilton)				+			-
6.	<i>Acanthocobitis pavonaceus</i> (McClelland)							+
7.	<i>Acanthocobitis zonalternans</i> (Blyth)						+	
8.	<i>Acanthopthalmus pangia</i> (Hamilton)			+				
9.	<i>Acantopsis choirorhynchus</i> (Bleeker)							+
10.	<i>Ailia coila</i> (Hamilton)			+			-	-
11.	<i>Ailia punctata</i> (Day)			+				
12.	<i>Amblyceps mangois</i> (Hamilton)				+			
13.	<i>Amblyceps apangi</i> (Nath & Dey)			+		-	-	-
14.	<i>Amblyceps arunanchalensis</i> (Nath & Dey)			+			-	
15.	<i>Amblypharyngodon mola</i> (Hamilton)	-	-			+	-	-
16.	<i>Anabas testudineus</i> (Bloch)			+				
17.	<i>Anabas oligolepis</i> Bleeker							+
18.	<i>Anguilla bengalensis</i> (Gray & Hardwicke)		+					
19.	<i>Aorichthys aor</i> (Hamilton)							+
20.	<i>Aorichthys seenghala</i> (Sykes)							+
21.	<i>Aplocheilichthys panchax</i> (Hamilton)						+	
22.	<i>Apocryptes bato</i> (Hamilton)							+
23.	<i>Aristichthys nobilis</i> * (Richardson)	-	-	-			-	+
24.	<i>Aspidoperia jaya</i> (Hamilton)			+			-	
25.	<i>Aspidoperia morar</i> (Hamilton)				+	-		-
26.	<i>Badis badis badis</i> (Hamilton)				-			+
27.	<i>Badis badis burmanicus</i> Ahl				-			+
28.	<i>Bagarius bagarius</i> (Hamilton)			+			-	-
29.	<i>Balitora brucei</i> Gray		-		+			-
30.	<i>Barilius barila</i> (Hamilton)			+				-
31.	<i>Barilius barna</i> (Hamilton)			-	+			-
32.	<i>Barilius bendelisis</i> (Hamilton)				+			-
33.	<i>Barilius bola</i> (Hamilton)							+
34.	<i>Barilius dogarsinghi</i> Hora		+					-
35.	<i>Barilius gatensis</i> (Valenciennes)							+
36.	<i>Barilius guttatus</i> (Day)						-	+
37.	<i>Barilius radiolatus</i> Gunther			-	-		-	+
38.	<i>Barilius shacra</i> (Hamilton)				+			-
39.	<i>Barilius tileo</i> (Hamilton)			-	+			-
40.	<i>Barilius vagra</i> (Hamilton)			+	-		-	-
41.	<i>Batasio batasio</i> (Hamilton)			-				+
42.	<i>Batasio tengana</i> (Hamilton)			-	-		-	+
43.	<i>Bengala elanga</i> (Hamilton)				-		-	+
44.	<i>Botia berdmorei</i> (Blyth)		+	-	-	-	-	-

Table 1. Contd.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
45.	<i>Botia dario</i> (Hamilton)							+
46.	<i>Botia histrionica</i> Blyth	-	-	+			-	-
47.	<i>Botia lohachata</i> Chaudhuri		+					
48.	<i>Botia rostrata</i> Gunther							+
49.	<i>Catla catla</i> (Hamilton)			+				
50.	<i>Chaca chaca</i> (Hamilton)		+					
51.	<i>Chagunius chagunio</i> (Hamilton)							+
52.	<i>Chagunius nicholsi</i> (Myers)							+
53.	<i>Chanda nama</i> Hamilton							+
54.	<i>Chandramara chandramara</i> (Hamilton)							+
55.	<i>Channa barca</i> (Hamilton)							+
56.	<i>Channa marulius</i> (Hamilton)				+			
57.	<i>Channa orientalis</i> Bloch & Schneider			+				
58.	<i>Channa punctatus</i> (Bloch)	-	-	-	+		-	-
59.	<i>Channa stewartii</i> (Playfair)							+
60.	<i>Channa striatus</i> (Bloch)					+		
61.	<i>Chaudhuria indica</i> (Yazdani)			+				
62.	<i>Chaudhuria khajuriai</i> (Talwar, Yazdani & Kundu)	-	+					
63.	<i>Chela cachiui</i> (Hamilton)							+
64.	<i>Chela laubuca</i> (Hamilton)					+		
65.	<i>Chitala chitala</i> (Hamilton)		+					
66.	<i>Cirrhinus mrigala</i> (Hamilton)				+			
67.	<i>Cirrhinus reba</i> (Hamilton)			+				
68.	<i>Clarias batrachus</i> (Linnaeus)			+				
69.	<i>Clarias gariepinus</i> * (Burchell)							+
70.	<i>Clupisoma garua</i> (Hamilton)			+				
71.	<i>Clupisoma montana</i> Hora							+
72.	<i>Colisa fasciatus</i> (Schneider)	-	-		+			
73.	<i>Colisa labiosus</i> (Day)	-	-				-	+
74.	<i>Colisa lalia</i> (Hamilton)	-	-					+
75.	<i>Colisa sota</i> (Hamilton)							+
76.	<i>Conta conta</i> (Hamilton)							+
77.	<i>Crossocheilus burmanicus</i> (Hora)			+				
78.	<i>Crossocheilus latius latius</i> (Hamilton)						+	
79.	<i>Ctenopharyngodon idella</i> * (Valenciennes)					-		+
80.	<i>Ctenops nobilis</i> McClelland	-	-					+
81.	<i>Cyprinion semiplotum</i> (McClelland)							+
82.	<i>Cyprinion modestum</i> (Day)		-			-		+
83.	<i>Cyprinus carpio</i> * Linnaeus							+
84.	<i>Danio aequipinnatus</i> (Hora)			+				
85.	<i>Danio aequipinnatus</i> (McClelland)				+			
86.	<i>Danio dangila</i> (Hamilton)							+

Table 1. Contd.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
87.	<i>Danio devario</i> (Hamilton)	-	-	-	+	-	-	-
88.	<i>Danio naganensis</i> (Chaudhuri)	-	-	+	-	-	-	-
89.	<i>Danio reginal</i> (Fowler)	-	-	-	-	-	-	+
90.	<i>Danio rerio</i> (Hamilton)	-	-	-	+	-	-	-
91.	<i>Erethestis montana montana</i> (Hora)	+	-	-	-	-	-	-
92.	<i>Erethestis pussiles</i> (Mull. & Tros.)	-	-	-	-	-	-	+
93.	<i>Esomus danricus</i> (Hamilton)	-	-	-	-	+	-	-
94.	<i>Euchiloglanis hodgarti</i> (Hora)	-	-	+	-	-	-	-
95.	<i>Euchiloglanis kamengensis</i> Jayaram	-	+	-	-	-	-	-
96.	<i>Eutropiichthys murius</i> (Hamilton)	-	-	-	+	-	-	-
97.	<i>Eutropiichthys vacha</i> (Hamilton)	-	+	-	-	-	-	-
98.	<i>Exostoma bermorei</i> Blyth	-	-	-	-	-	-	+
99.	<i>Exostoma labiatum</i> (McClelland)	-	-	-	-	-	-	+
100.	<i>Exostoma stuartii</i> (Hora)	-	-	-	-	-	-	+
101.	<i>Gagata cenia</i> (Hamilton)	-	-	-	-	-	-	+
102.	<i>Gagata gagata</i> (Hamilton)	-	-	-	-	-	-	+
103.	<i>Gagata sexualis</i> Tilak	-	-	-	+	-	-	-
104.	<i>Ganiolosa manmina</i> (Hamilton)	-	-	-	-	-	-	+
105.	<i>Garra annandalei</i> Hora	-	-	-	-	-	-	+
106.	<i>Garra gotyla gotyla</i> (Gray)	-	-	+	-	-	-	-
107.	<i>Garra gravellyi</i> (Annandalei)	-	-	-	-	-	-	+
108.	<i>Garra kempfi</i> Hora	-	-	+	-	-	-	-
109.	<i>Garra lamta</i> (Hamilton)	-	-	-	-	-	-	+
110.	<i>Garra lissorhynchus</i> (McClelland)	-	-	+	-	-	-	-
111.	<i>Garra litanensis</i> (Viswanath)	+	-	-	-	-	-	-
112.	<i>Garra manipurensis</i> (Viswanath and Sarojnolini)	+	-	-	-	-	-	-
113.	<i>Garra mcClellandi</i> (Jerdon)	-	-	-	-	-	-	+
114.	<i>Garra naganensis</i> Hora	-	-	+	-	-	-	-
115.	<i>Garra nasuta</i> (McClelland)	-	-	-	-	-	-	+
116.	<i>Garra rupecula</i> (McClelland)	-	-	+	-	-	-	-
117.	<i>Glossogobius giuris</i> (Hamilton)	-	-	-	+	-	-	-
118.	<i>Glyptothorax brevipinnis</i> Hora	-	-	+	-	-	-	-
119.	<i>Glyptothorax manipurensis</i> (Menon)	-	-	-	-	-	-	+
120.	<i>Glyptothorax pectinopterus</i> (McClelland)	-	-	-	-	-	-	+
121.	<i>Glyptothorax platypogonoides</i> (Bleeker)	-	-	-	+	-	-	-
122.	<i>Glyptothorax telchitta</i> (Hamilton)	-	-	-	+	-	-	-
123.	<i>Glyptothorax annandalei</i> Hora	+	-	-	-	-	-	-
124.	<i>Glyptothorax cavia</i> (Hamilton)	-	+	-	-	-	-	-
125.	<i>Glyptothorax coheni</i> (Ganguly, Dutta & Sen)	-	-	-	-	-	-	+
126.	<i>Glyptothorax conirostre conirostre</i> (Steindachner)	-	-	-	-	-	-	+

Table 1. Contd.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
127.	<i>Glyptothorax indicus</i> (Talwar)	-	-	+	-	-	-	-
128.	<i>Glyptothorax striatus</i> (McClelland)	-	-	+	-	-	-	-
129.	<i>Glyptothorax trilineatus</i> (Blyth)	-	-	-	-	-	-	+
130.	<i>Gudusia chapra</i> (Hamilton)	-	-	-	-	+	-	-
131.	<i>Gudusia variegata</i> (Day)	-	-	-	-	-	-	-
132.	<i>Hara hara</i> (Hamilton)	-	-	-	-	-	-	-
133.	<i>Hara horai</i> (Misra)	-	+	-	-	-	-	-
134.	<i>Hara jerdeni</i> (Day)	-	-	-	-	-	-	+
135.	<i>Heteroneustes fossilis</i> (Bloch)	-	-	+	-	-	-	-
136.	<i>Hilsa ilisha</i> (Hamilton)	-	-	+	-	-	-	-
137.	<i>Homaloptera modesta</i> (Vinciguera)	-	-	-	-	-	-	+
138.	<i>Hypophthalmichthys molitrix</i> *Bleeker	-	-	-	-	-	-	+
139.	<i>Ilisha melanostoma</i> (Schneider)	-	-	-	-	-	-	+
140.	<i>Johnius coitor</i> (Hamilton)	-	-	-	-	-	-	+
141.	<i>Kryptoterus indicus</i> (Datta, Burman & Jayaram)	+	-	-	-	-	-	-
142.	<i>Labeo angra</i> (Hamilton)	-	-	-	+	-	-	-
143.	<i>Labeo bata</i> (Hamilton)	-	-	-	+	-	-	-
144.	<i>Labeo boga</i> (Hamilton)	-	-	-	+	-	-	-
145.	<i>Labeo calbasu</i> (Hamilton)	-	-	-	+	-	-	-
146.	<i>Labeo dero</i> (Hamilton)	-	-	+	-	-	-	-
147.	<i>Labeo devdevi</i> (Hora)	-	-	-	-	-	-	+
148.	<i>Labeo dyocheilus</i> (McClelland)	-	-	+	-	-	-	-
149.	<i>Labeo gonius</i> (Hamilton)	-	-	-	+	-	-	-
150.	<i>Labeo nandina</i> (Hamilton)	-	-	-	-	-	-	+
151.	<i>Labeo pangusia</i> (Hamilton)	-	-	-	+	-	-	-
152.	<i>Labeo rohita</i> (Hamilton)	-	-	-	+	-	-	-
153.	<i>Laguvia ribeiroi</i> Hora	-	-	-	+	-	-	-
154.	<i>Laguvia shawi</i> Hora	-	+	-	-	-	-	-
155.	<i>Lepidocephalus annandalei</i> (Chaudhuri)	-	-	-	+	-	-	-
156.	<i>Lepidocephalus berdmorei</i> (Blyth)	-	+	-	-	-	-	-
157.	<i>Lepidocephalus guntea</i> (Hamilton)	-	-	-	-	-	-	+
158.	<i>Lepidocephalus irrorata</i> (Hora)	-	-	+	-	-	-	-
159.	<i>Lepidocephalus menoni</i> (Pillai & Yazdani)	-	-	-	-	-	-	+
160.	<i>Macrognathus aral</i> (Bloch & Schneider)	-	-	-	+	-	-	-
161.	<i>Macrognathus pancalus</i> Hamilton	-	-	-	+	-	-	-
162.	<i>Maringua hodgati</i> (Hamilton)	+	-	-	-	-	-	-
163.	<i>Mastocembelus armatus</i> (Lacepede)	-	-	-	-	-	-	+
164.	<i>Mesonoemacheilus sijuensis</i> (Menon)	-	-	+	-	-	-	-
165.	<i>Microphis deocata</i> (Hamilton)	-	-	-	-	-	-	+
166.	<i>Monopterusuchia</i> (Hamilton)	-	-	-	+	-	-	-
167.	<i>Mystus bleekeri</i> (Day)	-	-	+	-	-	-	-
168.	<i>Mystus cavasius</i> (Hamilton)	-	-	-	+	-	-	-

Table 1. Contd.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
169.	<i>Mystus menoda</i> (Hamilton)			-	-	-	-	+
170.	<i>Mystus montanus</i> (Jerdon)			+	-		-	-
171.	<i>Mystus tengara</i> (Hamilton)			-			-	+
172.	<i>Mystus vittatus</i> (Bloch)			+	-			
173.	<i>Nandus nandus</i> (Hamilton)				+			-
174.	<i>Nangra assamensis</i> (Sen & Biswas)					-	-	+
175.	<i>Nangra viridescens</i> (Hamilton)				+			-
177.	<i>Nemacheilus corica</i> (Hamilton)				+			-
178.	<i>Nemacheilus peguensis</i> Hora				-	-		+
179.	<i>Nematolosa nasus</i> (Bloch)				-	-	-	+
180.	<i>Neoeucirrhichthys maydelli</i> (Banerescu)			+			-	-
181.	<i>Neolissocheilus hexastichus</i> (McClelland)				-	-	-	+
182.	<i>Neolissocheilus hexagonolepis</i> (McClelland)				-			+
183.	<i>Noenemacheilus labeosus</i> (Kottelat)					-		+
184.	<i>Notopterus notopterus</i> (Pallas)				+			-
185.	<i>Olyra burmanica</i> (Day)							+
186.	<i>Olyra horai</i> (Prashad & Mukerji)				-			+
187.	<i>Olyra longicaudata</i> McClelland							+
188.	<i>Ompok bimaculatus</i> (Bloch)	+			-			-
189.	<i>Ompok pabda</i> (Hamilton)		+	-				-
190.	<i>Ompok pabo</i> (Hamilton)				-	-		+
191.	<i>Ophisternon bengalense</i> McClelland							+
192.	<i>Oreichthys casuatis</i> (Hamilton)							+
193.	<i>Oreochromis mossambicus</i> * (Peters)							+
194.	<i>Oreochromis niloticus</i> * (Linnaeus)							+
195.	<i>Osphronemus goramy</i> Lacepede							+
196.	<i>Osteobrama belangeri</i> (Valenciennes)		+					-
197.	<i>Osteobrama cotico cunma</i> (Day)			+	-		-	-
198.	<i>Osteobrama cotio cotio</i> (Hamilton)				+			-
199.	<i>Osteochilus neilli</i> (Day)							+
200.	<i>Pangasius pangasius</i> (Hamilton)	+		-	-	-	-	-
201.	<i>Pangasius sutchi</i> *							+
202.	<i>Pisodonophis boro</i> (Hamilton)					-		+
203.	<i>Pseudambasis baculis</i> (Hamilton)			-				+
204.	<i>Pseudambasis lala</i> (Hamilton)			-				+
205.	<i>Pseudambasis ranga</i> (Hamilton)						-	+
206.	<i>Pseudechenies sulcatus</i> (Prashad & Mukerji)		-				-	+
207.	<i>Pseudeutropius atherinoides</i> (Bloch)							+
208.	<i>Psilorhynchus balitora</i> (Hamilton)		-					+
209.	<i>Psilorhynchus gracilis</i> (Rainboth)			-			-	+
210.	<i>Psilorhynchus homaloptera</i> (Hora & Mukherjee)			+			-	-
211.	<i>Psilorhynchus sucatio</i> (Hamilton)		+				-	-

Table 1. Contd.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
212.	<i>Puntius chola</i> (Hamilton)			+				
213.	<i>Puntius clavatus</i> (McClelland)		+					
214.	<i>Puntius conchoni</i> (Hamilton)			+				
215.	<i>Puntius filamentosus</i> (Valenciennes)							+
216.	<i>Puntius fraseri</i> (Hora and Misra)							+
217.	<i>Puntius gelius</i> (Hamilton)							+
218.	<i>Puntius gonionotus</i> *							+
219.	<i>Puntius guganio</i> (Hamilton)				+			
220.	<i>Puntius phutunio</i> (Hamilton)					+		
221.	<i>Puntius sarana orphoides</i> (Valenciennes)							+
222.	<i>Puntius sarana sarana</i> (Hamilton)			+				
223.	<i>Puntius shalynius</i> Yazdani&Talukdar			+				
224.	<i>Puntius sophore</i> (Hamilton)				+			
225.	<i>Puntius terio</i> (Hamilton)				+			
226.	<i>Puntius ticto</i> (Hamilton)				+			
227.	<i>Rasbora daniconius</i> (Hamilton)							+
228.	<i>Rasbora rasbora</i> (Hamilton)							+
229.	<i>Rhinomugil corsula</i> (Hamilton)			+				
230.	<i>Rita rita</i> (Hamilton)				+			
231.	<i>Salmostoma bacaila</i> (Hamilton)					+		
232.	<i>Salmostoma clupeoides</i> (Bloch)					+		
233.	<i>Salmostoma phulo</i> (Hamilton)							+
234.	<i>Schismatorhynchus nukta</i> (Sykes)							+
235.	<i>Schistura ariotes</i> (Sen & Nalbant)							+
236.	<i>Schistura arunachalensis</i> (Menon)		+					
237.	<i>Schistura beavani</i> (Gunther)							+
238.	<i>Schistura cinticauda</i> (Blyth)							+
239.	<i>Schistura denisoni dayi</i> Hora							+
240.	<i>Schistura devdevi</i> Hora		+					
241.	<i>Schistura kangjupkhulensis</i> Hora			+				
242.	<i>Schistura manipurensis</i> Chaudhuri			+				
243.	<i>Schistura multifaciat</i> Day			+				
244.	<i>Schistura nagaensis</i> (Menon)		+					
245.	<i>Schistura prashadi</i> Hora			+				
246.	<i>Schistura reticulofasciatus</i> (Singh & Banarescu)							+
247.	<i>Schistura savona</i> (Hamilton)							+
248.	<i>Schistura scaturigina</i> (McClelland)							+
249.	<i>Schistura sikmainensis</i> Hora							+
250.	<i>Schistura singhi</i> (Menon)	+						
251.	<i>Schistura vincigeurra</i> Hora		+					
252.	<i>Schizopygopsis esocinus</i> (Heckle)							+
253.	<i>Schizopygopsis progastus</i> (McClelland)							+

Table 1. Contd.

Sl. No.	Species	Conservation status						
		CR	EN	VU	LRnt	LRlc	DD	NE
254.	<i>Schizopygopsis stoliczkae</i> (Steindachner)					-		+
255.	<i>Schizothorax richardsonii</i> (Gray)			+				
256.	<i>Securicula gora</i> (Hamilton)							+
257.	<i>Setipinna phasa</i> (Hamilton)							+
258.	<i>Sicamugil cascasia</i> (Hamilton)			+				
259.	<i>Silonia silondia</i> (Hamilton)				+			
260.	<i>Silurus afghana</i> Gunther		+					
261.	<i>Silurus berdmorei</i> (Blyth)							+
262.	<i>Silurus torrentis</i> (Kobayakawa)							+
263.	<i>Sisor rhabdophis</i> (Hamilton)		+					
264.	<i>Somileptes gongota</i> (Hamilton)				+			
265.	<i>Strongylura strongylura</i> (Van Hasselt)							+
266.	<i>Tetradon cutcutia</i> Hamilton				+			
267.	<i>Tor chelynoides</i> (McClelland)							+
268.	<i>Tor mosal</i> (Hamilton)		+					
269.	<i>Tor progeneius</i> (McClelland)						+	
270.	<i>Tor putitora</i> (Hamilton)		+					
271.	<i>Tor tor</i> (Hamilton)		+					-
272.	<i>Triplophysa gracilis</i> (Day)							+
273.	<i>Wallago attu</i> (Schneider)				+			
274.	<i>Xenentodon cancila</i> (Hamilton)				+			
TOTAL			10	28	54	48	08	04

CR – Critically Endangered, EN – Endangered, VU – Vulnerable, LRnt – Low Risk-near threatened, DD – Data deficient, NE – Not evaluated, ‘+’ – Positive, ‘-’ – Negative, *Exotic fish species.

2) Harvesting can be encouraged only in the “population collapse” phase not in the “growing” phase.

3) The biology of the fish especially feeding and breeding biology including behaviour should be studied properly for right utilization.

4) For stock enhancement collectors and culturists should adopt the captive breeding process.

5) Export of ornamental fish should be made keeping in mind the conservation of gene pool of the indigenous fish.

CONCLUSION

Considering the diversity of native fish fauna of NEH Region and scenario of freshwater

aquaculture both nationally and globally, a serious thought can be given and concerted efforts are needed from all concerned stake holders like fisher folk, exporters, importers, village headmen, panchayat members, teachers, students, scientists and top level planners in order to develop and sustain the growth of the fish and fishery resources of the region as well as for better employment and foreign exchange earning from the fish trade especially from the ornamental fish export.

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LITERATURE CITED

- CAMP. 1998. Report of the workshop on "Conservation Assessment and Management Plan (CAMP) for Freshwater Fishes of India" Zoo Outreach organization and NBFGR, Lucknow, 22-26 September, 1997, 156p.
- DAS, S. K. and KALITA, N. 2003. Captive breeding of Peacock Eel, *Macrognathus aculeatus*. *Aquaculture Asia*, 8 : 17-21.
- DUTTA, O.K. 2000. Ornamental Ichthyofauna of Assam. In : *Fish Biodiversity of North East India*. (Ponniah, A.G. and Sarkar, U.K. Eds.). NBFGR, NATP Publ. 2.
- GHOSH, A., MAHAPATRA, B.K. and DATTA, N.C. 2002. Studies on native ornamental fish of West Bengal with a note on their conservation. *Environment & Ecology*, 20 : 787-793.
- GHOSH, S. K. and LIPTON, A.P. 1982. Ichthyofauna of the N.E.H. Region with special reference to their economic importance. ICAR Spl. Bulletin No. 1. ICAR Research Complex for NEH Region, Meghalaya, 126 p.
- JAYARAM, K. C. 1999. The freshwater fishes of the Indian region. Narendra Publishing House, Delhi, 551p.
- KOTTELAT, M. and WHITTEN, T. 1996. Freshwater biodiversity in Asia with special reference to Fish : *World Bank Tech. Paper No.*, 343. The World Bank, Washington, D.C. : 17-22.
- MAHAPATRA, B.K., VINOD, K. and MANDAL, B.K. 2003a. Fish biodiversity of Meghalaya with a note on their sustainable utilization. *Aquacult.*, 4 : 1-10.
- MAHAPATRA, B. K., VINOD, K. and MANDAL, B.K. 2003b. Scope of ornamental fishery in Meghalaya. In : *Approaches for Increasing Agricultural Productivity in Hill and Mountain Ecosystem*. (Bhatt, B.P., Bujarburah, K.M., Sharma, Y.P. and Patirama Eds). ICAR Research Complex for NEH Region, Umiam, Meghalaya, pp 397-401.
- MAHAPATRA, B. K., VINOD, K. and MANDAL, B.K. 2003c. Studies on native ornamental fish of Meghalaya with a note on their cultural prospects. *Aquacult.*, 4 : 173-182.
- MAHAPATRA, B.K., VINOD, K. and MANDAL, B.K. 2004a. Fish biodiversity of North Eastern India with a note on their sustainable utilization. *Environment & Ecology*, 22S : 56-63.
- MAHAPATRA, B. K., VINOD, K. and MANDAL, B.K. 2004b. Ornamental Fish of North Eastern India-Its distribution and conservation status. *Environment & Ecology*, 22 : 674-683.
- MAHAPATRA, B.K., VINOD, K. and MANDAL, B.K. 2005. Export potentiality of native ornamental fish from North Eastern Hill States of India with a note for development of such fisheries. *Environment & Ecology*, 23 : 780-786.
- MAHAPATRA, B.K., VINOD, K. and MANDAL, B.K. 2007a. Native ornamental fisheries in Sikkim with its prospects and constraints, *Environment & Ecology*. 25S : 125-128.
- MAHAPATRA, B.K., VINOD, K. and MANDAL, B.K. 2007b. Breeding and larval rearing of *Labeo gonius* (Hamilton) under mid hill altitudinal region of Meghalaya. *Environment & Ecology*. 25S : 98-101.
- MAHAPATRA, B.K., VINOD, K. and MANDAL, B.K. (2007c). Breeding and larval rearing of *Labeo calbasu* (Hamilton) under mid hill altitudinal region of Meghalaya. *J. Interacad.* 11 : 345-350.
- NAYAK, P.K. and MANDAL, B.K. 1988. Composite fish culture in hills, using hill stream carps as components for pond culture. *Nat. Symp. Environ. Pr. Hill Dev.*, 15-17 Feb., pp. 83-86.

- NAYAK, P.K. and MANDAL, B. K. 1989a. Studies on composite fish culture in hills. *Indian J. Hill Farming*, 2 : 91-97.
- NAYAK, P.K. and MANDAL, B.K. 1989b. Feasibility of paddy-cum-fish culture in hills. *Indian J. Hill Farming*, 2 : 69-78.
- NAIR, K.S. (2004). Scope of expanding ornamental fish culture and trade and role of MPEDA. In: *Ornamental fish culture and trade in Northeastern India*. (Bhattacharjya, B. K. and Choudhury, M. Eds.). Work. Proc. CIFRI, Brackpore, Kolkata.
- SARMAH, S., BHATTACHARJYA, B.K., ZAIDI, S. and LANDGE, A. T. 2004. Indigenous ornamental fish biodiversity of central Brahmaputra valley zone, Assam. *J. Inland Fish. Soc. India* 36 : 29-35.
- SEN, N. 2000. Occurrence, distribution and status of diversified fish fauna of North East India. In : *Fish Biodiversity of North East India*. (Ponniah, A.G. and Sarkar, U.K. Eds.). NBFGF, NATP Publ., 2 : 31-48.
- SINHA, M. 1994. Fish Genetic Resources of Northeastern Region of India. *J. Inland Fish. Soc. India*, 26 : 1-19.
- TALWAR, P. K. and JHINGRAN, A. 1991. Inland fishes of India and adjacent countries. Oxford and IBH Publishing, Delhi, Vol. 1 and 2 : 1158 p.
- VINOD, K., MAHAPATRA, B. K. and MANDAL, B.K. 2006. Fish biodiversity of Nagaland and their conservation status. *Environment & Ecology*, 24S : 203-207.
- YADAVA, Y.S. and CHANDRA, R. 1994. Some threatened carps and cat fishes of Brahmaputra river system. Pages 45-55. In : P.V. Dehadrai, P. Das and S.R. Verma (eds.). *Threatened fishes of India*, Nature Conservators, Muzaffarnagar.

ICHTHYOPLANKTON LOSS IN COASTAL WEST BENGAL

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ABSTRACT

Wild harvest of prawn seeds is a common practice in the coastal zone of West Bengal due to which a wide variety of Ichthyoplankton are trapped and destroyed during the screening operation. A survey on this aspect was conducted at Namkhana fish landing station during 2004. The findings of this paper highlight that the quantum of loss is maximum during the premonsoon, followed by post-monsoon and monsoon. Some conservation oriented schemes have been proposed to divert the prawn seed collectors from this destructive operation.

Keywords : *Ichthyoplankton, prawn seed, Mangrove*

INTRODUCTION

The demand for protein in the western world has increased significantly since last two decades. To keep pace with this ever-increasing demand attention from the terrestrial resources has been shifted to the blue soup of this planet, which covers about 3/4th of the total earth's surface. This is the marine and estuarine compartment, which is not only a unique storehouse of chemicals, natural gas and minerals, but also a reservoir of aquacultural products like scallops, mussels, oysters, kelps, crabs, shrimps and prawns. The thrust towards tiger prawn (*Penaeus monodon*) culture has, however, exceeded any other aquacultural products in the present era and hence the industry of shrimp culture has taken a giant leap in recent times.

In order to keep pace within the aquacultural growth of Govt. of India and many other maritime Indian states, West Bengal intensified efforts during the Sixth plan to develop coastal aquaculture, especially shrimp farming (BOBP/WP/80). Presently a large number of farms have

been developed in coastal areas, which are mainly dependent on the supply of prawn seeds (post larval stages of tiger prawn) collected widely from the coastal and estuarine waters (Trivedi *et al.*, 1994). In fact this practice of wild harvesting of prawn seed has been adopted due to meager supply of seeds from the hatcheries which is almost nil in West Bengal (MOEF Project report, 1996, J/22014/11/93 CSC M). It has been observed that during the collection of prawn seeds from coastal waters, juveniles of many species of finfish and shellfish are trapped in the nets, but they are thrown away and wasted, as they are non remunerative (BOBP/WP/80).

The present article aims to highlight the quantum of finfish juveniles destroyed during the wild harvest of prawn seeds at Namkhana during January, 2004 to December, 2004. The diversity index values ($\bar{H}$) were computed on monthly basis from the wasted Ichthyoplankton to get a problem picture of the quantum of the ecological crop loss that may pose a negative impact on the pelagic and demersal fishery stock around the study area in near future.

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MATERIALS AND METHODS

Ichthyoplankton were collected monthly from prawn seed collectors and preserved in 4% formalin for taxonomic identification and species-wise quantification. 10g composite samples, randomly pooled from 15 different nets were taken to enumerate the number of Ichthyoplankton species, the number of individual of each species and total number of individuals of all the species. These data were finally used to compute Shannon Weaver Species Diversity index (1949) by developing a programme in FORTRAN. The data collection and enumeration of ecological index continued for 12 successive months from Namkhana

(during January, 2004 to December, 2004) of coastal West Bengal.

RESULTS AND DISCUSSION

The values of Shannon Weaver Species Diversity index showed a unique seasonal variation with highest value during premonsoon and lowest during monsoon. This may be attributed to breeding period of most of the marine and estuarine fishes during March/April in this part of the Indian Sub-continent. The order of ecological diversity is Apr > Jun > May > Oct > Nov > Feb > Jan > Dec > Aug > Jul > Sept. Hence from the biodiversity point of view, the premonsoon season appears to be at the top of seasonal Ichthyoplankton calendar (Table 1).

Table 1. Mean number of finfish species in 10 g composite wasted sample collected from Namkhana during January 2004 to December 2004.

Species	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1 <i>Coilia</i> sp.	13	2	1	4	2	11		1		2	5	1
2 <i>Thryssa hamiltonii</i>	20	6	9	11	4	16				7	15	
3 <i>Thryssa baelama</i>	28	9	11	12	1	23	2	9	2	15	21	2
4 <i>Torquigener oblongus</i>	18	5	5	8	4	15	-	2		6	9	4
5 <i>Rhinomugil corsula</i>	9	1	1	2	2	6				5	2	
6 <i>Mugil cephalus</i>	15	4	5	6	2	11	2	2	4	5	9	1
7 <i>Sillaginopsis panijus</i>	11	1	9	7	2	9		1		4	8	2
8 <i>Sillago sihama</i>	5	5	2	2	5	4				5	2	4
9 <i>Sillago soringa</i>	9	2	4	2	11	6				2	5	7
10 <i>Xenarchopterus dispar</i>	2			4		5				1	1	
11 <i>Glossogobius guiris</i>	19	9	7	10	5	12			2	10	11	2
12 <i>Pseudapocryptes lanceolatus</i>	9	1		1	4	7					7	1
13 <i>Eupleurogrammus glossodon</i>	1				-		2	1	7			2
14 <i>Pseudorhombus</i> sp.	12	1	7	8	4	10		4		7	9	1
15 <i>Pisodonophis boro</i>		11			10		7	4	7			9
16 <i>Tenualosa ilisha</i>		2	6	8	1	1				7	2	-
17 <i>Cynoglossus arel</i>	5	-		1		4					1	
18 <i>Stolephorus</i> sp.	7	4	5	4	5	6	1	1	1	5	2	2
19 <i>Leiognathus</i> sp.	1	2	1	2	1	4				1	4	1
20 <i>Hilsa</i> sp.		1	2	2		1			-	1	1	
21 <i>Scatophagus argus</i>	1	1	2	2	1	4	2	5	5	1	2	1
22 <i>Liza parsia</i>	1	1	1	4	1	6	2	1	-	1	5	
23 <i>Liza tade</i>	1		2	4	1	2		1		2	8	-

Table 1. *Contd.*

Species	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
24 <i>Stolephorus commersonii</i>	2	4	6	5	4	5	2	1	1	2	4	2
25 <i>Stolephorus baganensis</i>	2	1	1	5	3	2	4	5	1	4	2	1
26 <i>Stolephorus kammalensis</i>	1	2	2	1	5	4	8	6	2	5	2	1
27 <i>Lutjanus johni</i>	4	4	5	5	5	4			-	7	2	
28 <i>Setipinna taty</i>	1	1	4	2	2	2				5	2	4
N	197	80	93	122	85	180	32	44	32	110	141	48
($\bar{H}$)	2.795	2.858	2.912	3.041	2.941	3.011	2.087	2.409	2.059	2.938	2.928	2.655

Marine ecologists generally agree that inshore areas are highly productive and provide unique nursery and breeding grounds for various types of organisms (Jansson *et al.*, 1988). The correlation between offshore prawn catches and real extent of mangroves have been suggested to be indicative of the dependence of juveniles prawns on mangroves rather than of the food chain link (Macnae, 1974; Turner, 1977; Hatcher *et al.*, 1989). Although of off-shore region did not carry the mangrove carbon signal, it was shown that several species of juvenile prawns collected from mangrove inlet consumed mangrove derived carbon (Rodelli *et al.*, 1984).

The coastal zone of West Bengal supporting the world's famous mangrove chunk, the Indian Sundarbans is the most biologically productive ecotone of the country (Mitra *et al.*, 1992) which is nourishing billions of drifting communities, macro and micro, phyto and zoo, known as **plankton** of which the post larval stage of *Penaeus monodon* is a vital component. After being hatched mainly in the shelf-slope break of the oceanic compartment, these larvae migrate to the coastal region in billions to obtain their nourishment from the ambient aquatic medium.

A significant portion of the coastal fisher folk in the state of West Bengal, constantly

expose themselves, irrespective of sex and age to estuarine water for catching prawn seeds in order to earn their livelihood. They employ nets of smaller mesh sizes to haul the drifting community irrespective of the high and low tides and throw away the major portion of the haul (containing the juveniles of other varieties of finfish and shellfish) after sorting out the post larvae (or seeds) of tiger prawn (*Penaeus monodon*). Thus the practice inflicts a great loss on diversity, which might cause an adverse effect on the delicate ecological balance of the system (Trivedi *et al.*, 1994). A negative impact is also obvious in the prospect of pelagic as well as demersal fisheries of the coastal zone due to such indiscriminate destruction of various species of fishes in their juvenile stages. This prompted to choose the present problem to highlight the quantum of damage cause to the environment in the advent of 21st century. It is no exaggeration to say that this wild harvest of prawn seeds destroy huge quantum of different categories of fishes in their juvenile stage, which, if allowed to grow without damaging their population might contribute to the economic development of the country through capture and culture fisheries. The magnitude of destruction is maximum during premonsoon, followed by post monsoon. Hence a signal of caution may be transmitted to the coastal fisher folk to avoid this destructive

practice at least in the month of March to June from the conservation point of view.

The present practice has penetrated its root deep into the socio-economic matrix of the coastal fisher folk and therefore forceful banning may create a problem of different dimension. Hence initiation of tiger prawn

nursery, mass awareness programme on regular basis, self-help group formation and alternative source of income (through crab fattening, oyster culture, ornamental fish culture, fish feed formulation and preparation, etc.) are some of the positive steps to eradicate this destruction practice of tiger prawn seed collection.

LITERATURE CITED

- BANERJEE, B.K. and SINGH, H. 1993. The shrimp fry by-catch in West Bengal, India. Technical Report of the Bay of Bengal Programme (BOBP/WP/80). 1-26.
- HATCHER, B.G., JOHANNES, R.E. and ROBERTSON, A.I. 1989. Review of research relevant to the conservation of shallow tropical marine ecosystems. *Oceanogr. Mar. Biol. Annu. Rev.*, 27 : 337-416.
- JANSSON, B.O., MCLNTYRE, A.D., NIXON, S.W., PANATMAT, M., ZEITZSCHEL, B and ZIJLSTRA, J. J. 1988. Coastal offshore interactions an evaluation of presented evidence. In B.O. Jansson (ed.), *Coastal offshore ecosystem interactions*, Springer verlag., 357-363.
- MACNAE, W. 1974. Mangrove forests and fisheries. FAO, Rome. 35.
- MITRA, A., CHOWDHURY, A, and ZAMADAR, Y. 1992. Seasonal variation in metal content in the gastropod *Cerithedia cingulata*. *Proc. Zool. Soc., Calcutta*, 45 : 497-500.
- MITRA, A.; NIYOGLI, S and CHOWDHURY, A. 1989. In Living resources of India's Exclusive Economic Zone, Society for Indian Ocean Studies, New Delhi (India) Quasim. S. Z. and Roonwal, G.S. (eds). Omega Scientific Publishers, India, 86-96.
- MOEF, 1996. Final report of the project entitled "Impact of mass collection of prawn seeds in mangrove ecosystem of Sunderban Biosphere Reserve". Sanction No. J-22014/11/93-CSC[M]; Project undertaken by S.D. Marine Biological Research Institute (Sagar Island).
- RODELLI, M.R., GEARING, J.N., GEARING, P.J., MARSHALL, N. and SASEKUMAR, A. 1984. Stable isotope ratio as a tracer of mangrove carbon in Malaysian ecosystems. *Ecologia*, 61 : 326-333.
- SHANNON, C.E. and WEAVER, W. 1949. The mathematical theory of communications. University of Illinois press. Urbana.
- TRIVEDI, S., MITRA, A., CHOWDHURY, A., GUPTA, A., SINGH, B. and CHOWDHURY, A. 1994. Case study of the loss of biodiversity during prawn seed collection from the Hooghly estuary, India. *Proceedings of the National Convention of Environment of India : Challenges for the 21st century, India* : T-V/16T-V/24.
- TURNER, R.E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. *Trans. Am. Fish. Soc.*, 106 : 411-416.

DIVERSITY OF MICROARTHROPODS AND THEIR ROLE IN THE PLANT LITTER DECOMPOSITION IN THE COASTAL TRACT OF EAST MIDNAPORE DISTRICT, WEST BENGAL, INDIA

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ABSTRACT

Soil microarthropods represent an important group of faunal components in any coastal mangroves estuarine ecosystem. Midnapore coastal tract represents 27% (60km) of West Bengal coastal line. Out of two coastal districts of West Bengal, coastal tract of Midnapore (East) district is characterized by sand dunes, long shore currents, high salinity and less vegetational coverage in comparison to its counter part South 24 Parganas district supported by Sundarban Mangrove Ecosystem. This coast extends along the West Bank of Hooghly Estuary from New Digha at the extreme south point of Midnapore district and then curving around Junput, Dadanpathrabhar, Khejuree and Nayachar Island. An attempt has been made in the present paper to document the distributional pattern of intertidal microarthropods of this short, sensitive, productive and eco-degrading coastal tract of West Bengal and also to study the role of microarthropods in the process of selected mangrove plant litter decomposition at a selected study site. A total of 7 major groups of soil microarthropods viz., Acarina, Collembola, Coleoptera, Diptera, Isopoda, Hymenoptera and other arthropods were found to be the inhabitants of different areas of coastal environment of Midnapore District(East). A total number of 51 species were found to belong under those groups of microarthropods. Maximum number was recorded from Nayachar Island (Number of Species 44) followed by Dadanpathrabhar (26 species) Khejuree (25 species) and Junput (22 species). Comprehensive laboratory studies on the role of different microarthropods in the decomposition of a selected mangrove plant species, *Rhizophora mucronata* (L) revealed successional occurrences of different microarthropods in the different stages of decomposition. The changes of physico-chemical parameters were also studied viz., pH, Organic Carbon (%), Salinity (ppt), Total-N(ppm), Total-phosphorus(ppm) and Available-K (ppm) to relate such changes with the changing pattern of species composition and density fluctuation of microarthropods in the process of litter decomposition.

Keywords : Midnapore Coast, Microarthropods, Mangroves, and Decomposition.

INTRODUCTION

The mangrove-estuarine ecosystem represents one of the most productive ecosystems of the world because it combines two sub-systems—shallow water forest mangrove subsystem and estuarine aquatic subsystem linked together by virtue of one important physical process, the tidal cycle enjoying two high tides and two low tides in a

day. The shallow water forest sub-system exports energy and nutrient to deeper water of estuaries and other coastal areas in the form of mangrove plant's contributed detritus which are transported from the mangrove forest to adjoining open water bodies (Odum and Heald 1975). The living organisms viz., plankton, benthos and necton move freely between the two fixed sub-systems producing, converting and transporting nutrient and energy, while

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responding to diurnal, tidal and seasonal periodicity (Odum 1971). Soil microarthropods and their role in the decomposition and nutrients cycling of different terrestrial forest ecosystems have been a subject for scientific investigations all over the globe since the pioneer work of Diem 1903 followed by subsequent researchers of McAttee 1907, Imms 1912, Dixon 1928, Agrell 1941, Choudhuri and Roy 1970, Prabhoo 1967, Bhattacharya and Roychoudhuri 1979, Reynolds and Hunter 2001. However, investigations on soil microarthropods in any marine estuarine coastal mangrove system have been restricted mainly on taxonomic studies and scanty information have been available on the ecology of these groups of organisms (Hazra and Choudhuri 1990, Holfield and Dimmick 1995, Chattopadhyaya and Hazra 2000, Hazra and Sanyal 1996, Das and Nandi 1999). The role of mangrove-supratidal litter inhabiting microarthropods on mangrove-litter decomposition process has not yet been dealt with from any part of the globe.

In the above context, the objective of the present study was of four folds—(i) to make an inventory of different microarthropods that occurred throughout the East Midnapore coastal tract of West Bengal, (ii) to record the seasonal dynamics of different soil parameters in different study sites of this coastal environment and to document the distributional pattern of microarthropods in those studied biotopes, (iii) to determine the in-situ decomposition of a selected mangrove *Rhizophora mucronata* (L) plant litter and the role of microarthropods in the process of decomposition and lastly (iv) to assess the successional changes of microarthropod community in respect to the changes of different physical parameters of the decomposing litters in different phases of decomposition process.

MATERIALS AND METHODS

A) Selection of study sites

The coastal area of West Bengal extends over 0.82 million hectares and along 220km of coastal line. Out of two coastal districts of West

Bengal, coastal zones of Midnapore (East) is characterized by sand dunes, long shore currents, high salinity, less turbidity and less vegetational coverage in comparison to its counter part South 24 parganas district supported by Sundarban Mangrove Ecosystem of global importance. Midnapore coast (60km) represents 27% of West Bengal coastal tract extending along the West Bank of Hooghly Estuary from New Digha at the extreme Southwest point of Midnapore district and then curving around Junput, Dadanpathrabarh, Khejuree and Haldia along with Nayachar Island. A variety of geomorphological structures including estuaries, mangrove swamps, sandflats and mudflats, dunes, tidal creeks have been found to reveal different characteristics in different study sites (sites-1-4) along the stretch of Hooghly estuary of East Midnapore district (Fig. 1). Out of four study sites, mudflats were noticed in three study sites viz., Nayachar, Khejuree, Junput, while sandflat was found in Dadanpathrabhar (Khalua *et al.* 2003). Tidal creeks of different lengths and dimensions have been located in different study sites and their functional contribution to the intertidal zones differ with regard to their location in respect to sea in different study sites. Mudflats were supposed to have been developed in some sheltered areas along the East Midnapore coast because of higher rate of sedimentation coupled with low velocity of tidal currents. The finer sediment constituting the thick mudflats was rich in organic contents and was ideal for penetration by plant roots. The growth and propagation of plants help the mudflats to stabilize and thereby paved the way for the creation of new landmasses with their specialized characteristics. The activities of fauna in the intertidal mudflats create several micromorphological structures, which are very important for trapping more sediment, and in turn promote the growth of algae and higher plants. Sandflats were thought to have been developed in the areas of coastal tract where strong tidal action usually plays significant role at the estuarine mouth where a large quantity of sediments after being carried by estuary are deposited. The formation of ripples and dunes

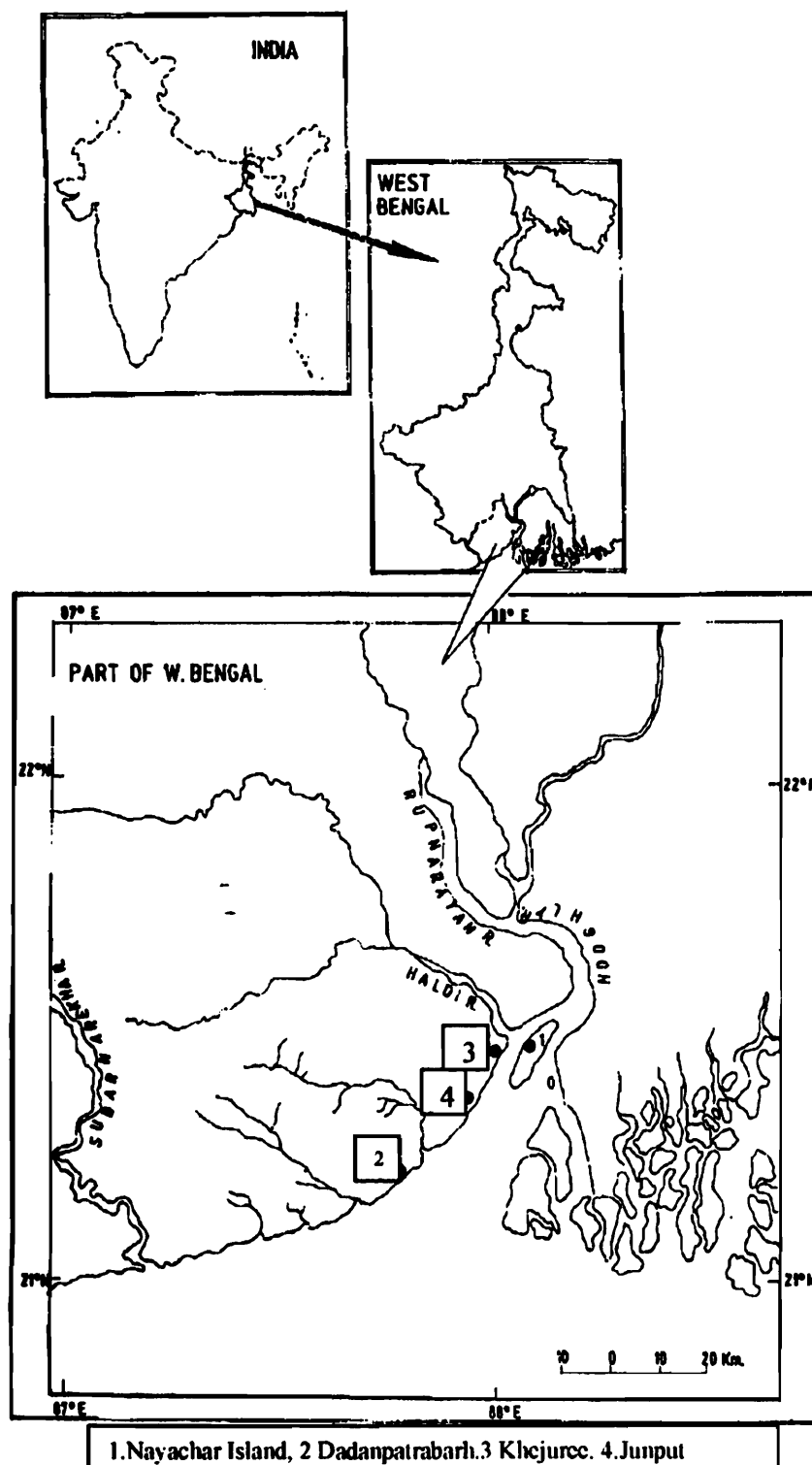


Fig. 1. Map showing different study sites (S-1–S-4) along the coastal tract of Midnapore (E) District, West Bengal.

by the long shore current with higher intensity increase the rate of sedimentation and thereby form the surface of the sandflats.

Ecological characteristics of different study sites

i) **Study site-1 :** The Nayachar Island representing the study site-1 is encircled on all

of its sides by the river Hooghly estuary and its tributaries and enjoys a position just opposite to the port of Haldia in West Bengal. The island is spindle shaped with total area of about 29.38 sq km. The island is flat with an average height of 3' to 5' from riverbed. The formation of the island is the outcome of the high tide and low tide action of river water since 1988. It bifurcates

the Hooghly River into Haldia and Rangafalla channels. This island has been formed because of sediment deposition during the past several decades and started accreting from 1945. Between 1967 and 1997, the island progressively enlarged in its area. The Calcutta port trust started re-vegetating this erosion prone island with mangroves in collaboration with Zoological Survey of India at its North-Eastern region covering an area of about 4 sq km during 1991. The climate in this island is of subtropical type. Mangrove plants like *Sonneratia apetala* (Buch-Hum) was first planted followed by *Avicennia marina* (Forsk), *A. officinalis*(L), *Rhizophora mucronata* (L), *Exocoecaria agallocha* (L), *Xylocarpus mekongensis* Koenig and *X. granatum* Koenig. With the passage of time other halophytic vegetations like *Porteresia coarctata* (Roxb) Takeoka, *Salicornia brachiata* Roxb, *Acanthus ilicifolius* (L) and *Ipomoea bilobata*(L) have been grown up in different parts of this island.

ii) **Study site-2** : This study site has been selected in the supratidal zone of Dadanpathrabarh which has been developed as an important fish landing and processing center, 18km away from Kontai by the side of Hooghly Estuary. A small patch of old degraded mangroves has been thriving for their survival. Soil of the intertidal belt is sandy with the *Suaeda mudiflora* (Roxb) and *Exocoecaria agallocha* (L). Supratidal zone is characterized by the presence of several dunes stabilized by *Ipomoea bilobata*(L), *A. officinalis*, *Salicornia brachiata* Roxb and *Derris indica* Bennet.

iii) **Study site-3** : This study site named as Khejuree, a small coastal area with historical importance is situated at the flank of Haldi estuary. This area is under tremendous ecological threat due to deforestation coupled with rapid pace of urbanization. Intertidal zone is characterized in having scanty old mangrove plants viz., *Avicennia alba*, *Exocoecaria agallocha*, *Salicornia brachiata* and *Derris indica*. A good number of newly planted mangroves like *Rhizophora mucronata* and *A.officinalis* have been growing up in this coastal tract. The soil is basically muddy with very fine sand particles on the top.

iv) **Study site-4** : The supratidal zone of Junput, an important fish landing center, located 15km east of Contai sub-divisional town has been selected as study site-4. Scanty patches of old and newborn mangroves are present in this study site. Soil is basically sandy loam type in the supratidal levels while low and midtidal zone are with soft mud.

B) Methods of Samplings, Collection, Extraction, Preservation and Identification of different soil arthropods

Soil samples were collected at the rate of three samples per plot at monthly interval during July 2003–to December 2005. Samples were drawn by using a stainless steel corer (inner cross sectional diameter is 8.5sq/cm) from a depth of 5 cm. Every study site has three subsampling plots. Therefore, nine samples were collected from each study site. Altogether 36 samples were collected in every month.

Separate samples were collected from each study site for estimation of soil parameters, like salinity, total nitrogen, total phosphorus, available potassium and organic carbon. The soil samples after being collected were kept in sterile polythene packets for future laboratory analysis.

The apparatus used for the extraction of soil microarthropods was designed following Macfadyen (1953). Soil fauna were preserved in the glass tubes with 70% alcohol. The collected fauna were then sorted out into different groups under stereoscopic binocular microscope, counted and preserved in glass vials containing 70% alcohol for further study.

C) Studies on Decomposition of litter

For the study of decomposition of mangrove leaves, one mangrove plant *Rhizophora mucronata* was selected. Litter decomposition and the mode of release of nutrients was determined by litterbag methods (Anderson 1973). The leaves of *Rhizophora mucronata* were collected from the mangrove belt of Nayachar Island and then packed in litterbags. All the time, four bags containing 200gms of litters were placed in the forest floor (below 5cm) with

a distance of 10-feet from each others. One set of litterbag was drawn from the forest floor after 3 months and other 3 sets were drawn at 6 months, 9 months and 12 months intervals respectively. The litter decomposition rate was calculated according to Obson's (1963) exponential decay model.

D) Analysis of Physico-chemical parameters of soil and decomposed plant-litter soil

(i) **Temperature**—Soil thermometer was used to record the temperature of soil. (ii) **pH**—pH of the soil was determined by electronic pH meter (WTW pH 320); (iii) **Moisture**—moisture of the sample was measured by the 'Oven-Dry method' (Dowdenswall 1959); (iv) **Organic carbon**—organic carbon content of the soil was determined by rapid titration method (Walkely and Black 1934); (v) **Salinity**—salinity of different soil samples were estimated according to Strickland and Parsons 1968; (vi) **Total phosphorus**—total phosphorus of soil samples were measured by the method of Murphy and Riley 1962; (vii) **Total nitrogen and Available potassium** of soil samples were estimated by Jackson 1967 and Murphy and Riley 1962 respectively.

RESULTS

Ecological parameters viz., temperature, humidity, rainfall, pH, organic carbon, total-N, total-P and available-K of different study sites displayed similar trend of fluctuation through different months, seasons and years of the study period (July, 2003-December 2005). However, some ecological parameters viz., Organic carbon, total-N and available-K of soil exhibited differences with regard to their seasonal variation in different study sites. Maximum and minimum temperature during the study period was found to be 14°C (December 2003 at study site-1) and 38°C (May, 2004 at study site-3). Maximum and minimum rainfall were recorded during the month of July, 2003 (study site-1) and December, 2004 (study site-4). However, maximum humidity was found to be 98% in July at study site-1 and 70% in February at study site-3. pH ranged from 6.67 in October 2004 at study site-1 and 7.65 in

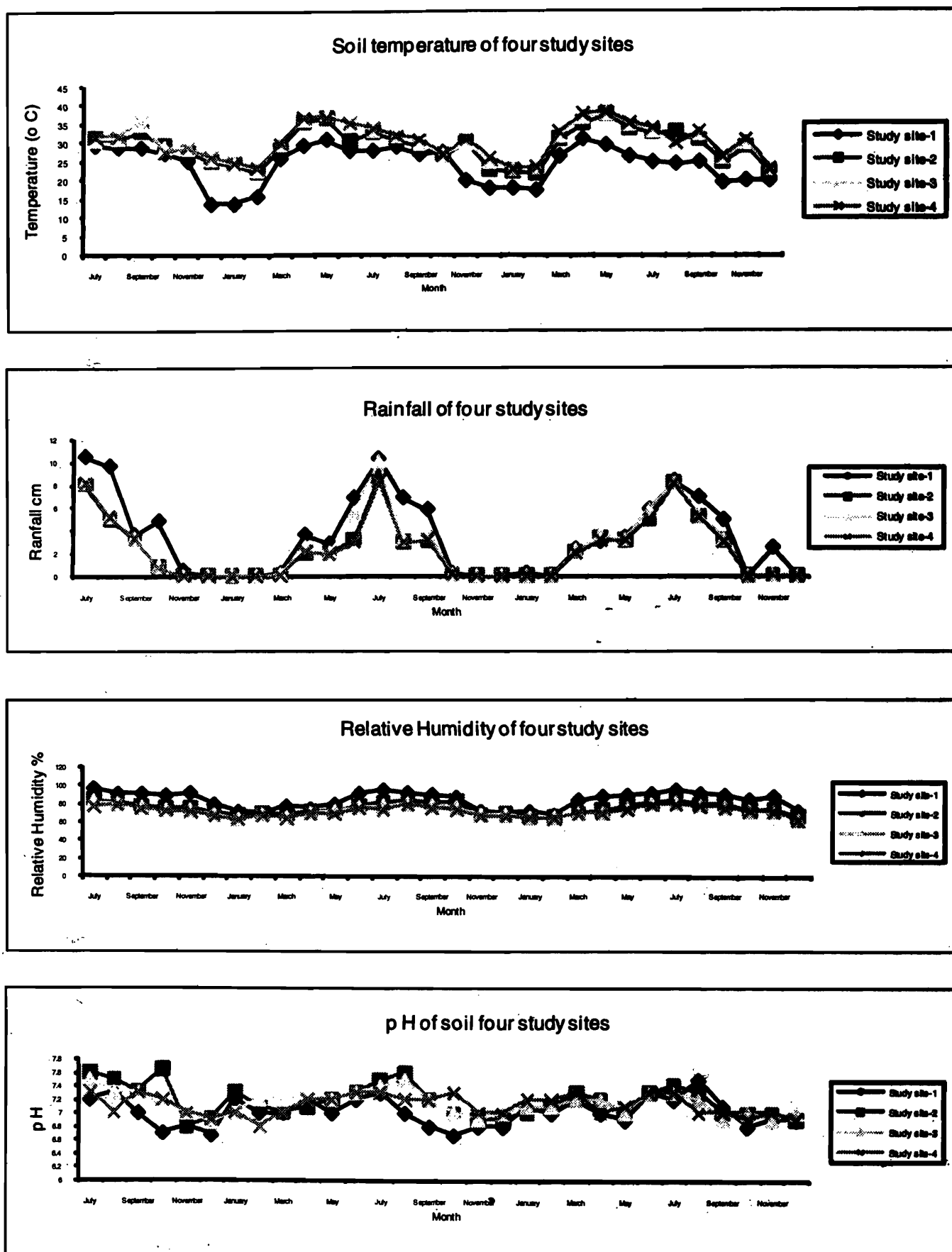
October 2003 at study site-1. Organic carbon of the soil displayed maximum value in the month of November (6.7%) at study site-1 and that of minimum (1.7%) in October 2005 (study site-4). Minimum salinity (0.2 ppt) was recorded in the month of February 2005 at study site-1 and that of maximum (7.2 ppt) was found in the March 2004 at study site-4. Maximum value of total-N (4020 ppm) was observed in November 2003 at study site-1 whereas minimum (490ppm) value was recorded in the month of January 2004 at study site-4. Maximum and minimum values of total-P were recorded (360ppm) in August 2004 at study site-1 and in February 2004 at study site-2 respectively. Values of available-K were estimated highest (280 ppm) and lowest (190 ppm) during the months of October 2005 at study site-1 and May 2004 at study site-4 respectively (Fig-2).

Species composition and distribution of all study sites

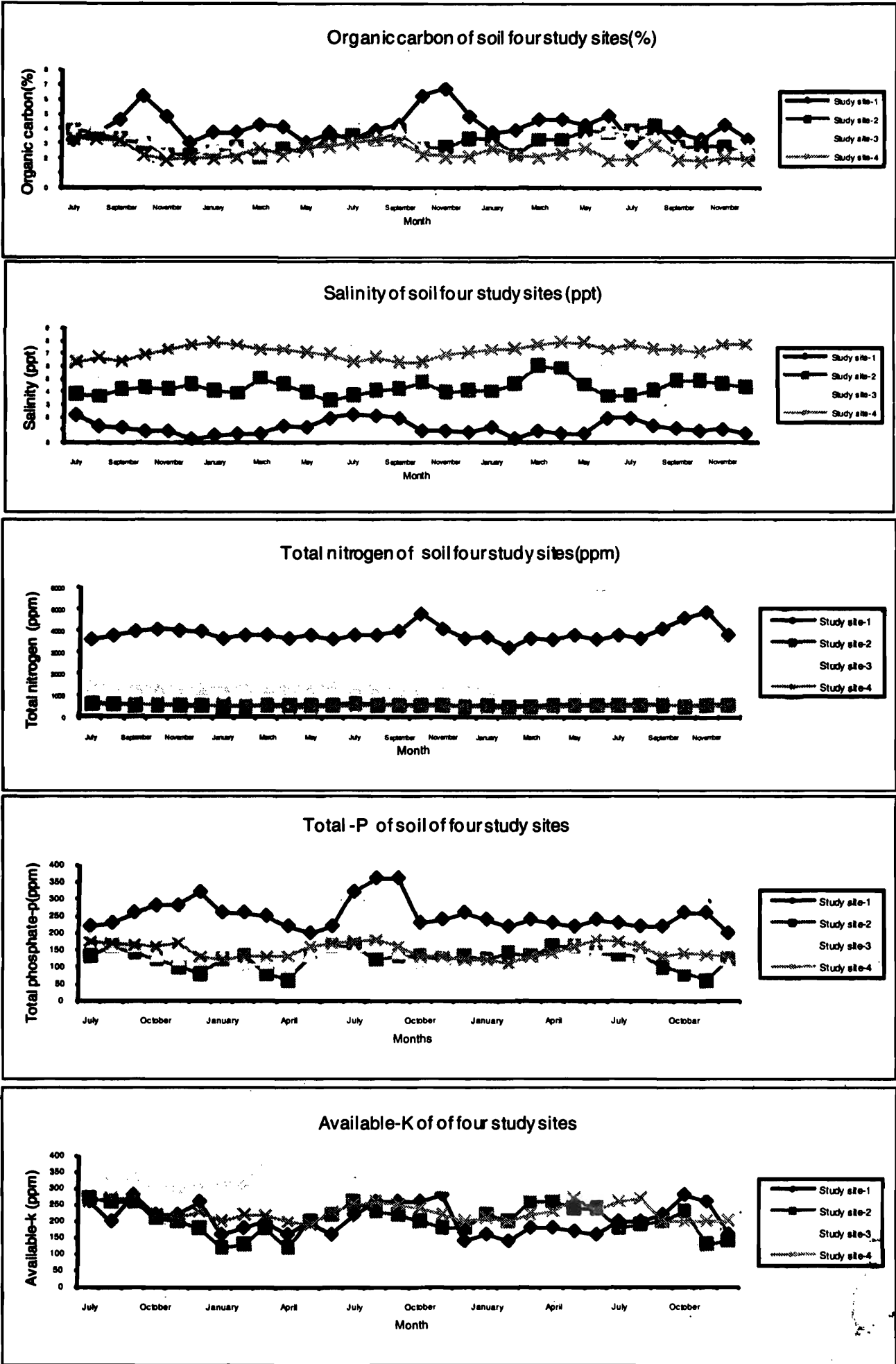
The different species under the order Collembola represented the most abundant faunal component constituting the microarthropod communities, which included 15 genera. Maximum number of Collembola were encountered in the month of October and November (study site-1) whereas minimum collembola population was recorded in the month of March and April of the year 2003 (study site-4). Out of 15 species of collembola, genus *Isotomurus* sp was found in all study sites, and in the most of the months of the study period. Other Collembola species in terms of their abundance were *Isotomurus ciliatus*, *Isotomocella minor*, *Stenognathellus* sp., *Entomobrya* sp., *Sinella* sp., *Lepidocyrtus* sp., *Calx* sp., *Lepidocyrtus medius*, *Pseudochorts* sp., *Megatothorax minimus*, *Smithurus* sp., *Cyphoderus* sp., *Subisotoma fitchioides*, *Cryptopygus* sp. and *Proisotoma* sp., (Tables.1-4).

Acarina fauna was recorded from all the study sites and it included 13 species under 11 genera. Maximum number of Acarina occurred in the month of October and November of the year 2004 (study site-1), whereas minimum occurrence was recorded in the month of March and April of the year 2003 (study site-4). Out of

Fig. 2. Seasonal fluctuation of different ecological parameters of four different study sites during the study period (July, 2003-Dec, 2005)



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13 species of Acarina, *Scheloribates* sp., was recorded in the maximum number throughout the study period. Other Acarina species in terms of their abundance were *Scheloribates thermophilus*, *Scheloribates parvus*, *Scheloribates praeincisus*, *Xylobates seminudus*, *Galumna flabellifera*, *Oppia* sp., *Javacarus kuhneli*, *Atropacarus* sp., *Mesotritia* sp., *Megalozetes procesus* and *Hypoaspis aculeifer*. (Tables. 1-4)

Dipteran fauna belonging to families Tipulidae and Mycetophilidae were recorded from all four study sites. Maximum Diptera population was recorded in the months of September and October of the year 2004 (study site-1) whereas minimum population was found in the months of March and April 2005 (study site-4). The Dipteran family Mycetophilidae was found in all of the study sites, while the diptera under the family Tipulidae was recorded in the study sites-1,2 and 3. Two different species under two orders of Isopoda were recorded from four study sites. Maximum population of Isopoda was recorded in the months of January and September (study site-1) whereas minimum population was found in the month of March (study site-4) (Tables.1-4).

Hymenopteran fauna from four study sites included four species under two genera. Maximum Hymenoptera population was found in the month of October of the year 2004 (study site-1) whereas minimum population was recorded in the months of March and April 2005 (study site 1 and 2). Only Hymenopteran species *Monomorium latinode* was found to occur in the study site-1. Other Hymenoptera species like *destructor* and *floricole* were recorded from all study sites. Other soil arthropods recorded from four study sites belonged to three groups like Araneae, Centipede and Millipede (Tables-1-4).

Role of microarthropods and their succession in the process of litter decomposition

One major mangrove plant species, *Rhizophora mucronata* (L) was selected for the experimental studies to record the rate of leaf litter decomposition, the succession in the occurrence of different microarthropodal faunal

components and trend of changes of different physico-chemical parameters in different phases of decomposition process. The rate of decomposition of *Rhizophora mucronata* after 3 months was 47.50% whereas after 6 months it reached to 54% and 65% after 9 months whereas after 12 months it was 72% (Table-5). Relative abundance of soil microarthropod fauna found after 3 months were in the order of Acarina (37.5%) followed by Collembola (31.25%), Coleoptera (6.25%), Diptera (18.75%), Isopoda (0%), Hymenoptera (0%) and other arthropods (6.25%). After 6 months of decomposition, Collembola population (55.55%) was followed by Acarina (31.74%), Coleoptera (4.76%), Diptera (1.58%), Isopoda (1.58%), Hymenoptera (1.58%) and other arthropods (3.17%). After 9 months, Acarina population was recorded as 23.52% followed by Collembola (20.58%), Coleoptera (14.7%), Diptera (8.82%), Isopoda (14.7%), Hymenoptera (11.76%) and other arthropods (6.25%). After 12 months, 18.75% Acarina was recorded followed by Collembola (15.62%), Coleoptera (12.5%), Diptera (9.37%), Isopoda (21.87%), Hymenoptera (15.62%) and other arthropods (6.25%). Physico-chemical parameters also displayed unique variation in different phases of decomposition. After 3 months, changes of physico-chemical parameters were recorded as pH(7.5), organic carbon (5.44%), salinity (0.12%), total-N(1240), total-P(104) and available-K (10). After 6 months of decomposition, the parameters were recorded as pH (6.2), organic carbon (6.4%), total-N (1280), total-P(134) and available-K(16). After 9 months, pH (6.6), organic carbon (6.3%), total-N (1290), total-P(120) and available-K(14). After 12 months, final record of different parameters were as pH (6.9), organic carbon (6%), total-N (1290), total-P (120) and available-K (14). (Figs.-3-9).

DISCUSSION

The present study was based on the sample survey of four different selected ecological habitats of Midnapore (East) coast of West Bengal, India, over a period of 30 months (July 2003-December 2005). Out of four study sites,

Table-1. Species composition of microarthropods under different order at study site-1 (Nayachar Island)

		2003							2004							2005																
Acarina	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D		
Scheloribates thermophilus	+			+		+		+				+			+	+	+		+			-	-			+	+	+		+		
Scheloribates parvus					+	+	+				+	+			+	-			+			-	-	+		+		+	+			
Scheloribates praeincisus	+	+	+	+	+					+	+					+	+	+					-				+		+			
Xylobates seminudus					+		+					+	+	+		+			-	+		-	-	+	+	-		+	-	+		
Galumna flabellifera		+	+	+				+	+	+						-	+	+	+			-	-			+	+		+			
Oppia sp						+							+	+		+	+					-	+		-		+	+		+		
Multioppia sp	+			+	+			-					+			+						-	-	+			+	+				
Tectocephus velatus					+	+										+		+		+	+	-	-		+	-			+			
Tavacarus kubnelti				+			+			-					+	+	+					-	-			-		+		-		
Atropacarus sp				+	+							+				-	+				+	+	-		+			+		-		
Mesotritia sp				+			+					+				+	+	+	-			-	-				+	-	+			
Megalozetes proceseus					+	+										+	+					-	+				+	+				
Hypohispis aculeifer					-									-		-		+									+	+	-			
Collembola	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D		
Isotomurus ciliatus	+	+	+	+	+	+	+			+	+	+	+		+	+	+		+	+		-	+			+	+	+	+	+		
Isotomicella minor		+	+	+	+											+	+				+	+	-				+	+	-			
Stenognathellus sp	+			+	+	+										-	+	-			+	-	-									
Entomobrya sp				+				+	+		+	+		+	+	+	+		+			+	+	+				+	+	+		
Sinella (Sinella)sp													+					-				-	-									
Lepidocyrtus(Ascocyrtus)sp				+	+	+	+	+	+	+						-	+	+	+			-	-		+	+	+		+			
Calt sp				+	+	+	+				-					+		-				-	-	-								
Lepidocyrtus medius													+			+	+			-		-	-		+	+	+	+	+			
Psedochorutes sp					+									-		-						-	-					-				
Megatothorax minimus					+				-		-			-	-	-		-		-		-	-					+	+			
Smithurus sp						+			-		-				+	+	+	+				-										
Cephoderus sp																+	+			-		-	-	+	+			+	+			
Subisotoma fitchioides																		+	+			-	-									
Cryptopygus sp					-										-							-				-	+	+	+			
Proisotoma sp																-						-					+	+				
Coleoptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D		
Carabidae		+	+	+							+			+	+	-						-			+				+			
Staphylinidae						+										-		+		+				+				+	+			
Dytiscidae				+										+	+			+				-										

Table-1. Contd.

Diptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Mycetophilidae</i>				+			+	+	+							+	+			+	+		+	+	+	+	+		+	
<i>Tipulidae</i>						+										-						-	-							
Isopoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Philoscia sp</i>													+		+	-						-	-				+			
<i>Porcellionides sp</i>							+	+								+			+			-	-		+	+		+	+	
Hymenoptera	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Monomorium destructor</i>			+				+									-		+	+			-	-					+	+	
<i>Monomorium floricola</i>					+	+			-		+				+	-			+			+	-		+	+			+	
<i>Monomorium latinode</i>									+						+	-	+					-	-			+	+			+
<i>Pheidole roberti</i>									+	+			-			-		+				-	-			-				-
Other arthropoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
Spider (Arenae)																														
<i>Marpissa sp</i>				+	+											-														
<i>Artema sp</i>																-										+				
<i>Uroctea sp</i>							+									-						+	-	+						
<i>Centipede</i>													+			-				+		-	-					+		
<i>Milliped</i>																-			+			-	-							+

Table-2. Species composition of microarthropods under the order Acarina at study site-2 (Dadanpathrabhar)

			2003						2004													2005												
Acarina	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D				
<i>Scheloribates thermophilus</i>	+				+	+						+	+			-		+		+								+						
<i>Scheloribates parvus</i>		+	+							--					+	-	-	+					+											
<i>Scheloribates praeincisus</i>				+		+							+		-	+			+		+	-					+	+	+					
<i>Xylobates seminudus</i>		+					+	+	+						+	-															+			
<i>Galumna flabellifera</i>			+													-	+								+	+		-						
<i>Oppia</i> sp	+												+		-				+								-							

Species composition of microarthropods under the order Collembola at study site-2 (Dadanpathrabhar)

			2003							2004												2005													
Collembola	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D					
<i>Isotomurus ciliatus</i>	-	+				+	-		-	-	-	+	+												+	+									
<i>Isotomicella minor</i>	+	+	+	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-		-	+									

<i>Stenognathellus sp</i>		-		-	+					+										--	-	+		--	
<i>Entomobrya sp</i>		-		+				+					+		+	+	-	-			-				
<i>Sinella (Sinella)sp</i>		-		-			+						-				-	-				--			
<i>Lepidocyrtus(Ascocyrtus)sp</i>		-		-								+											--		
<i>Calt sp</i>		-		-									+	+		+							+	+	
<i>Lepidocyrtus medius</i>				-															+	+	-				
<i>Pseudochorutes sp</i>				-						--			--					-	-			+			

			2003						2004											2005															
Coleoptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D					
Carabidae	-	-	-	-	-	-	-	+	-	-	-	+	+	-	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Staphylinidae	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	

	2003								2004								2005													
Diptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Mycetophilidae</i>	+	+		-									+	+		-			+	+			-		+	+				

			2003					2004											2005											
Isopoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Philoscia sp</i>		-		-		+	+									-													+	
<i>Porcellionides sp</i>				-			+				+					-						-	-	+						

	2003			2004										2005																
Hymenoptera	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Monomorium destructor</i>		-		-		+				+						-					+	-	-	+						+
<i>Monomorium floricola</i>				-			+									-			+				-	+						+

			2003						2004										2005											
Other arthropoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Spider (Arenae)</i>																														
<i>Marpissa sp</i>	+		+													-						-	-							
<i>Centiped</i>				-		-	+								+	-						-	-			+				
<i>Millipede</i>				-										+		-						-	-				--			

			2003						2004											2005										
Acarina	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Scheloribates thermophilus</i>	+			-			+	+				+	+			-		++	+			-		+	+					
<i>Scheloribates parvus</i>				-				+					+			-	+		+			-	-		+	+				
<i>Scheloribates praeincisus</i>		-	+	-		+	+		+					+		-	-			+		-	-							+
<i>Xylobates seminudus</i>	+	+		-						+					+	-				+		-	-			+	+			
<i>Galumna flabellifera</i>		+			+	+					+			+		-					+		-					+	+	+
<i>Oppia</i> sp				+								+			+	+						+	-							

[illegible]

			2003						2004										2005											
Coleoptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
Carabidae		+	+													-											+			
Staphylinidae													+			-								+						

			2003						2004										2005											
Diptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Mycetophilidae</i>	+	+	+		+		+					+				-								+		+	+	+		

[illegible]

Table-3. Contd.

Species composition of microarthropods under the order Hymenoptera at study site-3 (Khejuree)

		2003								2004								2005																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																

Species composition of Other arthropods at study site-3(Khejuree)

			2003						2004												2005									
Other arthropoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
Spider (Arenae)																														
Marpissa sp				+												-														
Centiped		—				+										--			+	+					+					
Milliped										+						-														+

Table-4. Species composition of microarthropods under the order Acarina at study site-4 (Junput)

			2003						2004											2005										
Acarina	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Scheloribates thermophilus</i>								+								+	-									+				
<i>Scheloribates parvus</i>	+	-					+							+	+	-	+							+						
<i>Scheloribates praecinctus</i>						+									+	-			+	+						+				
<i>Xylobates seminudus</i>		+	+									+	+			-											+			
<i>Galumna flabellifera</i>				+					+			+				-	-	-	+											
<i>Oppia</i> sp	+													+		-		+	+											+
<i>Multioppia</i> sp					+											-													--	

Species composition of microarthropods under the order Collembola at study site-4 (Junput)

			2003						2004											2005										
Collembola	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Isotomurus ciliatus</i>	+	+					+									-		+	+											
<i>Isotomicella minor</i>					+								+	+		-								+	+					
<i>Stenognathellus</i> sp		+		+								+	+			-					+	+	—			-				
<i>Entomobrya</i> sp			+				+									-											+			
<i>Sinella</i> (<i>Sinella</i>)sp	+			+				+						+	+	-									+					
<i>Lepidocyrtus</i> (<i>Ascocyrtus</i>)sp											+	+				-	+						+							

Table-4. Contd.

Species composition under the different families of Coleoptera at study site-4 (Junput)

			2003										2004																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															

Species composition under the different families of Diptera at study site-4 (Junput)

			2003									2004									2005														
Diptera (Family)	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D					
Mycetophilidae	+	+				+						+	+	+	+	-	--		+		--				+										

Species composition of microarthropods under the order Isopoda at study site-4 (Junput)

			2003						2004											2005										
Isopoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D
<i>Philoscia sp</i>				-			+								--	-										+	+	+		
<i>Porcellionides sp</i>										+						-														

Species composition of microarthropods under the order Hymenoptera at study site-4 (Junput)

			2003											2004																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														

Species composition of Other arthropods at Study site-4

			2003									2004									2005																
Other arthropoda	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D	JA	F	MA	A	M	J	JL	A	S	O	N	D							
Spider (Arenae)																																					
Marpissa sp			+	-												--														-				+			
Centiped							+							+		-		+								+											

Table-5. Changes in the weight of plant litter of *Rhizophora mucronata* in different phases of decomposition

S. No.	Period	Changes in the weight of litter	
1	June 04-August 04	Initial	200gm
		Final	105gm
		Difference	95gm
		%	47.50%
2	June 04-November 04	Initial	200gm
		Final	92gm
		Difference	108gm
		%	54%
3	June 04-February 05	Initial	200gm
		Final	70gm
		Difference	130gm
		%	65%
4	June 04-May 05	Initial	200gm
		Final	56gm
		Difference	144gm
		%	72%

one site was with good mangrove coverage and other sites contained patchy as well as scanty mangrove vegetation.

The soil fauna recorded from different study sites belonged mostly to seven orders *viz.* Collembola, Acarina, Coleoptera, Diptera, Isopoda, Hymenoptera and Araneae. Besides, occasional presence of Centipeds and Millipeds were observed (Table 1-4). All the soil and litter microarthropods displayed distinct seasonal dynamics and such fluctuation also varied from one group to others. Collembola was recorded in maximum abundance during post-monsoon at Nayachar Island while same group registered maximum abundance during monsoon at other 3 study sites. This variation of seasonal dynamics of microarthropods was supposed to be due to the association of this group with profuse mangrove litter at Nayachar Island (study site-1) and thereby experienced favourable ecological conditions (Hazra and Sanyal 1996). Out of different groups of microarthropods, Acarina and Collembola were distributed in all the study sites. The wide range of distribution and numerical dominance suggested the capability of these groups to exist in varying ecological condition.

The total population of soil microarthropods at different sampling sites showed numerical variation with the change of seasons. Minimum density was recorded mainly in the summer months in all study sites except Nayachar island (study site-1). Such findings also coincide with the observations on soil microarthropods of West Bengal by different workers like Banerjee (1984), Hazra and Choudhuri (1990), Choudhuri and Roy (1970). In Nayachar island (study site-1), population density of total soil microarthropods were higher mainly in post-monsoon and sometimes in pre-monsoon periods, which agreed with the observations of Hazra and Sanyal (1996), Pimentel and Warneke (1989), and Culliney and Pimentel (1986). On the other three study sites (sites-1, 2 and 3), maximum population density was found mainly in monsoon and sometimes in post monsoon periods. Most of the commonly occurring soil arthropods exhibited a single population peak in a year. According to Seasted (1984), within soil microarthropods community, some groups have sharp peak in definite months whereas others tend to fluctuate gradually throughout the year. The pattern of seasonal variations appeared to be differing in

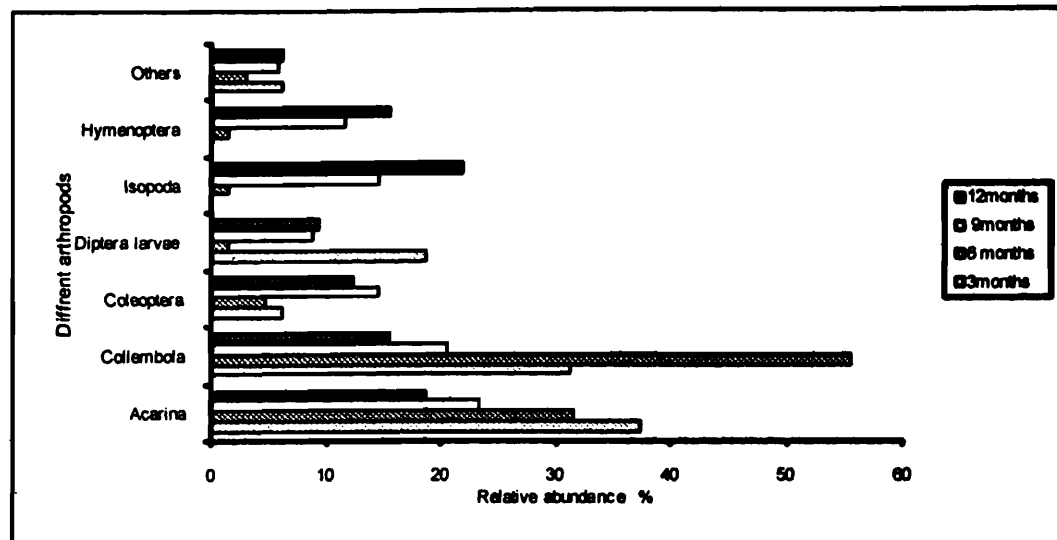


Fig. 3. Micoarthropod's population dynamics in different phases of litter decomposition

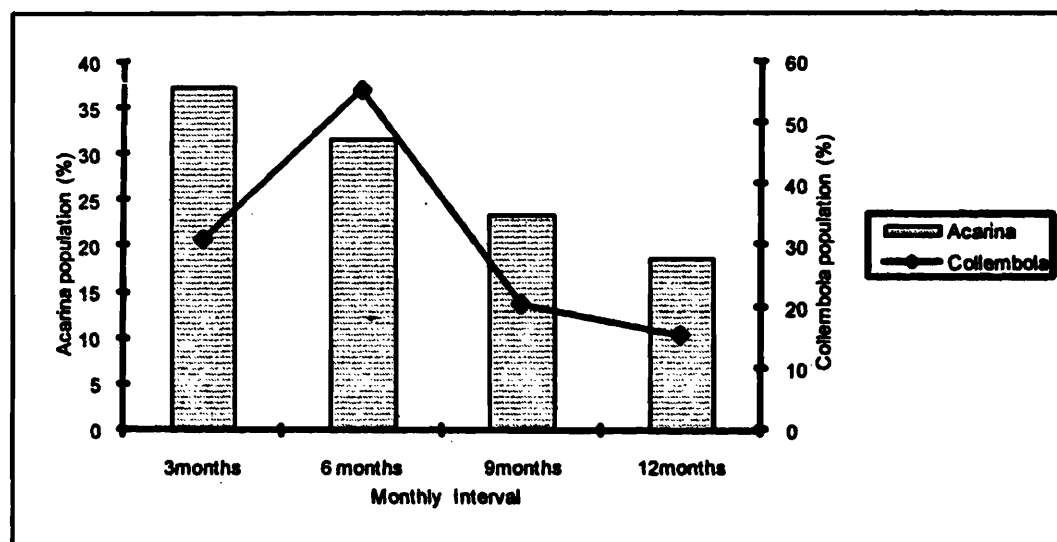


Fig. 4. Changes in the Relative abundance of Acarina and Collembola in different phases of Mangrove litter decomposition

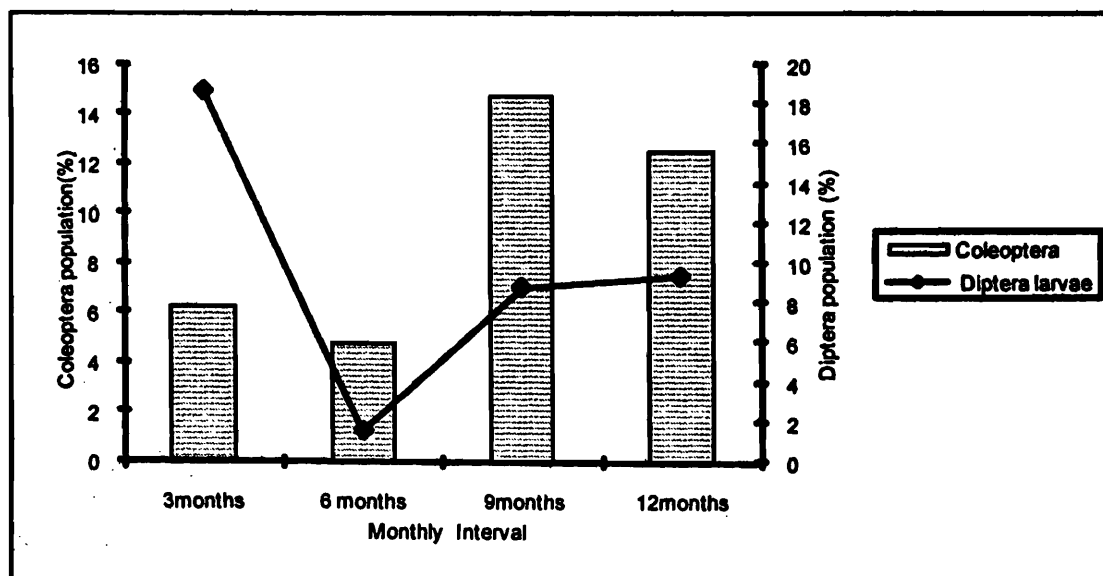


Fig. 5. Changes in the Relative abundance of Coleoptera and Diptera in different phases of Mangrove litter decomposition

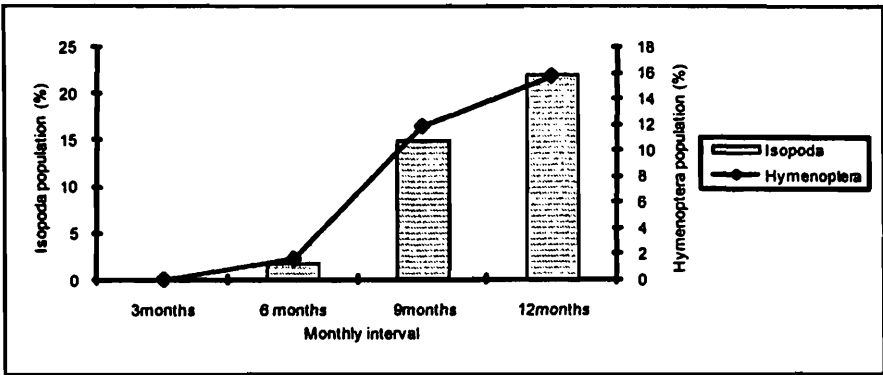


Fig. 6. Changes in the Relative abundance of Isopoda and Hymenoptera in different phases of Mangrove litter decomposition

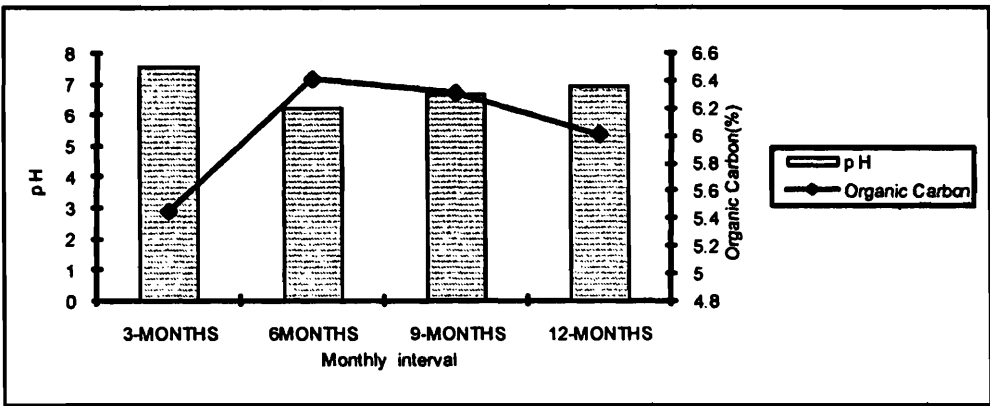


Fig. 7. Changes of pH and Organic carbon in different phases of mangrove litter decomposition

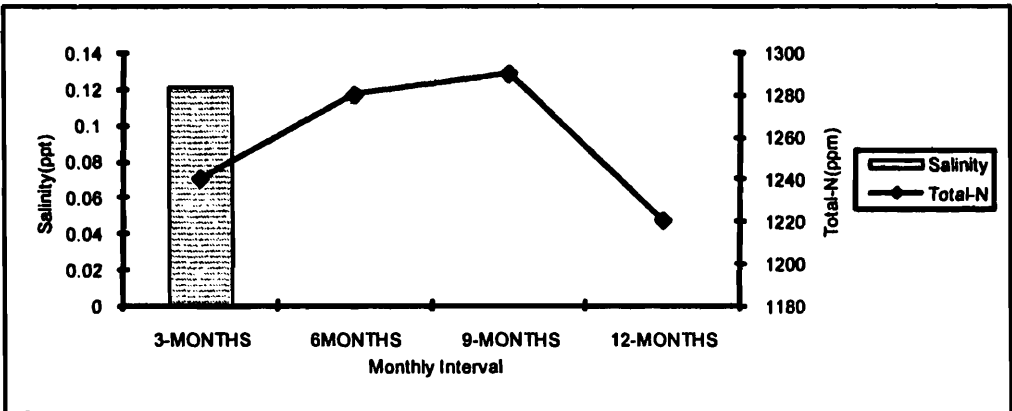


Fig. 8. Changes of Salinity and Total-N in different phases of mangrove litter decomposition

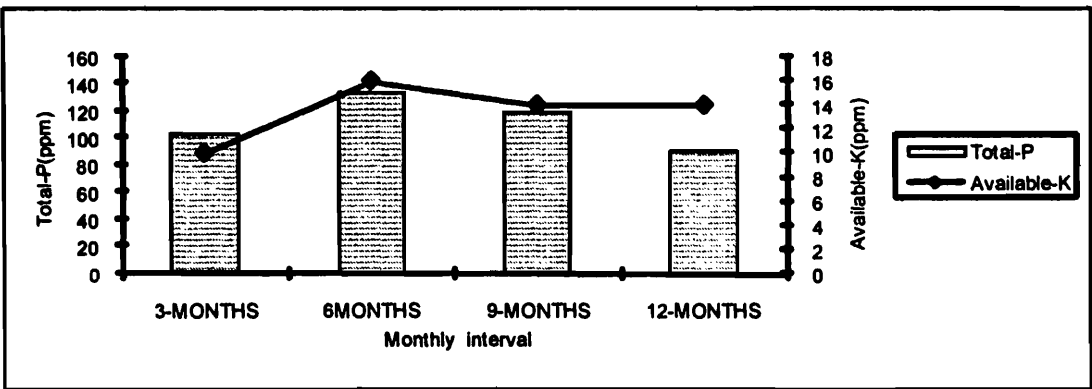


Fig. 9. Changes of Total-P and Available-K in different phases of mangrove litter decomposition

different forms, which perhaps indicate the existence of different breeding periods. Existence of single peak was supposed to be due to the probability of single generation per year. Bellinger (1954) opined that the species showing two annual peaks, had two generations in a year. Peak population of various soil arthropods was related to their life cycles and caused by the prevalence of large number of juveniles in the samples, which could be correlated with the occurrence of egg-laying species in the field (Bellinger 1954). The differences in the population peak of microarthropods among different study sites were noticed which was supposed to be due to the differences of soil types, microbial population and also other ecological parameters. Bellinger (1954) suggested that the habitat preference of soil fauna was determined by soil microflora with many edaphic factors. According to Prabhoo (1967) certain microflora present as gut symbionts in Collembola might have an important role in the digestion of plant materials consumed by the host. Satchell (1974) reviewed the interactive roles of the litter microflora and fauna in decomposition processes and he reiterated the view that soil invertebrate biomass acted "as a reservoir of plant nutrients" and served as a brake of nutrient leaching from decomposing litter. Collins (1980) stated Collembola and mites constitute 75% to 80% of soil arthropods and they feed on soil bacteria and fungi, while other soil arthropods like Isopoda and Hymenoptera feed the mites and Collembola. According to Bengtsson *et al.* (1983) different species of Collembola and mites survive on different kinds of food e.g detritus, bacteria, algae and different species of fungi, which triggered their habitat preference and competitive availability. Meermut (1985) studied the role of invertebrates in determining the composition of soil microbial communities and their role in other soil properties. Veeresh (1990) recognized the soil fauna as an important link between microorganisms and humification and postulated that the rate of microbial decomposition and mineralization, as the food passes through their gut and makes the organic matter into small fragments. Difference in

vegetation composition among different study sites was thought to be the main reason of unique and dissimilar species composition of Nayachar Island (study site-1) in comparison to other three sites as the vegetation governs the microfloral composition, soil moisture and other physico-chemical factors.

Laboratory and field studies conducted to assess the role of different microarthropods in the decomposition of a selected mangroves plant (*Rhizophora mucronata*) revealed the succession of different microarthropods in the different phases of decomposition. Plant litter decomposition (*Rhizophora mucronata*) was recorded as maximum after 12 months followed by 9 months, 6 months and 3 months. Therefore, it was observed that the period of interval was very important for successful decomposition process. At the time of decomposition, maximum nutrient content was found after 6 months followed by 9 months, 12 months and 3 months. It can be inferred that microarthropod population peak coincided with the maximum nutrient status. After 6 months of decomposition, relative abundance of soil microarthropods was maximum in collembola followed by Acarina, Coleoptera, other arthropods, Diptera, Hymenoptera and Isopoda. After 9 months of decomposition period, relative abundance of soil microarthropods was maximum in Acarina followed by Collembola, Coleoptera, Isopoda, Hymenoptera, Diptera and other arthropod population. Therefore, the succession of soil microarthropods was initiated with the occurrence of Collembola followed gradually by Acarina, Coleoptera, Diptera, Isopoda, Hymenoptera and other arthropod population which together played their role in the decomposition process resulting in the generation of maximum nutrients after 6 months of decomposition of mangrove litter.

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LITERATURE CITED

- AGRELL I. 1941. Zurokologic der collembolan Untersuchungen in Schwedischen lappland opusc. *Ent. Suppl.* 3 : 236.
- ANDERSON, J.M. 1973. The breakdown and decomposition of sweet chestnut (*Castanea sativa* Mill) and beech (*Fagus sylvatica*) leaf litter in two deciduous woodland soils. Breakdown leaching and decomposition. *Oecologia*, 12 : 251-274.
- BANERJEE, A.K. 1984. Forests of Sundarbans, In centenary commemoration volume, West Bengal Forest. Calcutta : 166-175.
- BELLINGER, P.F. 1954. Studies of soil fauna with special reference to collembola. *Comm. Agric. Expt. Sta. Bull.* 538 : 1-67.
- BENGTTSSON, G., GUNNARSON, T. and RUNDGREN S. 1983. Growth changes caused by metal uptake in a population of *Onychiurus armatus* (Tulb) (Collembola) feeding on metal polluted fungi. *Oikos*. 40 : 216-225
- BHATTACHARYA, T. and ROYCHOUDHURY, D.N. 1979. Monthly variation in the density of soil microarthropods in relation to some climate and edaphic factors. *Entomon*, 4(4) : 313-318.
- BISHT, B.S. and CHATTORAJ, A.N. 1986. Seasonal changes in densities of collembolan populations in Khola-Gaon forest of Garwal Himalaya, India, *Environment and Ecology*, 4(2) : 211-214.
- CHOUDHURI, D.K. and ROY. S. 1970. Qualitative composition of collembola of some uncultivated fields in Nadia district (W.B) with correlation between monthly population and individual soil factors. *Rev. Ecol. Biol. Soil.*, 4 : 507-515
- CHATTOPADHYA, A. and HAZRA, A.K. 2000. Effects of Heavy metals contaminated sewage effluents on soil arthropods fauna in and around Calcutta. *Rec. Zool. Sur. India, Occasional Paper No.*, 185 : 111-140.
- COLLINS, N.M. 1980. The distribution of soil macrofauna on the West range of ganung (M ount) Mulu sarawak. *Oecologia*, 44 : 263-275.
- CULLINEY, T. and PIMENTEL, D. 1986. Ecological effects of organic agricultural practices in insect populations. *Agric. Ecosyst. Environ.*, 15 : 253-256.
- DAS, A.K. and NANDI, S. 1999. Fauna of Indian Sundarban mangroves and their role in the ecosystem. In Sundarban Mangroves (Eds. D.N. Guha Bakshi, P. Sanyal and K. R. Naskar) : 417-427.
- DIEM, K. 1903. Untersuchungen uber die Bondenfauna in den Alpn, *J. Natural. Ges. Studies Gallon*, 1901-2 : 234-414.
- DIXON, D. 1928. The microorganisms of cultivated and bush soils in Victoria. *Aus. J. Exp. Biol. Med. Sci.*, 5 : 223-232.
- DOWDENS WALL, W.H. 1959. Practical Animal Ecology. Methuen and Co London : 331-337.
- HAZRA, A.K. and CHOUDHURI, D.K. 1990 Ecology of subterranean macro and micro arthropods fauna in different degraded and polluted soil environment of West Bengal. India. *Rec. Zool Surv. India. Occassional Paper No.*, 120.
- HAZRA and SANYAL, A. 1996. Ecology of collembola in a periodically inundated newly emerged alluvial island in the river Hooghly, West Bengal. *Proc. Zool. Soc. Calcutta*, 49(2) : 157-169.
- HOLLFIELD, B.K and R.W DIMMICK. 1995. Arthropods abundance relative forest management practices benefiting ruffed grouse in southern Appalachian; *Wildlife Society Bulleline*, 23 : 756-764.

- IMMS, A.D. 1912. On some collembola from India, Burma and Ceylon, with a catalogue of the oriental species of order, *Proc. Zool. Soc. London* : 80-125.
- JACKSON, M.L. 1967. Soil chemical Analysis prentice HALL of India Ltd. New Delhi : 583.
- KHALUA, R.K., CHAKRABORTY, G. and CHAKRABORTY, S.K. 2003. Annotated list of molluscs from the coastal tract of Midnapore district, *J. Mar. Biol. Assoc. India*, **45**(2) : 245-249
- MACATTEE, W.L. 1907. Census of four square feet. *Science*, **26** : 447-449.
- MACFADYEN, A. 1953. Notes on methods for the extraction of small soil arthropods. *J. Anim. Ecol.*, **22** : 65-77.
- MERMUT, A.R. 1985. The role of invertebrates in determining the composition of soil microbial communities and their role in other soil properties. *Quaestionesent*, **21**(4) : 595-608
- MURPHY, J. and J.P. RILAY. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chem. Acta.*, **27** : 31-36.
- OBSON, J.S. 1963. Energy storage and the balance of producers and consumers in Ecological system. *Ecology*, **44** : 322-331.
- ODUM, E.P. 1971. Fundamentals of Ecology, W.B Saunders Company, London : 1-574.
- ODUM, E.P. and E.J. HEALD, 1975. Mangrove forest and aquatic productivity. In coupling of Land and Water system, *Ecological studies*, Vol, 10 (Ed. Haster A.D.), Springer-Verlag, New York pp. 129-36.
- PAI, C.GA and PRABHOO, N.R. 1981. Preliminary observation on the microarthropod fauna of paddy fields and adjoining uncultivated soils. In south Kerala. In. *Progress in soil biology and ecology in India* (Ed. G.K.Veeresh), USA Tech. Series No., **37** : 27-32.
- PIMENTEL, D. and WARNEKE, A. 1989. Ecological effect of manure, sewage, sludge and other organic wastes on arthropod populations. *Agric. Zool. Reviews*, **3** : 1-30.
- PRABHOO, N.R. 1967. Microgeographic variation in Collembola. *Bull. nat. Inst. Sci. India*, **37** : 225-231.
- REYNOLDS B.C. and HUNTER M.D. 2001 Responses of soil respiration, soil nutrients, and litter decomposition; *Soil Biol and Biochem.*, **33** : 1641-165.
- SATCHELL, J.E. 1974. Introduction. Litter-interface of animate/inanimate matter. In : *Biology of Plant Litter Decomposition* (Eds. C.H. dickson and G.J.F Pugh) A. P. Lond., **1** : 13-44.
- SCHUPHAN, W. 1974. Nutritional value of crops as influenced by organic and inorganic fertilizer treatments. *Qualitative Plant PL. Foods for Human Nutrition*, **23** : 333-358.
- SEASTED, T.R. 1984. The role of microarthropods in the decomposition and mineralization of litter. *Annu. Rev. Ecol. Syst.*, **29** : 25-46.
- SENGUPTA, D. and SANYAL, A.K. 1999. Distribution of soil acari in south Bihar, with special referance to cryptostigmata and mesostigmata-A preliminary report. *Acarology*, **11** : 59-66.
- STEBAEVA, S.K. 1963. Ecological distribution of Collembola in the forest and steppes of the Southern Tura. *Pedobiologia*, **3** : 73-85.
- STRICKLAND, J.D. and PARSONS, T.R. 1968. A practical hand book of sea water analysis. *Fish. Res. Bd. Can, Bull. No.*, **167** : 57-143.
- VEERESH, G.K. 1990. Role of soil fauna in organic matter turnover and nutrient cycling, *J. Soil. Biol. Ecol.*, **10**(2) : 64-72.

BIODIVERSITY-CAUSES OF ITS EROSION AND METHODS FOR ITS REJUVINATION

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ABSTRACT

No ecosystem and its biodiversity can continue to survive until it is assured of non-interference from human beings at least, to a large extent. Human beings owing to their higher intellect and anthropocentric attitude have been exploiting the ecosystems since the dawn of agriculture. Mother Earth had no peace. First, in small patches here and there, but later in ever widening patches, the beautiful robe of her has been torn and disfigured. This tendency has accelerated after European renaissance when the intrepid Europeans armed with modern science, fire arms and limitless greed, crossed the seas and spread over Americas, Africa, Asia and Australia. In these countries as the European populations grew and agriculture spread, the native populations dwindled and biodiversity shrunk. Before renaissance the total area of European countries (minus Russia) was 27.9 million sq.km. but since then these countries added vast areas of north and south Americas, Australia and New Zealand amounting to 418.5 million sq.km. into their fold. The population of European blood into these open vast territories also quickly rose. Between 1810 and 1910 this population grew from 5,670,000 to 200,000,000. (Collins, p. 208, 1998).

Keywords : Biodiversity Erosion, Anthropocentrism, Population, Afforestation, Incentives, Corridors, Education and Ethics.

INTRODUCTION

Passenger Pegions of North America which once flew in hundreds of millions are no more. Bisons which once numbered 60 millions or so and roamed over north America are now protected animals (Parkman, 1967). Asiatic lions who once proudly strutted over vast areas of western Asia are now confined within Gir forest of India. The Argentine pampas whose vast fauna which once supported Darwin and its companions and also the local Indians is now a mere beef country (Moorehead, 1971). The tropical forests of the vast Amazon basin is being gradually stripped of its regal prime trees leading to a havoc in its faunal and floral diversity. The Himalayan forests are also falling prey to human greed. Consequently in every monsoon India is facing more severe and more destructive floods. The mangrove forest of Sundarban of India which is the abode of Royal Bengal Tigers is being constantly nibbled at by

the ever growing human population at its periphery. Today Sundarban occupies only 2585 sq.km. This can support at most 50 tigers. Such a small number of tigers in a small and isolated ecosystem is not genetically sound. Now we are hearing that people are thinking of erecting an atomic power plant in Sundarban. Nothing can be ecologically more damaging. The mangroves will almost vanish releasing a chain of ecological disasters. The very existence of Kolkata will be at stake.

CAUSES OF EROSION OF BIODIVERSITIES

1. EXPLOSION OF HUMAN POPULATION

Repeated explosive rise of human populations of world

The first cause of erosion of biodiversity is the explosion of human populations whenever and wherever opportunities were there. Within mere one hundred years (1810 to 1910), when

Table-1. Territories of European Countries Prior to renaissance and under their occupation since renaissance

Countries	Countries	Total areas (sq. km.)
EUROPE (Most countries except Russia)	Chekoslovakia France Germany Italy Poland Spain Sweden U.K.	27,96000
NORTH AMERICA	Canada Mexico 215,77000 U.S.A.	Countries occupied and populated by Europeans 418,52000
SOUTH AMERICA (Selected countries)	Argentina Brazil 123,20000 Nicaragua Venezuela	
AUSTRALIA & NEW ZEALAND	Australia & New Zealand 79,55000	

the vast new continents were made available to them, the European population exploded from 5,670,000 to 200,000,000 (totaly). Similarly the population of India, particularly after independence when better medical facilities were available to many, rose from 251 millions to nearly a 1250. In 1911 the population of India was 252 millions which rose to 312 in 1941 but within next 30 years i.e. 1971 when India was independent but truncated, her population leaped to 548 millions and by next 30 years even more. Table 2 will show.

This five fold increase in the human population of India within a short span of ninety years, is not due to any rise in female fertility but owing to reduction in child mortality which is owing to better medical facilities. Such quick rise in human poipulations occurred elsewhere too.

2. DEFORESTATION

Deforestation of prime forests all over the world

The second cause of erosion of biodiversity

is Deforesation. Assured food-supply must preceed any population growth. For this extensive deforestations were required in order to provide for agriculture to raise crops or for pastures to raise livestock. Wherever prime forests were felled extensively, the endemic flora and fauna suffered hugely, i.e. the biodiversitites of the countries suffered. Beautiful orchids, mosses, butterflies all suffered. Other remarkable animals such as African gorillas, Australian dingo dogs, marine turtles, whales, sharks, coral fishes and corals—the numbers of all are declining alarmingly. Besides tragic losses in biodiversities, unplanned deforestation results into many other owes. These are silting of river beds from silt deposition, creation of ravines, recurrent floods, lowering of water tables, rise in ambient temperature and many other associated tragedies. During the last century the forest covers of almost all countries have shrunk. Table-3 gives today's status.

This twin assault on forest cover from unbridled growth of human population and

thoughtless deforestation, is crushing biodiversities all over the world. To-day India is left with only 19% or so of her virgin forests (table-3) while Japan has 67%, although population density of Japan is more than India.

3. LAND FOR MAN’S PLEASURE

The third cause of erosion of biodiversity is the increasing demand of land for purpose other than food production. After Second World War particularly after the quantum jump in oil price, percentage of affluent people all over the world has also taken a quantum jump. Affluent people today want to live in a much better style than before. Earlier peoples’ needs were only a few items which could mostly be met from 5 to 6 acres of land. Today many people want much more. Large houses with cars, TV, computers, etc. and wide roads, swimming pool, stadium, golf courses, holiday resorts etc. are parts of a

modern man’s life. To meet all these demands a single man now-a-days needs a minimum of 10 to 25 acres of land. Besides modern man’s food habit is so variegated that he uses food items collected from all over the world. Further, to provide modern societies with all such amenities huge trunk roads, factories and airfields are popping up everywhere. For all these more and more ecosystems are being destroyed and biodiversity impoverished. Here I shall give one example from my experience. In early ’60s when I joined Birla Institute at Pilani, Rajasthan, a cobra used to visit my courtyard, partridges roamed freely in my back-garden and nil gais were frequent visitors on the sand dunes behind our house. Only a few months ago I revisited Birla Institute to give a lecture there. Pilani is no longer that quiet university hamlet where I stayed for more than 30 years. The place is buzzing with cars and taxis and the population has swelled

Table-2. Rise in the population of India, Pakistan and Bangladesh from 1911 to 2001

Years		India			Pakistan	Bangladesh
	Population in Millions	Birth Per 1000	Death Per 1000	Growth Per %	Populations millions	Populations millions
1911	252	49	43	0.6		
1941	312	45	31	1.4		
1971	548	41	19	2.2	65	
1991	844	32	11	2.1	132	
2001						129

(From PTI)

Table-3. Present forest cover of India and three other countries

Countries	Total Areas (mil. Hec.)	Forest Cover (m.n.)	%
Australia	762	107	14
India	329	63	19
Japan	37	24	67
U.S.A.	936	290	41
WORLD	13390	4077	30

(From Sagreiya, 2005, after F A O, 1985).

like a fast growing town; but no partridges and no 'nil gais'

Today India has only 3400 sq.m. land per head while China has 8000, U.S.A. 35,000 and Australia, a whopping 400,000 sq.m. land per head (Kundu, 2006, Table-4.)

METHODS FOR REJUVINATION OF BIODIVERSITIES

With so little land per head countries like India can hardly expect to be affluent unless the following vigorous steps are taken.

ONE : POPULATION CONTROL : The present fertility rate of Indian females is 3.29 per female and the population growth is 1.72% per year while the parallel data for China are 1.81 and 0.93% respectively. At this rate India would double her population in 40 years and China in 75 years. In the table 5 below some of such data are given.

Unless India's population growth is totally checked her economic growth would not be sustained. The best practical method of achieving this is simultaneous use of incentives and disincentives. Any woman who goes for family planning after having two children (irrespective of sex) may be handsomely rewarded such as, Rs. 20,000/- or even more. To spend Rs. 20 to 30,000 at one shot would be far more cheap for the Government than to face

the immense demands that a single human being places on his/her environment. As disincentives lower priorities for admission in public facilities such as, schools, colleges, etc. for 3rd, 4th and such children should be effective. Such steps would be much less painful than the draconian methods China adopted but will serve the purpose almost as well.

TWO : AFFORESTATION : Vigorous steps have to be taken for afforestation. Here too incentive and disincentive model should be used. Old people of villages and towns and those living in the fringe of forests should be handsomely rewarded for planting and nurturing trees/herbs, etc. People who participate in afforestation should be allowed to share income from trees planted by them for a reasonable period of time. Logging has to be very strictly monitored. Loggers have to replant saplings of trees they have removed and protect these till these grow up sufficiently. Adequate security money should be kept from loggers. For forests to grow and survive as far as possible, all the forests and reserve forests should be connected with corridors. This will not only help biodiversity but will also facilitate gene flow. If the corridors are in north-south direction then these will particularly help seasonal migration. Our elephants stray out of forests for they lack migratory routes and food.

Table-4. Relative densities of human populations of some countries and land available per capita there

S. No.	Country	Population (per sq.km.)	Land available per head (sq.m.)
1.	Gaza Strip	2744	364
2.	Bangladesh	871	1150
3.	Japan	333	3003
4.	India	294	3401
5.	U.K.	241	4149
6.	China	127	7874
7.	U.S.A.	28	35714
8.	Brazil	19	52631
9.	Australia	3	416883

(Source : C.I.A. Data 1999)

Table-5. Some important population related data of some selected countries of the world

Country	Area (1000 sq.km.)	Population (in 1000 s)	Fertility (per female)	Population Growth %	Income per capital (\$)
Afganistan	647	24,792	4.21	6.01	800
Bangladesh	144	125,340	1.82	3.45	1,200
China	9,597	1,221,591	0.93	1.81	2,800
Gaza Strip	0.36	987	6.59	7.68	1,100
India	3,287	984,003	1.72	3.29	1,600
Israel	20	5,334	2.01	2.74	16,400
Pakistan	803	132,185	2.22	5.08	2,300
Saudi Arabia	1,960	20,087	3.42	6.41	10,600
Ethiopia	1,127	58,732	2.67	6.94	430
South Africa	1,212	42,327	1.51	3.22	5,400
Brazil	8,512	164,511	1.1	2.29	6,300
U.S.A.	9,629	270,311	0.87	2.07	32,200
U.K.	244	58,970	0.25	1.7	21,200
Australia	7,686	18,438	0.96	1.83	23,600

(From Kundu, 2006; Source : C.I.A. data, 1988)

Recently an African lady Professor Wangari Maathai of Kenya has been awarded Nobel Peace Prize for her spectacular work in afforestation in Kenya. Since 1977 as a one-person crusader she has been motivating local ladies to plant trees. Today she and her ladies have planted millions of trees in Kenya. There is another point. To encourage biodiversity forest rangers may have to inculcate new forests with soil from old forests complete with flora and fauna and detritus.

THREE : EDUCATION : Today education is mostly career and money oriented. Few are worried about ethics and morals. Nobody doubts the importance of career and money still 'men does not live by bread alone'. Our children need to be taught love and respect for Nature and also ethics and morals. Then only they will be good custodians of Mother earth and make her a source of joy and pleasure to us and our children.

LITERATURE CITED

- CENTRAL INTELLIGENCE AGENCY of U.S.A. (1998).
CENTRAL INTELLIGENCE AGENCY of U.S.A. (1999).
COLLINS, HARPER. *Atlas of World History*. Times Books Ltd. (1998).
FOOD AND AGRICULTURAL ORGANISATION OF UNITED NATIONS (1985).
KUNDU, H. L. *Ecology for Millions*. New Age International Publishers, New Delhi (2006).
MOOREHEAD, A. *Darwin and the Beagle*. Penguin Books (1971).
PARKMAN, F. *The Oregon Trail*. Bantam Books (1967).
SAGREIYA, K. P. *Forests and Forestry*. National Book Trust, India (2005).

**CYTOGENETICS, IMMUNOLOGY
AND
MOLECULAR BIOLOGY**

CELL SURFACE ACTIVATION OF MMP-2

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ABSTRACT

Among proteases involved in invasion and metastasis, matrix metalloproteinases (MMPs) are of importance. MMP expression and activity are increased in almost all cancers. Activation of MMP-2/72 kDa type IV collagenase correlates with increased invasiveness and worse prognosis. MMP-2 is activated in a unique membrane associated manner. We studied cell surface associated activation of MMP-2 in A375 (human melanoma cells) and SiHa (human cervical carcinoma cells). An appreciable increase in MMP-2 expression and activation in tumour tissue samples compared to non-malignant samples and in serum collected from cancer patients compared to normal serum was observed, indicating importance of MMP-2 in tumour progression. A375 and SiHa cells activated 72 kDa collagenase type IV and pro-MMP-2. Activation of MMP-2 and 72 kDa collagenase type IV by cell membrane fractions and cell membrane extracts indicated that MMP-2 activation is membrane associated. This membrane-associated activation was found to be specific for MMP-2. Treatment of cells with anti-MT1-MMP antibody appreciably decreased collagenase type IV activation, indicating that this activation is MT1-MMP mediated. As MT1-MMP was found to localize to focal adhesion sites, activation of pro-MMP-2 by MT1-MMP and subsequent degradation of ECM components by MMP-2 at the migration front could facilitate directed cellular invasion. Tumour cells may also be able to entrap exogenous MMP-2 secreted by fibroblasts or stromal cells; this MMP-2 may then be activated by the activation complex. Our findings furnished further examples of the cell membrane associated MT1-MMP mediated MMP-2 activation in A375 and SiHa cells under native conditions and suggested that MT1-MMP mediated MMP-2 activation is of importance in tumour invasion. This information could help in developing new therapies designed to interfere with MMP activation and control of metastasis in cancer.

Keywords : MMP-2, MT1-MMP, TIMP-2, membrane

INTRODUCTION

Among the proteases involved in the proteolytic events which occur during invasion and metastasis, matrix metalloproteinases (MMPs) are of crucial importance. MMPs, a family of zinc dependant endopeptidases, are key mediators of extracellular matrix (ECM) remodelling which occur during development, tissue morphogenesis and repair. MMPs play a vital role in the extensive ECM degradation that occurs during cancer invasion and metastasis (Egeblad *et al.* 2002; Sternlicht *et al.* 2001) and their expression and activity are increased in almost every type of human cancer (Egeblad *et*

al. 2002, Courrens *et al.* 1996, Nagase 1997). All MMPs are synthesised as inactive pro-MMPs. Activation involves proteolytic cleavage of the propeptide prodomain by serine proteases either intracellularly or extracellularly (Egeblad *et al.* 2002, Nagase 1997).

MMP-2 (also known as gelatinase A) is a 72 kDa type IV collagenase which degrades various ECM components like gelatins and collagens (including type IV collagen of basement membrane). The activation of MMP-2 differs from other MMPs as it is not activated by physiological activators like the serine proteases. Pro-MMP-2 binds to the cell

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membrane and is activated by a unique cell membrane associated mechanism (Egeblad *et al.* 2002, Nagase 1997, Strongin *et al.* 1995). Significant associations between MMP-2 activation and metastasis have been reported from various carcinomas (Brown *et al.* 1993, Shimada *et al.* 2000).

Strongin *et al.* reported a plasma membrane dependant mechanism specific for activation of pro-MMP-2. The "activator" is a tri-molecular complex of MT1-MMP, TIMP-2 and pro-MMP-2 (Strongin *et al.* 1995). Cellular localization of active MMP-2 also plays a crucial role in cell invasion. $\alpha\beta 3$ integrin receptor and MT1-MMP help in localization of proteolytically active MMP-2 to surface of invasive cells facilitating directed cellular invasion and metastasis (Seihi *et al.* 2003, Hafmann *et al.* 2000).

In the present chapter, we studied the MT1-MMP dependant cell membrane mediated activation of pro-MMP-2/pro-72 kDa collagenase IV in the human melanoma cell line A375 and the human cervical carcinoma cell line SiHa.

MATERIALS AND METHODS

Materials

Dulbecco's Modified Eagle's Medium (DMEM), Minimal Essential Medium (MEM) and foetal bovine serum (FBS) were obtained from Life Technologies (Rockville, USA). Anti-MT1-MMP polyclonal antibody, purified human MMP-2 (CC071) and purified human MMP-9/MMP-2 mixture (CC073) were obtained from Chemicon (Temecula, USA). Anti-MMP-2 monoclonal antibody was obtained from Becton Dickinson Biosciences (San Diego, USA). Purified collagenase type IV (72 kDa) and other fine chemicals were obtained from Sigma (St. Louis, USA).

Tissue and Serum Samples

Malignant and normal (non-malignant) human cancer tissue samples were obtained from surgical specimens, Hospital Unit, Chittaranjan National Cancer Institute, Kolkata. Serum samples from cancer patients as well as

normal serum were collected from Hospital Unit, Chittaranjan National Cancer Institute, Kolkata. Tissue samples were extracted in Buffer A (50 mM Tris, 75 mM NaCl, 0.01% SDS) at 4°C. Amount of protein in the resultant extracts were estimated by Lowry's method (Lowry *et al.* 1951). Serum samples were diluted with phosphate buffered saline (PBS) and amount of protein was estimated by Lowry's method.

Cell lines

Moderately metastatic human melanoma cell line A375, human cervical carcinoma cell line SiHa and human fibrosarcoma cell line HT-1080 were obtained from National Centre for Cell Sciences (NCCS), Pune, India. A375 cells were cultured and maintained in Dulbecco's Modified Eagle's Medium (DMEM) containing 10% foetal bovine serum (FBS). SiHa and HT1080 cells were cultured and maintained in Minimal Essential Medium (MEM) containing 10% FBS. All cell lines were maintained at 37°C in a CO₂ incubator.

Assay of MMP-2 by in serum and tissue samples

Serum samples collected from cancer patients and normal individuals were diluted with PBS (25 µg) and added to wells of the ELISA plate. Tissue extracts of normal and cancerous tissue samples (25 µg) were added to wells of the ELISA plate. Samples were incubated with anti-MMP-2 monoclonal antibody followed by HRP-coupled anti-mouse second antibody. TMB (tetra-methyl-benzidine) substrate was used and optical density was measured at 450 nm. Serum samples and tissue extracts (25 µg each) were subjected to gelatin zymography.

Isolation of cell membrane and preparation of membrane extract

Cell membrane fraction was isolated from A375 and SiHa cells according to the method of Strongin *et al.* (Strongin *et al.* 1995). Amount of protein was estimated by Lowry's method¹⁰. Cell membrane fractions were extracted in

Buffer C (25 mM Hepes, 0.1 mM CaCl₂, 0.25% NP-40; pH : 7.5) at 4°C. Amount of protein in the resultant membrane extract was estimated by Lowry's method (Lowry *et al.* 1951).

Incubation of A375 and SiHa cells with 72 kDa collagenase type IV/ MMP-2

A375 cells (50,000) were incubated with purified 72 kDa collagenase type IV (5 ng) in serum free culture medium (SFCM) for 5–30 mins at 37°C. SiHa cells were incubated with purified MMP-2 in SFCM for 45 mins at 37°C. After incubation was completed, the samples were centrifuged and the supernatants subjected to gelatin zymography. When HT-1080 fibrosarcoma cells were grown in presence of 10 µg/ml Con A in SFCM for 24 hrs, pro-MMP-2 (72 kDa) was secreted in SFCM. A375 and SiHa cells (50,000) were incubated with this pro-MMP-2 containing SFCM for 15 mins and 30 mins respectively at 37°C. A375 and SiHa cells (50,000) were incubated with malignant human cervical cancer tissue homogenate (10 µg) for 30 mins and 1 hr respectively at 37°C. After incubation was completed, the samples were centrifuged and the supernatants subjected to gelatin zymography (Tath *et al.* 2001).

Activation of 72 kDa collagenase IV/ MMP-2 by membrane fraction and membrane extract

A375 cell membrane fraction (10 µg) was incubated with purified 72 kDa collagenase IV (5 ng) for 15 mins–1 hr at 37°C. SiHa cell membrane fraction (20 µg) was incubated with 75 ng of purified pro-MMP-2 for 15–45 mins. Cell membrane extract from A375 cells (5 µg) was incubated with purified 72 kDa collagenase IV (5 ng) for 30 mins–1 hr at 37°C. Cell membrane extract from SiHa cells (5 µg) was incubated with purified MMP-2 (75 ng) for 45 mins at 37°C. After incubation was completed, the reactions were terminated by adding sample buffer and the samples were subjected to gelatin zymography.

Effect of anti-MT1-MMP antibody on 72 kDa collagenase IV/ MMP-2 activation

A375 cells (50,000) were incubated with and without (control) anti-MT1-MMP polyclonal

antibody at different concentrations (1, 2.5, 5 µg) for 1 hr at 37°C and then incubated with purified 72 kDa collagenase IV (5 ng) for 30 mins at 37°C. After incubation was completed, the samples were centrifuged and the supernatants subjected to gelatin zymography. SiHa cell membrane fractions (20 µg) were incubated with and without (control) anti-MT1-MMP polyclonal antibody at different concentrations (1, 2 µg) for 1 hr at 37°C and then incubated with purified pro-MMP-2 (75 ng) for 45 mins at 37°C. After incubation was completed, reactions were terminated by adding sample buffer and the samples were subjected to gelatin zymography.

Incubation of A375 cells with MMP-9/MMP-2 mixture

A375 cells (50,000) were incubated with 125 ng purified MMP-9/MMP-2 mixture (CC073, Chemicon) in serum free culture medium for 1 hr at 37°C. After incubation was completed, the sample was centrifuged and the supernatant subjected to gelatin zymography.

Immunocytochemistry

A375 and SiHa cells grown overnight on coverslips were fixed with 3.5% formaldehyde solution for 20 mins, treated with 0.5% Triton X-100 for 5 mins and blocked with 1% BSA for 1 hr at 37°C. The cells were then incubated with anti-MT1-MMP polyclonal antibody for 1 hr at 37°C, washed thrice in PBS and incubated with FITC coupled second antibody for 1 hr at 37°C. The coverslips were then washed thrice in PBS, mounted on glass slides using glycerol and observed under a fluorescence microscope.

RESULTS

Assay of MMP-2 in serum and tissue samples

ELISA showed elevated expression of MMP-2 in serum collected from cancer patients and in cancerous tissue samples compared to serum collected from normal individuals and normal tissue (Fig. 1A and 1B). Gelatin zymography showed much greater MMP-2 activity and activation of MMP-2 to 68 kDa forms in serum

collected from cancer patients (Fig. 2A lanes 2-5) 68, 64 kDa forms in cancerous tissue (Fig. 2B lanes 2-5). Normal serum (Fig. 2A lane 1) and tissue showed much lower MMP-2 activity and virtually no MMP-2 activation (Fig. 2B lane 1).

Activation of collagenase type IV by A375 and SiHa cells

When purified 72 kDa collagenase type IV was incubated with A375 cells at 37°C, gelatin zymography showed that collagenase IV (Fig. 3A lane 1) was activated to 70 kDa form after 5 mins and 70 and 66 kDa forms after 15 mins incubation (Fig. 3A lanes 2-3). Activation to 70, 68, 66 and 64 kDa forms accompanied by an appreciable increase in activity occurred after 30 mins incubation (Fig. 3A lane 4). On incubation of purified pro-MMP-2 (Fig. 3B lane 1) with SiHa cells for 45 mins, pro-MMP-2 (72 kDa) was activated to 68, 66 kDa forms (Fig. 3B lane 2).

Activation of pro-MMP-2 from other biological sources

When A375 cells were incubated for 15 mins with serum free culture medium from Con A

stimulated HT-1080 cells (Fig. 4A lane 1), activation of pro-MMP-2 (72 kDa) to 68, 66, 56, 42 and 26 kDa forms occurred (Fig. 4A lane 2). On incubation of SiHa cells for 30 mins with SFCM from HT-1080 cells grown in presence of Con A, activation of pro-MMP-2 (72 kDa) to 68 and 60 kDa forms occurred (Fig. 4A lane 3). When A375 cells were incubated with malignant human cervical tissue homogenate for 30 mins at 37°C, activation of pro-MMP-2 (72 kDa) to active MMP-2 (66 kDa) was observed (Fig. 4B lane 3). When SiHa cells were with malignant human cervical tissue homogenate for 1 hr at 37°C, activation of pro-MMP-2 (72 kDa) to active MMP-2 (68, 66 kDa) was observed (Fig. 4B lane 4). Presence of pro-MMP-2 in cervical tissue homogenate was indicated by gelatin zymography (Fig. 4C lane 2) and confirmed by Western blot (Fig. 4C lane 1) using anti-MMP-2 monoclonal antibody.

Activation of 72 kDa collagenase type IV by cell membrane fraction and cell membrane extract

Gelatin zymography showed that when purified 72 kDa collagenase type IV (Fig. 5A

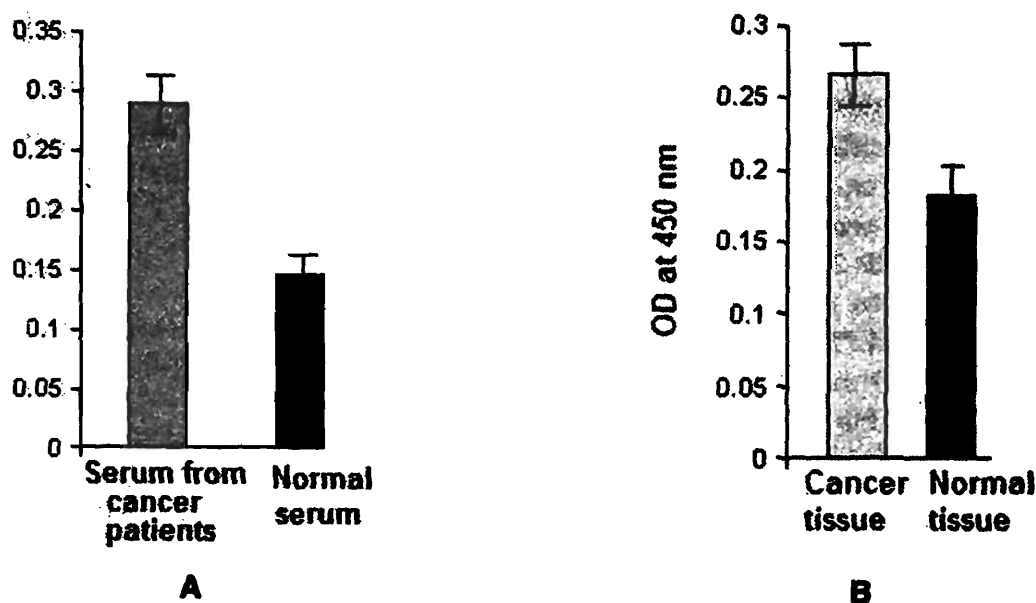


Fig. 1. Assay of MMP-2 expression in serum and tissue samples by ELISA.

Serum collected from cancer patients and normal individuals were diluted with PBS and added to wells of the ELISA plate (Fig. 1A). Normal and cancerous tissue samples were extracted in tissue extraction buffers. The tissue extracts were added to wells of the ELISA plate (Fig. 1B). Samples were incubated with anti-MMP-2 monoclonal antibody followed by HRP-coupled anti-mouse second antibody. TMB substrate was used and optical density was measured at 450 nm.

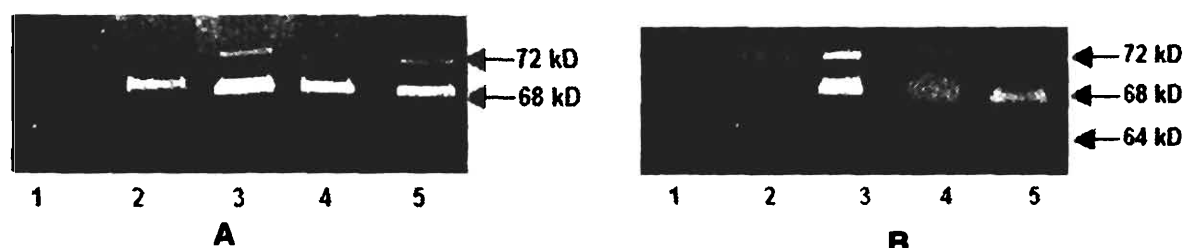


Fig. 2. Assay of MMP activity in serum and tissue samples by zymography

Serum collected from cancer patients and normal individuals were subjected to gelatin zymography on 10% SDS-PAGE co-polymerized with 0.1% gelatin (Fig. 2A lanes 1-5). Normal and cancerous tissue extracts (containing 25 μ g protein each) were subjected to gelatin zymography on 10% SDS-PAGE co-polymerized with 0.1% gelatin (Fig. 2B lanes 1-5).

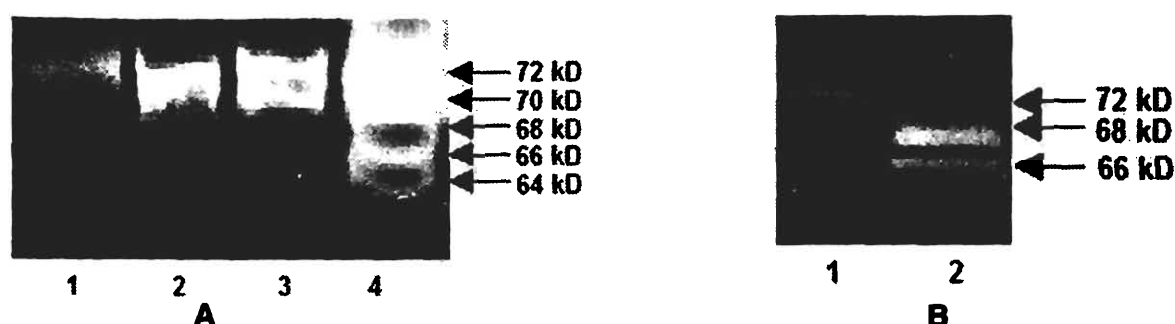


Fig. 3. Assay of 72 kDa collagenase type IV/ MMP-2 activation by A375 and SiHa cells.

Fig. 3A : Activation of 72 kDa collagenase type IV by A375 cells. A375 cells were incubated with purified 72 kDa collagenase type IV for 5 mins (lane 2), 15 mins (lane 3) and 30 mins (lane 4). Lane 1: Purified 72 kDa collagenase type IV. Fig 3B: Activation of MMP-2 by SiHa cells. SiHa cells were incubated with purified MMP-2 for 45 mins at 37°C (lane 2). Lane 1: Purified MMP-2. A375 and SiHa cells were incubated with purified 72 kDa collagenase type IV (5 ng) and purified MMP-2 (72 kDa) in SFCM for varying periods of time at 37°C. After incubation was completed, the samples were centrifuged and the supernatants subjected to gelatin zymography.

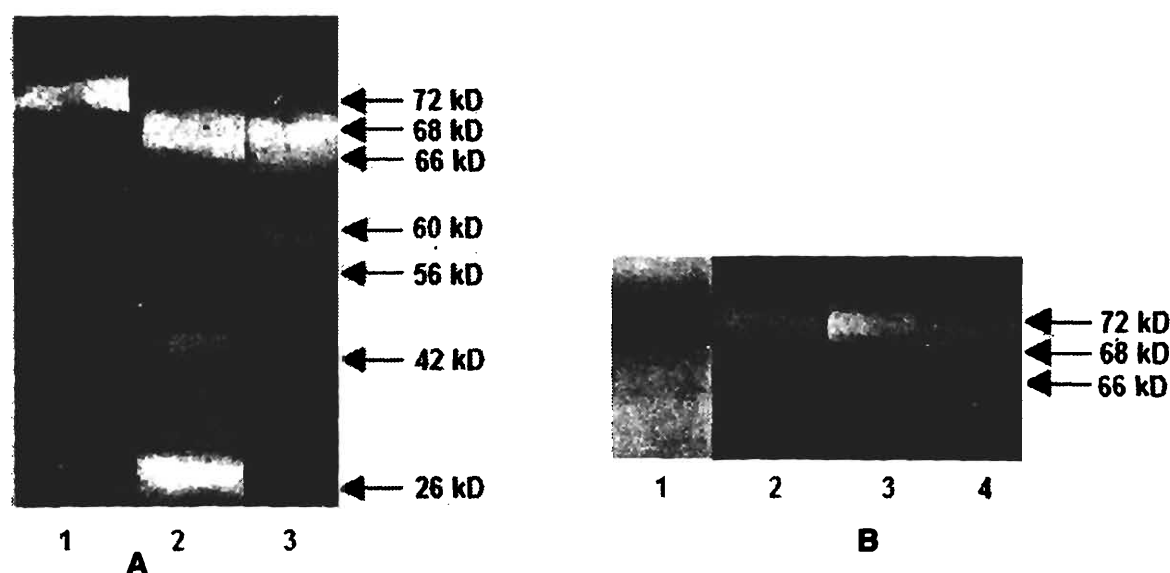


Fig. 4. Assay of MMP-2 activation from other biological sources by A375 and SiHa cells.

Fig. 4A: Activation of pro-MMP-2 from SFCM from HT-1080 cells grown in presence of Con A. SFCM from HT-1080 cells grown with Con A (lane 1) was incubated with A375 cells for 15 mins (lane 2) and SiHa cells for 30 mins (lane 3). Fig. 4B: Activation of pro-MMP-2 from cervical tissue homogenate by A375 cells. Cervical tissue homogenate (lane 2) was incubated with A375 cells for 30 mins (lane 3) and with SiHa cells for 1 hr (lane 4). Lane 1: Western blot of cervical tissue homogenate with anti-MMP-2 monoclonal antibody. A375 and SiHa cells were incubated with SFCM from HT-1080 cells and with human cervical tissue homogenate (10 μ g) at 37°C. After incubation was completed, samples were centrifuged and the supernatants subjected to gelatin zymography on 10% SDS-PAGE co-polymerized with 0.1% gelatin.

lane 1) was incubated with A375 membrane fraction at 37°C, collagenase type IV was activated to 70 kDa forms after 15 mins (Fig. 5A lane 2) and to 70, 64 kDa forms after 30 mins–1 hr incubation (Fig. 5A lanes 3-4). When purified collagenase type IV (72 kDa) was incubated with A375 membrane extract at 37°C, gelatin zymography showed that collagenase type IV (Fig. 5B lane 1) was activated to 70, 68, 64, 62 and 48 kDa forms after 30 mins (Fig. 5B lane 2) and to 70, 68, 64, 62 and 40 kDa forms after 1 hr of incubation (Fig. 5B lane 3). When purified pro-MMP-2 (72 kDa) was incubated with SiHa cell membrane fraction, pro-MMP-2 (Fig 5C lane 1) was activated to 68 kDa form

after 15–30 mins (Fig. 5C lanes 2-3) and to 68, 66 kDa forms after 45 mins (Fig. 5C lane 4). When purified pro-MMP-2 (72 kDa) was incubated with SiHa cell membrane extract for 45 mins, pro-MMP-2 (Fig 5D lane 1) was activated to 68, 66 kDa forms after 45 mins (Fig. 5D lane 2).

Role of MT1-MMP in collagenase type IV activation by A375 cells

When A375 cells were first incubated with increasing concentrations of anti-MT1-MMP antibody and then incubated with 72 kDa purified collagenase IV for 30 mins, gelatin zymography showed that masking of MT1-

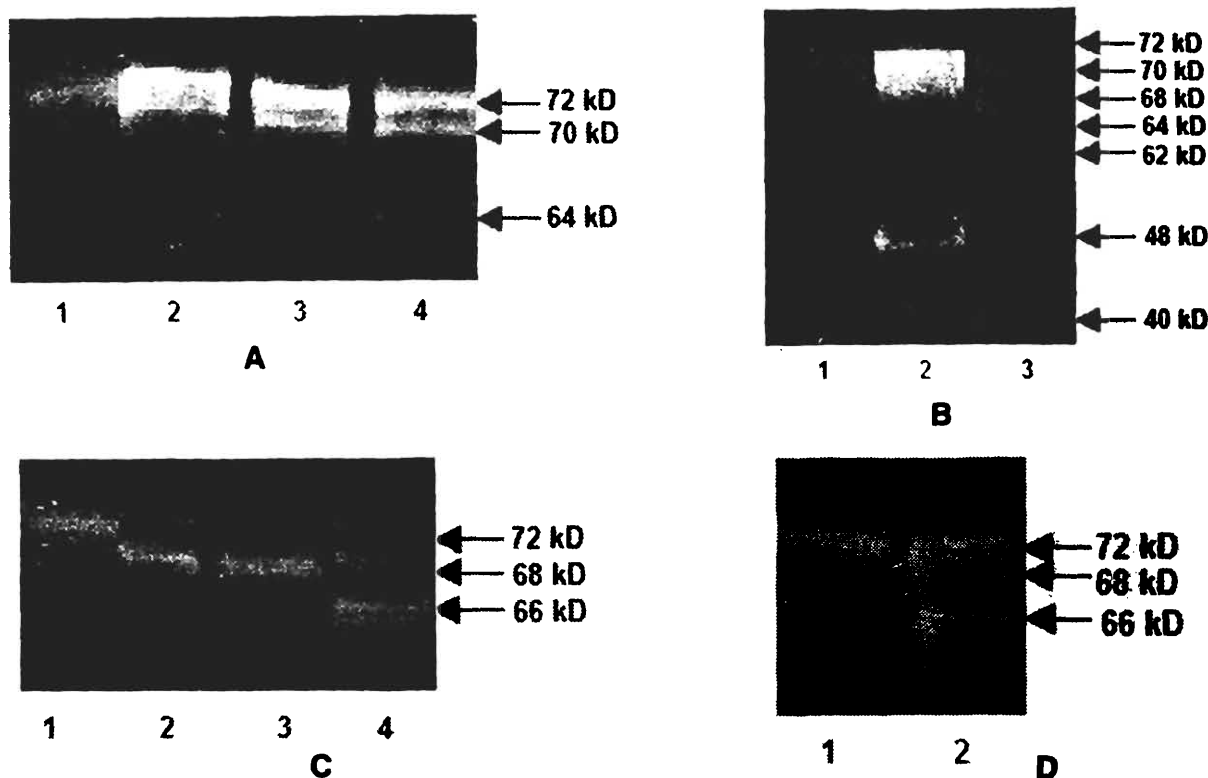


Fig. 5. Assay of A375 and SiHa cell membrane mediated collagenase type IV activation

Fig. 5A: Activation of collagenase type IV by A375 membrane fraction. A375 membrane fraction was incubated with purified 72 kDa collagenase type IV (lane 1) for 15 mins (lane 2), 30 mins (lane 3) and 1 hr (lane 4). Fig. 5B: Assay of collagenase type IV activation by A375 membrane extract. Purified collagenase type IV (lane 1) was incubated with 5 µg A375 cell membrane extract for 30 mins (lane 2) and 1 hr (lane 3). Fig. 5C: Activation of pro-MMP-2 by SiHa cell membrane fraction. SiHa cell membrane fraction (20 µg) was incubated with 75 ng of purified pro-MMP-2 (lane 1) for 15 mins (lane 2), 30 mins (lane 3), 45 mins (lane 4) at 37°C. Fig. 5D: Activation of pro-MMP-2 by SiHa cell membrane extract. SiHa cell membrane extract (5 µg) were incubated with 75 ng purified pro-MMP-2 for 45 mins at 37°C (lane 2). Lane 1: purified pro-MMP-2. Cell membrane fractions and membrane extracts were incubated with purified 72 kD collagenase type IV and purified pro-MMP-2. After incubation was completed, the reaction was terminated by adding sample buffer and the samples were subjected to gelatin zymography on 10% SDS-PAGE co-polymerized with 0.1% gelatin.

MMP with its antibody greatly downregulated collagenase IV activation—as well as activity of both pro- and activated forms (Fig. 6A lanes 2-4) compared to A375 cells untreated with anti-MT1-MMP antibody (Fig. 6A lane 1). When SiHa cell membrane fraction was first incubated with increasing concentrations of anti-MT1-MMP antibody and then incubated with purified pro-MMP-2 for 45 mins, gelatin zymography showed that masking of MT1-MMP with its antibody inhibited MMP-2 activation almost completely (Fig. 6B lanes 2-3), compared to SiHa cell membrane fraction untreated with anti-MT1-MMP antibody (Fig. 6B lane 1).

Activation of MMP-2 by A375 cells from purified MMP-9/MMP-2 mixture

Gelatin zymography showed that when purified MMP-9/MMP-2 mixture (Fig. 7 lane 1) was incubated with A375 cells for 1 hr at 37°C, activation of pro-MMP-2 (72 kDa) to active MMP-2 (68, 66 kDa) occurred while pro-MMP-9 (92 kDa) was not activated (Fig. 7 lane 2).

Immunocytochemical localisation of MT1-MMP on A375 cell surface

Immunocytochemistry of A375 and SiHa cells with anti-MT1-MMP antibody

demonstrated localisation of MT1-MMP at focal adhesion sites on A375 and SiHa cell membrane (Fig. 8).

DISCUSSION

Among the MMPs, the 72 kDa type IV collagenase MMP-2 (gelatinase A) is considered to play a critical role in tumour progression. Elevated expression and activation of MMP-2 has been shown to strongly correlate with invasive and metastatic potential and activation ratios of pro-MMP-2 correlate with lymph node metastasis in various carcinomas (Brown *et al.* 1993, Shimada *et al.* 2000, Seihi *et al.* 2003).

Our experiments showed an increase in MMP-2 expression and activation in serum collected from cancer patients and cancerous tissue, compared to normal samples. Notably, MMP-2 activation was detected only in samples collected from cancer patients. As activated MMP-2 regulates the tumour micro-environment and is also crucially involved in the extensive ECM degradation that occurs during cancer invasion and metastasis (Egeblad *et al.* 2002, Brown *et al.* 1993, Shimada *et al.* 2000) activation of pro-MMP-2 is an important step in the metastatic cascade. Our findings confirm the importance of MMP-2 expression and activation in cancer biology.

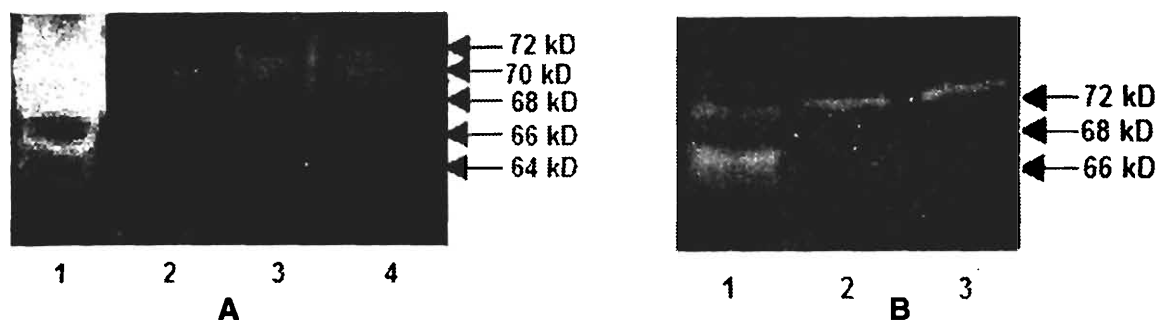


Fig. 6. Role of MT1-MMP in 72 kDa collagenase type IV/ pro-MMP-2 activation.

Fig. 6A : Role of MT1-MMP in 72 kDa collagenase type IV activation by A375 cells. A375 cells were treated with 1 μg (lane 2), 2.5 μg (lane 3) and 5 μg (lane 4) anti-MT1-MMP antibody for 1 hr prior to incubation with purified collagenase type IV for 30 mins at 37°C. A375 cells incubated with purified 72 kDa collagenase type IV (5 ng) for 30 mins (lane 1) were used as control. Fig. 6B: Role of MT1-MMP in MMP-2 activation by SiHa cell membrane fraction. SiHa cell membrane fraction was incubated with 1 μg (lane 2) and 2 μg (lane 3) anti-MT1-MMP polyclonal antibody for 1 hr at 37°C prior to incubation with pro-MMP-2 for 45 mins at 37°C. SiHa cell membrane fraction was incubated with purified pro-MMP-2 for 45 mins (lane 1) as control. After incubation was completed, the samples were subjected to gelatin zymography on 10% SDS-PAGE co-polymerized with 0.1% gelatin as described previously.

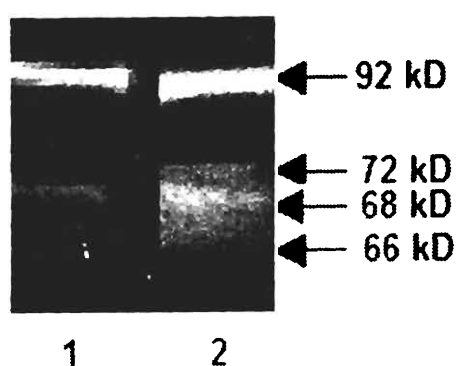


Fig. 7. Assay of specificity of MMP-2 activation by A375 cells.

A375 cells were incubated with 125 ng purified MMP-9/MMP-2 mixture in SFCM for 1 hr at 37°C (lane 2). After incubation was completed, the samples were centrifuged and the supernatant subjected to gelatin zymography on 10% SDS-PAGE co-polymerized with 0.1% gelatin. Lane 1: Purified MMP-9/MMP-2 mixture.

In our present communication we studied cell membrane associated activation of MMP-2 (gelatinase A/ 72 kDa type IV collagenase) in the moderately metastatic human melanoma cell line A375 and the cervical carcinoma cell line SiHa. Incubation of purified 72 kDa collagenase type IV with A375 cells, led to its activation into 70–64 kDa forms. On incubation of purified pro-MMP-2 with SiHa cells, pro-MMP-2 was activated to 68, 66 kDa forms. When different biological sources of pro-MMP-2 were incubated with A375 and SiHa cells, active MMP-2 was obtained. Although the rates and extents of activation varied, these experiments demonstrated that A375 and SiHa cells can efficiently activate pro-MMP-2 from other biological sources as well.

Activation of purified 72 kDa collagenase type IV to activated forms by A375 membrane fraction and A375 membrane extract were observed. Incubation of purified MMP-2 with SiHa cell membrane fraction and SiHa cell membrane extract showed activation of 72 kDa pro-MMP-2. These experiments indicate that mode of activation of pro-MMP-2/ 72 kDa pro-collagenase IV by A375 and SiHa cells is membrane linked. Interestingly, in both cases, membrane extract showed greater activation of

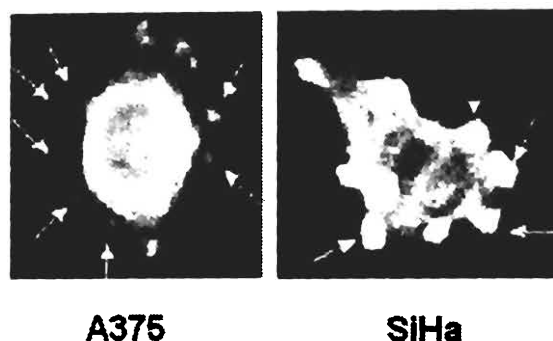


Fig. 8. Immunocytochemical localization of MT1-MMP.

A375 and SiHa cells were fixed with 3.5% formaldehyde solution, treated with 0.5% Triton X-100 and blocked with 1% BSA for 1 hr at 37°C. The cells were incubated with anti-MT1-MMP polyclonal antibody for 1 hr at 37°C, washed in PBS and incubated with FITC coupled goat anti-rabbit second antibody for 1 hr at 37°C. Coverslips were then washed in PBS, mounted on glass slides and observed under a fluorescence microscope.

72 kDa collagenase type IV/MMP-2 than the membrane fraction itself.

To study the role of MT1-MMP in MMP-2 activation, A375 cells and SiHa cell membrane fraction was incubated with varying concentrations of anti-MT1-MMP antibody and then with purified pro-MMP-2/purified 72 kDa collagenase IV. When A375 cells were first incubated with varying concentrations of anti-MT1-MMP antibody, activation of 72 kDa collagenase type IV was significantly decreased in a dose dependant manner and activity of both pro- and activated forms were also greatly decreased. In SiHa, masking of MT1-MMP with its antibody inhibited MMP-2 activation almost completely. Thus, masking of MT1-MMP with its antibody caused appreciable inhibition of collagenase IV/MMP-2 activation, indicating that cell membrane associated activation of 72 kDa type IV collagenase/MMP-2 by A375 and SiHa cells is MT1-MMP mediated.

When A375 cells were incubated with purified MMP-9/MMP-2 mixture, activation of pro-MMP-2 to active MMP-2 (68, 66 kDa) occurred but pro-MMP-9 was not activated even after 1 hour of incubation. In recent communications, we have shown that

incubation of cell membrane fraction of human cervical cancer cell line SiHa with purified MMP-9/MMP-2 mixture led to activation of pro-MMP-2 after 30 minutes while pro-MMP-9 was not activated (Mitra *et al.* 2004). These experimental findings indicate that membrane associated activation appears to be very specific for MMP-2 (gelatinase A) only, as MMP-9 (gelatinase B) is not activated under the same conditions. In previous communication, we had reported the presence of all components of the cell surface activation complex (MT1-MMP, TIMP-2, pro-MMP-2, $\alpha v \beta 3$ integrin) in SiHa human cervical cancer cell membrane fraction and expression of $\alpha v \beta 3$ integrin-associated MMP-2 on SiHa cell surface (Mitra *et al.* 2006).

Besides activation of MMPs, their cellular localization also plays a crucial role in tumour cell invasion. MT1-MMP and integrin $\alpha v \beta 3$ serve as cell surface receptors for MMP-2 and play an important role in positioning proteolytically active MMP-2 on cell surface (Seihi *et al.* Chattopadhyay *et al.* 2001, Sato *et al.* 1996). Immunocytochemistry showed localization of MT1-MMP on A375 and SiHa cell membrane at focal adhesion sites. Activation of pro-MMP-2 by MT1-MMP at focal adhesion sites and subsequent degradation of ECM components by MMP-2 at specific regions rather than a random digestion could regulate ECM degradation and motility, facilitating directed cellular invasion and metastasis. MT1-MMP may be able to entrap exogenous MMP-2 synthesized by other cells or derived from serum (Sato *et al.* 1996); this MMP-2 could then be activated by the membrane associated activation complex. In many tumours, stromal fibroblasts produce large amounts of MMP-2

(Egeblad *et al.* 2002, Sato *et al.* 1996); capture and subsequent activation of this MMP-2 by MT1-MMP could occur on cell surface of tumour cells. This would enable carcinoma cells to utilize MMP-2 secreted by other cells to accomplish ECM digestion and metastasis.

Significantly, in previous studies, cells were stimulated with TPA or Con A in order to demonstrate the cell membrane associated activation of MMP-2 (Strongin *et al.* 1995, Shiomi *et al.* 2003, Tester *et al.* 2004, Yu *et al.* 1998, Yu *et al.* 1995). However, in our present experiment, A375 and SiHa cells show cell membrane associated MMP-2/72 kDa collagenase type IV activation under native conditions ie. without treatment by TPA, Con A or any other compounds. This could be due to greater efficiency of A375 and SiHa cells in activating MMP-2.

Thus, our experimental findings furnish another example of the unique membrane associated MMP-2 activation mechanism, first reported by Strongin *et al.* (1995) (Strongin *et al.* 1995), in the human melanoma cell line A375 and the human cervical carcinoma cell line SiHa and clearly elucidate the role of MT1-MMP in MMP-2 activation. This information could help in developing therapies to interfere with MMP activation for management of cancer and metastasis.

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LITERATURE CITED

- BROWN PD, BLOXIDGE, RE, ANDERSON, E. and HOWELL, A. 1993. Expression of activated gelatinase in human invasive breast carcinoma. *Clin. Exp. Metastasis*, **11** : 183-189.
- CHATTOPADHYAY, N., MITRA, A., FREI, E. and CHATTERJEE, A. 2001. Human cervical tumour cell (SiHa) surface $\alpha v \beta 3$ integrin receptor has associated matrix metalloproteinase (MMP-2) activity. *J. Cancer Res. Clin. Oncol.* **127** : 653-658.
- COUSSENS, LM, and WERB, Z. 1996. Matrix metalloproteinases and the development of cancer. *Chem. Biol.*, **3** : 895-904.

- EGEBLAD, M. and WERB, Z. 2002. New functions for the matrix metalloproteinases in cancer progression. *Nature Reviews, Cancer*, **2** : 161-174.
- HOFMANN, UB, WESTPHAL JR, VAN KRAATS, AA, RUITER, DJ, and VAN MUIJEN, GNP, 2000. Expression of integrin avb3 correlates with activation of membrane-type matrixmetalloproteinase-1 (MT1-MMP) and matrix metalloproteinase 2 (MMP-2) in human melanoma cells in vitro and in vivo. *Int. J. Cancer*, **87** : 12-19.
- LOWRY, OH, ROSEBROUGH, NJ, FARR, AL and RANDALL, RJ. 1951. Protein measurement with the Folin phenol reagent. *J. Biol. Chem.*, **193** : 265-275.
- MITRA, A., CHAKRABARTI, J., BANERJI, A. and CHATTERJEE, A. 2004. Binding of $\alpha 2$ monoclonal antibody to human cervical tumour cell (SiHa) surface $\alpha 2\beta 1$ integrin modulates MMP-2 activity. *Gynecol Oncol.*, **94** : 33-39.
- MITRA, A., CHAKRABARTI, J., BANERJI, A. and CHATTERJEE, A. 2006. Cell Membrane Associated MT1-MMP Dependent Activation of MMP-2 in SiHa (Human Cervical Cancer) Cells. *J. Environ. Pathol. Toxicol. Oncol.*, **25** : 655-666.
- NAGASE, H. 1997. Activation mechanism of matrixmetalloproteinases. *Biol. Chem.*, **378** : 151-160.
- SATO, H. and SEIKI, M. 1996. Membrane-type matrix metalloproteinases (MT-MMPs) in tumour metastasis. *J. Biochem*, **119** : 209-215.
- SEIKI, M., KOSHIKAWA, N. and YANA, I. 2003. Role of pericellular proteolysis by membrane type1 matrix metalloproteinase in cancer invasion and angiogenesis. *Cancer Metastasis Reviews*, **22** : 129-143.
- SHIMADA, T., NAKAMURA, H., YAMASHITA, K., KAWATA, R., MURAKAMI, Y., FUJIMOTO, N., SATO, H., SEIKI, M. and OKADA, Y. 2000. Enhanced production and activation of progelatinase A mediated by membrane type-1 matrix metalloproteinase in human oral squamous cell carcinomas : Implications for lymph node metastasis. *Clin. Exp. Metastasis*, **18** : 179-188.
- SHIOMI, T, OKADA, Y. 2003. MT1-MMP and MMP-7 in invasion and metastasis of human cancers. *Cancer Metastasis Reviews*, **22** : 145-152.
- STERNLICHT, MD and WERB Z. 2001. How matrix metalloproteinases regulate cell behaviour. *Annu. Rev. Cell. Dev. Biol.*, **17** : 463-516.
- STRONGIN, AY, MARMER, BL, GRANT, GA, GOLDBERG, GI. 1993. Plasma membrane dependant activation of the 72 kDa type IV collagenase is prevented by complex formation with TIMP-2. *J. Biol. Chem.*, **268** : 14033-14039.
- TESTER, AM, WALTHAM, M, OH, SJ, BAE, SN, BILLS, MM, WALKER, EC, KERN, FG, STETLER-STEVENSON, WG, LIPPMAN, ME and THOMPSON, EW. 2004. Pro-matrix metalloproteinase-2 transfection increases orthotopic primary growth and experimental metastasis of MDA-MB-231 human breast cancer cells in nude mice. *Cancer Res.*, **64** : 652-658.
- TOTH, M. and FRIDMAN, R. 2001. Assessment of gelatinases (MMP-2 and MMP-9) by gelatin zymography. In Brooks SA, Schumacher U, eds. *Metastasis Research Protocols*. New Jersey, Humana Press : 163-173.
- YU M, SATO, H, SEIKI M, SPIEGEL, S. and THOMPSON, EW. 1998. Elevated cyclic AMP suppresses Con A-induced MT1-MMP expression in MDA-MB-231 human breast cancer cells. *Clin. Exp. Metastasis*, **16** : 185-191.
- YU M, SATO, H., SEIKI, M. and THOMPSON, EW. 1995. Complex regulation of membrane type matrixmetalloproteinase expression and matrix metalloproteinase-2 activation by concanavalin A in MDA-MB-231 human breast cancer cells. *Cancer Res.*, **55** : 3272-3277.

EXPRESSION PATTERNS OF DEVELOPMENTAL GENES IN WING AND LEG IMAGINAL DISCS OF *DROSOPHILA MELANOGASTER*

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ABSTRACT

The adult structures of *Drosophila melanogaster* are derived from larval imaginal discs, which originate as clusters of cells within the embryonic ectoderm. We have used the expression patterns of the genes known to be important during early *Drosophila* development to reassess the segment and parasegment organization of the wing and leg imaginal discs. We find that the pair rule gene, *even skipped (eve)*, was not expressed in wing disc while unexpected expression of *fushi tarazu (ftz)*, and *hairy (h)* was noted in both wing and leg discs. The *ftz-lacZ* expression and *vg boundary enhancer-lacZ* expression generally colocalize in wing disc cells. The *engrailed (en)* was expressed in posterior compartment, while *decapentaplegic (dpp)* and *wingless (wg)* were expressed along the border between the anterior-posterior domains. The *hedgehog (hh)* induced anterior cells to organize anterior posterior axis while *cubitus interruptus (ci)* was expressed exclusively in anterior cells. The cell fate specification by *vestigial (vg)* established the distal parts of the disc that straddles the interface between dorsal and ventral cells. The localized accumulation of these proteins within the cells of the two imaginal discs play a key role in the establishment of planar polarity of the discs. A comparison of expression pattern of the genes in the two type of imaginal discs clearly suggested that compartmental organization of the two discs are different.

Keywords : *Drosophila*, wing discs, leg discs, Organization of imaginal discs

INTRODUCTION

In *Drosophila melanogaster*, the body plan is set very early in development by five classes of genes. These genes function in a regulatory cascade which act in a hierarchical fashion. Maternal effect genes establish polarity and spatial co-ordinates of egg and developing embryo (Nusslein Volhard, 1979). In zygotes, subdivisions of the anterior/posterior axis into segmental units is defined by gap genes and pair rule genes (see Akam, 1987). The 'primary pair rule' genes [*even skipped (eve)*, *runt (run)* and *hairy (h)*] are first to express in complementary stripes, determined by the gap genes. Subsequently, they negatively regulate the expression of 'secondary pair-rule' gene

fushi-tarazu (ftz) to induce the segment polarity genes *engrailed (en)* and *wingless (wg)* in creation of necessary fourteen evenly spaced segments on either side of the segment border, thus establishing the segmental compartmentalization of the fly (Blair, 1995). A fifth class of genes, the homeotic genes, provide an identity to each segment (Duncan, 1987).

Previous studies have shown that pair rule genes encode transcription factors that are expressed in regions corresponding to each gene's domain of function (Akam, 1987). However, it is not known whether pair rule gene products are specifically synthesized for pair rule patterning or not. Recently, it has been noted that some pair rule genes are expressed

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in mesoderm, gut and most notably the central nervous system (<http://flybase.bio-indiana.edu/>). Unfortunately, their expression patterns in imaginal discs have never been investigated. Thus, the function of pair rule genes in structuring the adult morphology is unknown (see Mann and Morata, 2000; <http://flybase.bio-indiana.edu/>).

Each limb of *Drosophila* is derived from imaginal disc. Imaginal discs begin as small clusters of cells which are set aside during embryogenesis. These cells proliferate during larval development to form folded, single layer, epithelial sacs. The cells of each disc are stably determined to give rise to a specific segmental appendage. These discs remain largely undifferentiated in the larva. During pupation the discs begin to differentiate, they evert (or unfold) and fuse to form a continuous adult head and thoracic cuticle. The differentiation of the disc is regulated by positional signals within the imaginal disc (Campbell *et al.*, 1993). In reality, the complex pattern of cellular differentiation seen in the discs during pupation is not determined in the cells of primordia, but rather the patterns of growth and differentiation are specified during disc development. Various authors have noted that subdivision of the primordia appendages into distinct compartments controls growth and patterning during development (Bryant, 1978; Martinez-Arias and Lawrence, 1985; Tabata *et al.*, 1995; Zecca *et al.*, 1995; Lawrence and Struhl, 1996; Brook *et al.*, 1996; Acharyya and Chatterjee, 2001; Ray *et al.*, 2001). The compartments specify indirectly, a surface property, termed cell affinity. Cells that share the same affinity can intermingle during growth, while cells in the neighbouring compartment with a different basis for affinity self associate but minimize contact with cells in adjacent compartments. Each compartment acquires a genetic address, as a result of the function of active 'selector' genes that specify cell fate within a compartment and also instruct cells and other descendants how to communicate with cells in neighbouring compartments. Cells, believed to be assigned to their compartment specific identity by differential expression of

developmental genes, regulate pattern formation (Williams *et al.*, 1993; Freeland and Kuhn, 1996). Thus, a well defined boundary forms between adjacent compartments. The compartmental organization can also be traced to adult primordia which originate from the imaginal disc precursors.

The wing and leg discs provide excellent example of pattern formation in *Drosophila*. It has been observed that during development of the discs crucial expression of segmental polarity genes (*en*, *wg*, *vg*, *hh*, *dpp*, *ci*, etc.) are required to initiate cell lineage between appendage compartments assuring correct anterior/posterior polarity of the future limbs (Campbell *et al.*, 1993). The *dpp* along with *wg* and *hh*, defines the position of future wings and legs. Once active, Dpp acts as a long range morphogen to control growth and patterning the compartments (Zecca *et al.*, 1995; Nellen *et al.*, 1996). However, the molecular mechanisms responsible for signal induction are different for the ventral and dorsal appendages. The development of the leg disc is different from that of wing discs where patterning along the dorso-ventral and proximo-distal axes depends upon Dpp and Wg signaling (Basler and Struhl, 1994; Brook and Cohen 1996; Held and Heup, 1996). This indicates that different patterning mechanisms exist for different discs. Even, there is left-right asymmetry of fly wings and their evolution of body axes (Klingenberg *et al.*, 1998). These observations indicate that although same genes are expressed in different imaginal discs for morphogenesis and differentiation, the expression domain of the genes in different imaginal discs are different. Therefore, disc-to-disc comparison of expression pattern of different developmental genes is necessary to map the cellular identity of each disc for analysis of growth dynamic and differentiation of the discs. The fate maps of different imaginal discs are also unknown. Therefore, it would be necessary to reexamine the expression patterns of the developmental genes in different imaginal discs.

Furthermore, the combination of linear RNA amplification and DNA microarray

hybridization in wing disc clearly demonstrated that many genes with potential roles in wing disc development remain to be characterized (Klebes *et al.*, 2002). This may indicate that the signaling network involving in adult pattern development is not completely worked out. This information is necessary to provide the spatial cues to assign their cell fate and initiate cell-cell interaction in the disc.

In view of these reasons, we have designed an experiment to reassess the domains of expression of developmental genes in wing and leg discs to map the segmental/parasegmental organization of the discs. The segmental/parasegmental organization of the imaginal discs and adults have been extensively mapped by studying the expression pattern of *E. coli* *B*-galactosidase gene, under the control of developmental genes promoter (reporter gene). The expression patterns of following pair-rule genes (a) *eve*, (b) *ftz*, (c) *h*, and segment polarity genes (a) *en*, (b) *hh*, (c) *wg*, (d) *dpp*, (e) *ci* and (f) *vg* boundary enhancer and (g) *vg* (a transcription factor) were examined for present investigation. A catalogue of the expression patterns of above mentioned genes in the two discs may help to reconstruct the detail maps of cellular organization in the two types of discs.

MATERIALS AND METHODS

a. Fly Stocks

The following fly stocks (for details of mutation not specifically referred to in the following see Lindsley and Zimm, 1992)

(1) Oregon R strain of *wild type*

(2) *lacZ* insertion lines : (a) *CyO*, *wg-lacZ*, (b) *dpp-lacZ/CyO*, (c) *17-en 40*, (d) *eve-lacZ*, (e) *vg-lacZ*, (f) *hh-lacZ*, (g) *h-lacZ* C5/TM3, (h) *ci lacZ*, (i) *CyO*; *ftz lacZ/thv* [8], *Dll*, (j) *vg* boundary enhancer-*lacZ* (Williams *et al.*, 1993)

b. *Drosophila* Stock maintenance

The flies were cultured in a BOD incubator at $24^{\circ} \pm 1^{\circ}\text{C}$ at standard *Drosophila* food medium. The food medium was supplemented with yeast for better nourishment. The food free third instar larvae and adults were used for the experiments.

Methylparabenizin was added to the surface of the medium to suppress mold growth.

c. Detection of *B*-galactosidase activity staining

The procedure used to stain for *B* gal activity was similar to that used by Hama *et al.*, (1990). The adult flies and third instar larval imaginal discs were used for reporter gene expression assay. Imaginal discs were dissected out from third instar larvae, fixed in 4% paraformaldehyde, 0.5% Triton X 100 in PBS solution for 20 minutes, washed in PBS for 5 minutes and blocked in bovine serum albumin (BSA) 1%; 0.1% Tween 20 in PBS for 1 hour. The expression patterns of *ftz*, *eve*, *h*, *wg*, *en*, *ci*, *dpp*, *hh*, *vg* and *vg* boundary enhancer in the wing and leg discs of the late third instar larvae from the *lacZ* insertion lines were monitored by X-gal staining for *B* galactosidase activity. Using watchmaker's forceps, larvae and adult flies were dissected in buffered Ringer solution (pH-7.2) (Ashburner, 1989) and the imaginal discs and adults were transferred to the wells of a microtitre plate in which subsequent operations were performed. The tissues were fixed for 20 min at room temperature with 0.75% glutaraldehyde in PBS, washed 3 times with PBT (0.05% Triton X-100 in PBS) and stained in 0.2% X-gal staining solution [10mM sodium phosphate (pH 7.2), 150mM NaCl, 1mM MgCl₂, 5mM potassium ferricyanide, plus 5mM potassium ferrocyanide] freshly prepared from an 8% X-gal stock solution in DMSO kept at -20°C . Staining took place at 37°C in dark, with the plates covered to prevent evaporation, and was monitored at intervals by inspection of treated and control samples for each line in adjacent wells. Except when staining was very rapid, it was allowed to continue overnight. After the staining, the samples were washed in 50mM sodium phosphate buffer, mounted in 80% glycerol in PBS and photographed under a Zeiss photomicroscope.

RESULTS

a. Pair rule gene expression patterns

Figures 1a-c show unexpected expression patterns of *eve*, *h* and *ftz* in wing disc of third

instar larvae respectively. As it appears from the photomicrograph presented in Fig. 1a, *eve* was not expressed in the wing disc. On the other hand, *h* and *ftz* were expressed in dorso-ventral axis of the disc (Fig. 1bc). *h* was expressed in dorso-ventral domain in wing disc whilst *ftz* was expressed in dorso-ventral boundary and along part of the A/P boundary. Curiously, it may be noted here that *ftz-lacZ* expression and *vg boundary enhancer lacZ* expression generally colocalize in the wing disc cells (Fig. 1b). These observations clearly indicate that pair rule genes are also expressed parasegment in wing disc.

Analogous situation was noted in leg discs except that *eve* was expressed in a small area of the leg disc. The representative examples of expression patterns of *eve*, *h* and *ftz* in first leg discs (Fig. 1d-f) and third leg discs (Fig. 1g-i) are shown. As it appears from the photomicrographs, the expression pattern of the three genes are not very different in two types of discs. In this context, it may be noted here that, as it appears from Fig. 2 ab, the expression patterns of *hairy* (*h*) in second leg disc and third leg disc were same. However, the lateral view of second disc showed the multiple folds present in mature leg discs and summarizes the domains of gene expression (Fig. 2c). Therefore, for comparison, photographs of expression patterns of the above mentioned genes in the second leg discs were not included in the Figure 1. Comparative analysis of the expression pattern of the genes in leg imaginal discs, indicate that, as expected, the three genes were expressed in three different domains and there was an overlapping between the expression pattern of the three genes (Fig. 1e-i). For example, *h* was expressed in a large area of the leg imaginal disc. Thus, the β -galactosidase activity of *h* gene is demarcated the distal parts of the disc concentrated in the center and a thin stripe extended out towards the periphery in the presumptive thoracic regions of the disc. Similarly, *ftz* expression completely surrounds and partially overlaps with the *h* domain. The broad domains of pair rule gene expression in imaginal disc may be analogous to the way the gap gene domains

that are established in the embryo in response to the bicoid gradient. In this context it may be noted here that sub-division of the anterior/posterior axis into segmental units known as parasegments is carried out by pair rule genes. These data clearly indicate that there is focus of growth at any given stage of leg disc and that individual cells are not determined to form specific structures until prior metamorphosis.

During our investigation we also recorded that in salivary gland nuclei of the third instar larvae, *ftz* was unexpectedly expressed (Fig. 3cd). The reason is not clear to us.

b. Segmental polarity gene expression patterns

A comparative account of *lacZ* reporter gene expression of *ci*, *en*, *wg*, *dpp*, *hh* and *vg* in the wing and leg imaginal discs are presented below. As noted earlier, most of the genes, are expressed in compartment specific manner in both the discs. We noted that many of the genes were differentially expressed in wing and first, second and third leg discs.

Engrailed (*en*) defines anterior and posterior compartments both wing and leg discs. As it appears from the photomicrographs presented in Fig. 4a&f, in wing and leg imaginal discs, *en* expression subdivided the discs into two halves - anterior (A) and posterior (P) compartment. *Engrailed* expression results in cells becoming posterior in identity. *Engrailed* also defines anterior and posterior compartment in adult wing (see Fig. 5a). It is, therefore, reasonable to conclude that *en* expressing cells are fated to become the posterior most cells of the adult wing. Therefore, the domain of expression of *engrailed* was approximately half in the wing disc, while it was more than half in the leg disc.

The *decapentaplegic* (*dpp*) is expressed in a thin strip of cells that bisects the wing imaginal disc into anterior and posterior halves (Fig. 4b). This is true for the leg disc (Fig. 4g). Its spatial expression pattern and its function as a signaling molecule made it an excellent candidate to organize the pattern in the A/P axis. The imaginal disc, expression of *dpp* in a

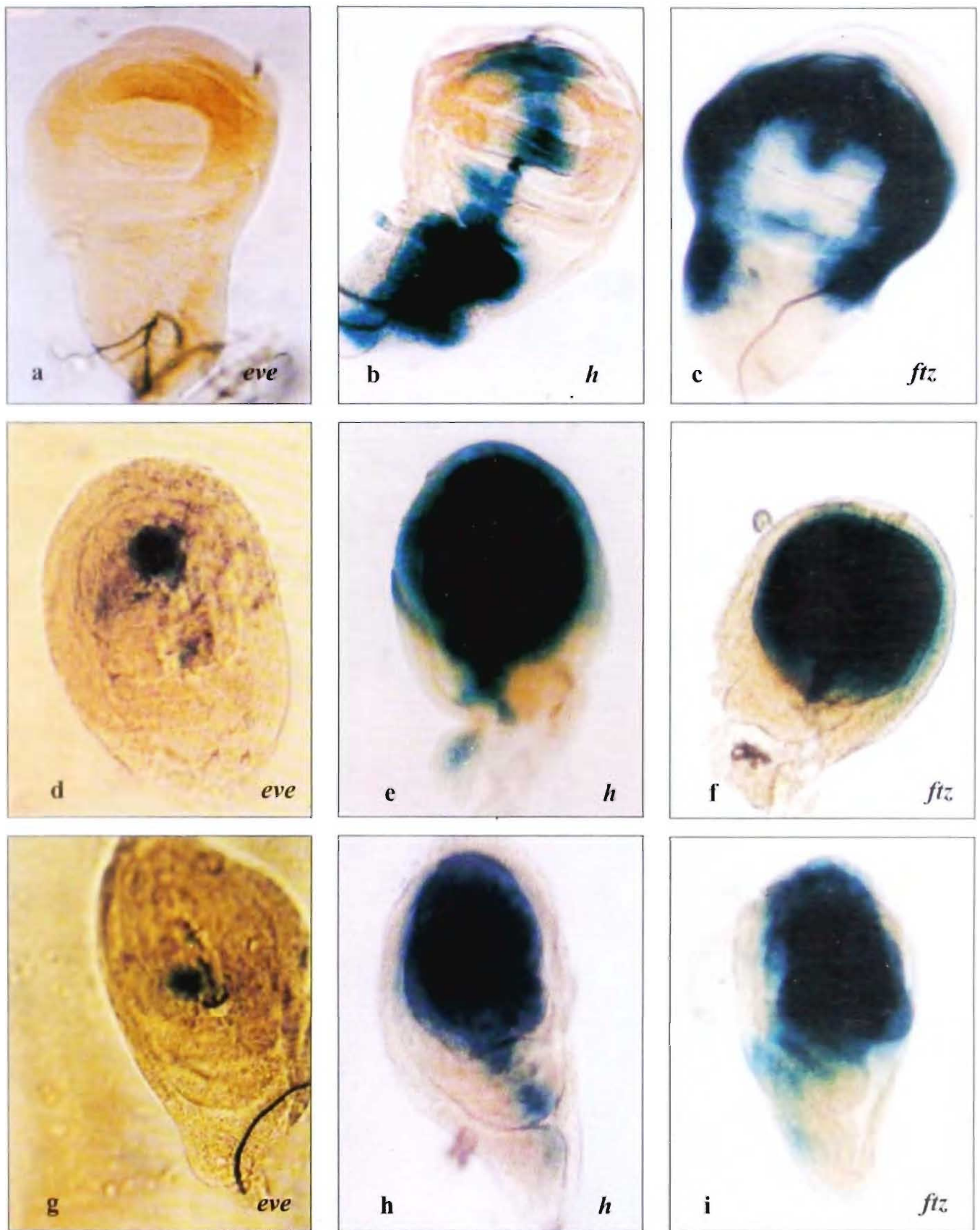


Fig. 1a-i. Expression patterns of the pair rule genes in wing and leg discs. (a) *even skip* (*eve*) expression pattern in a wing disc, (b) *hairy* (*h*) expression pattern in a wing disc, (c) *fuzhi tarazu* (*ftz*) expression pattern in a wing disc, (d) *eve* expression pattern in a 1st leg disc, (e) *h* expression pattern in a 1st leg disc, (f) *ftz* expression pattern in a 1st leg disc, (g) *eve* expression pattern in a 3rd leg disc, (h) *h* expression pattern in a 3rd leg disc and (i) *ftz* expression pattern in a 3rd leg disc. Note that *eve* was not expressed in the wing disc cells and the *ftz-lacZ* expression and *vg boundary enhancer-lac-Z* generally colocalize in the wing disc cells.

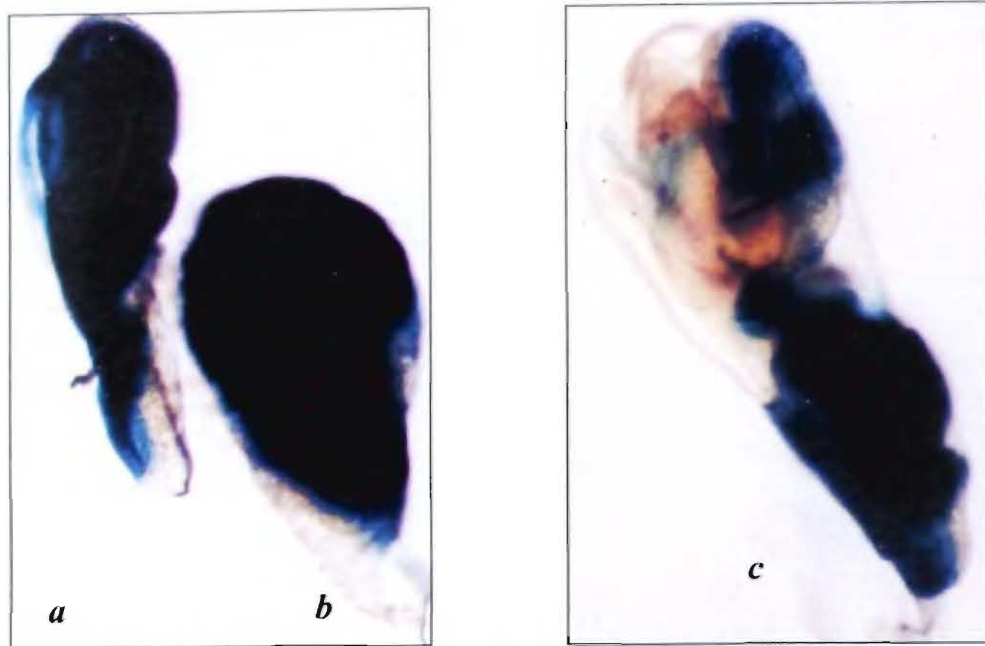


Fig. 2a-c. Expression pattern of *ftz* in a 2nd and 3rd leg discs (a and b). A lateral view of a second leg shows the multiple folds present in mature disc, (c). Note the expression pattern (not very different) of *ftz* in the 2nd and 3rd leg discs.

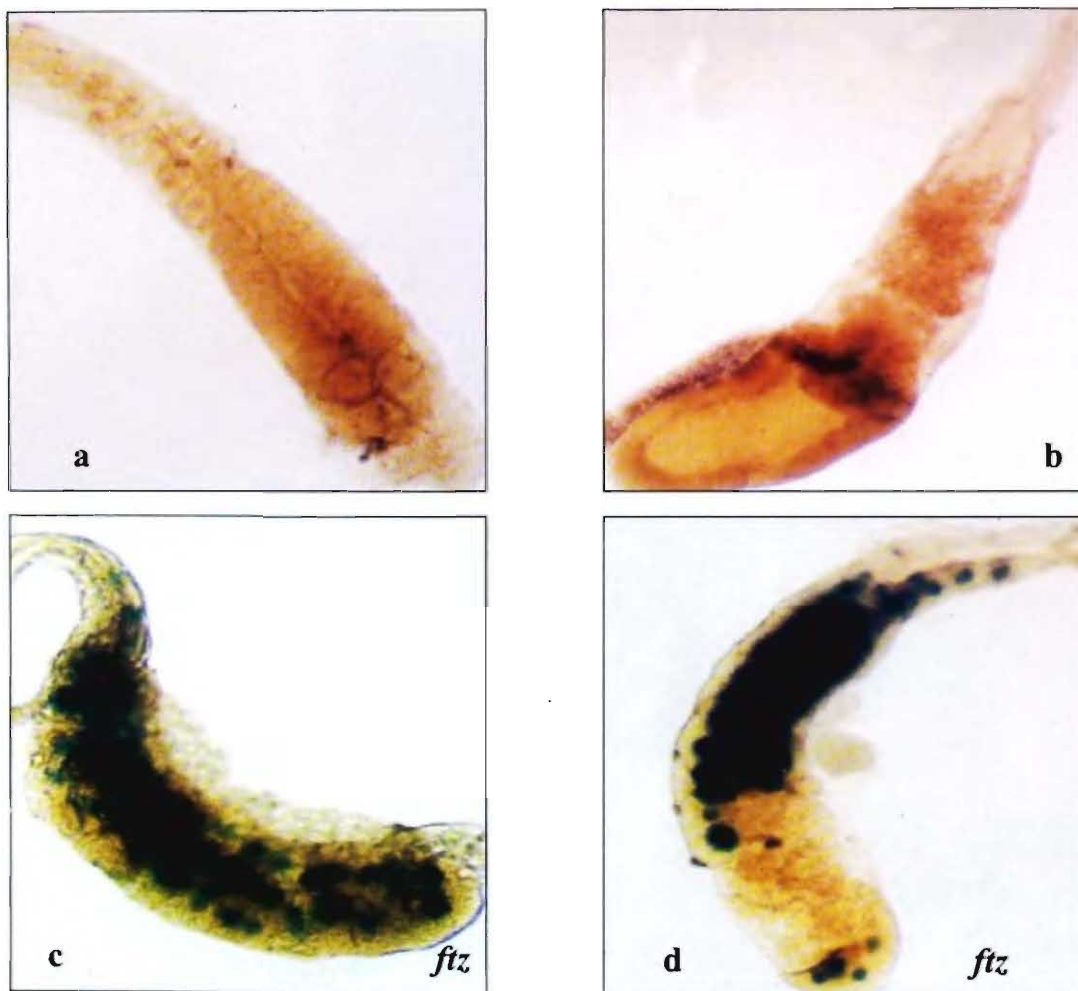


Fig. 3a-d. Expression pattern of *ftz* in the salivary gland nuclei of *D. melanogaster*, (a) a salivary gland of a third instar larva, (b) a salivary gland of a late third instar larva, (c) expression pattern of *ftz* in the salivary gland nuclei of a third instar larva and (d) expression pattern of *ftz* in the salivary nuclei of a late third instar larva.

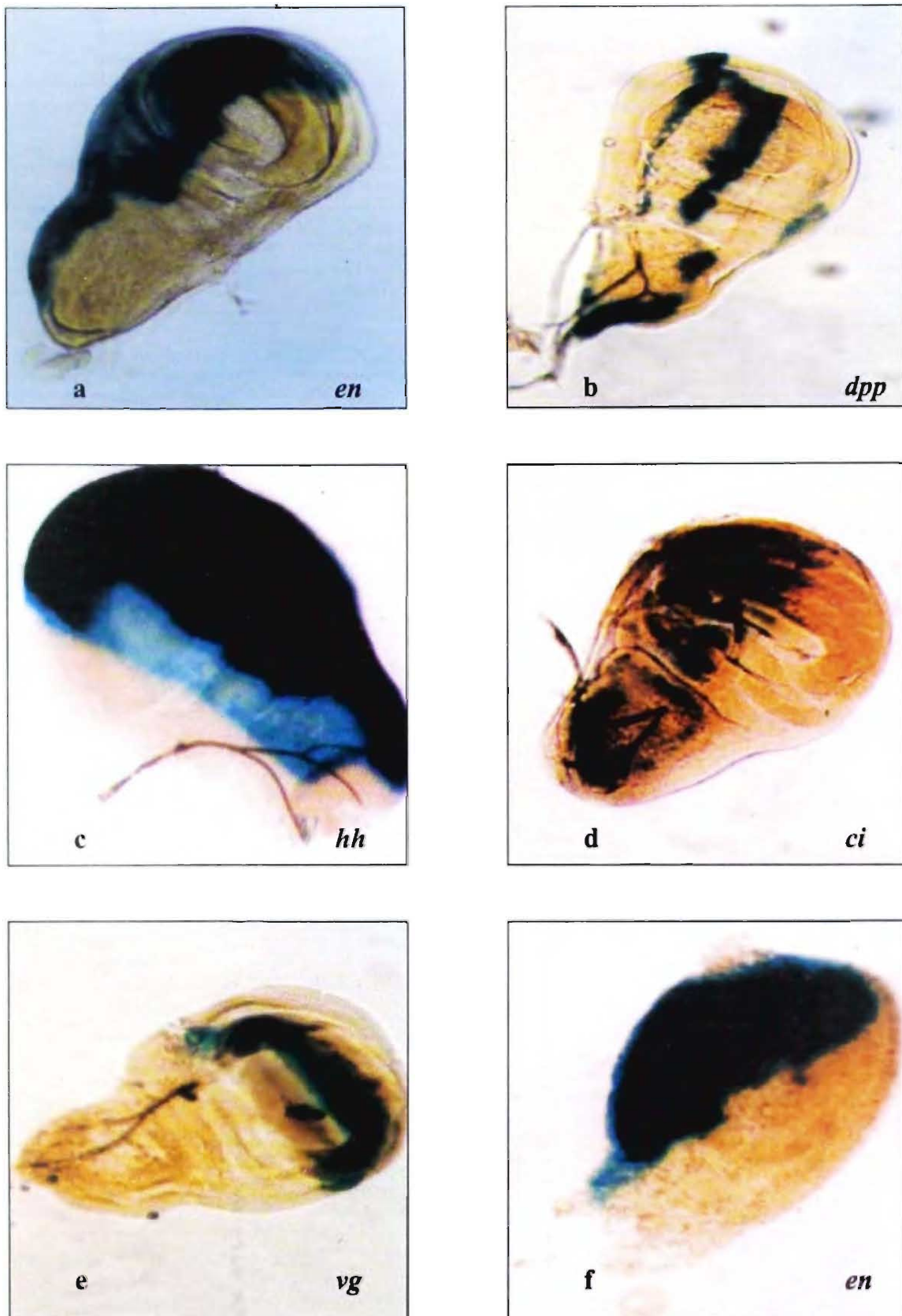


Fig. 4a-f. Expression pattern of the segment polarity genes in wing and leg discs. (a) *engrailed* (*en*) expression pattern in the wing discs, (b) *decapentaplegic* (*dpp*) expression pattern in wing disc, (c) *hedgehog* (*hh*) expression pattern in a wing disc (d) *cubitus interruptus* (*ci*) expression pattern in a wing disc, (e) *vestigial* (*vg*) expression pattern in a wing disc, (f) *en* expression pattern in a 1st leg disc (see text for leg disc expression pattern).

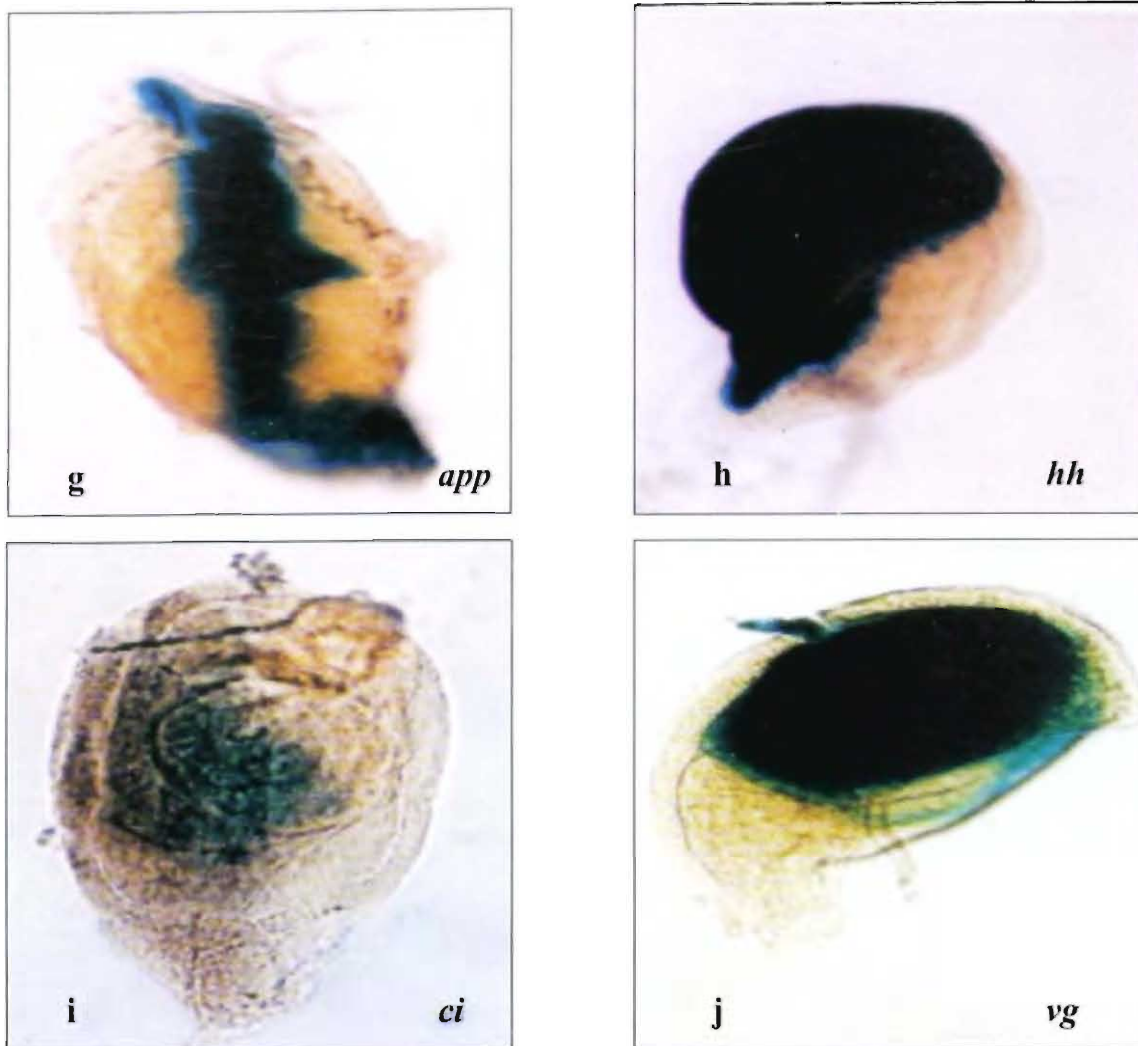


Fig. 4g-j. Expression pattern of the segment polarity genes in leg discs. (g) *dpp* expression pattern in a 1st leg disc, (h) *hh* expression pattern in a 1st leg disc, (i) *ci* expression pattern in a 1st leg disc and (j) *vg* expression pattern in a 1st leg disc.

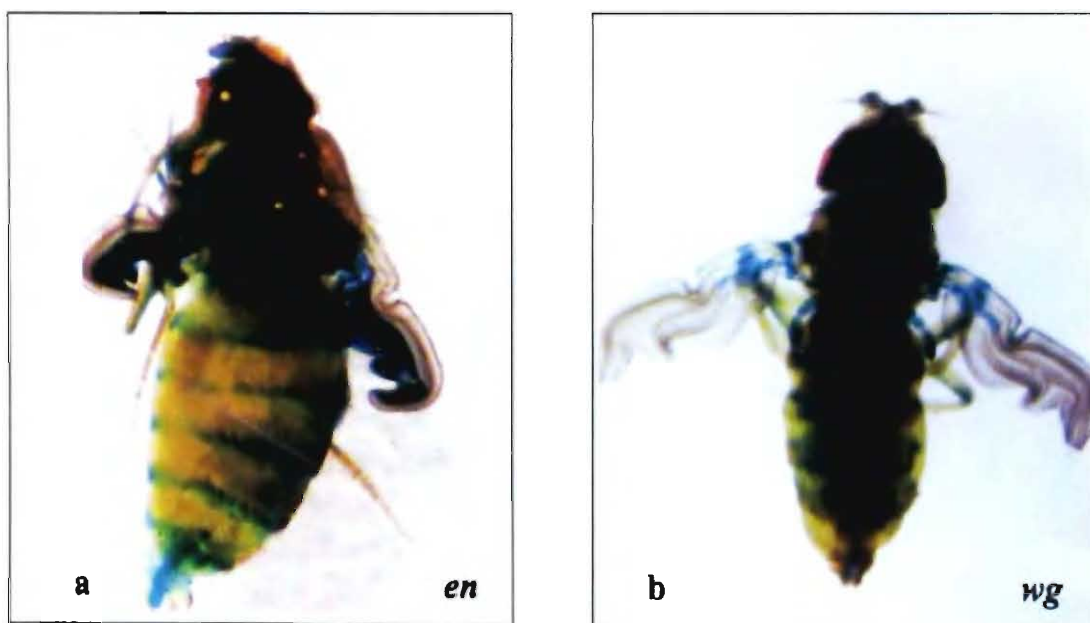


Fig. 5a-b. Expression pattern of (a) *engrailed* and (b) *wingless* in pharate adults of *D. melanogaster*. Note the expression pattern of *en* in adult wing disc (posterior compartment).

narrow stripe of cells along the anterior-posterior compartment boundary may be essential for proper growth and patterning of the wing and leg discs of *Drosophila*. The cell fate along the A/P axis is directly related to the perceived Dpp level.

As expected, *hedgehog* (*hh*) is co-expressed with *en* in posterior cells of wing and leg discs (Fig. 4c & h). Posterior cells heritably express the selector gene *en* which directs these cells to secrete the short range signaling molecule Hh (and at the same time makes posterior cells refractory to Hh signal). Posterior to anterior cell signaling is mediated by Hh.

Cubitus interruptus (*ci*) is expressed in anterior cells in both discs (Fig. 4d&i). *wg lacZ* expression is unique in wing imaginal disc. In third instar larval disc the *wg* is expressed in double ring (figure not included). In pharate adult, the *wg* is expressed in wing margin and

the presumptive wing hinge region (Fig. 5b). In the leg imaginal disc *wg* is expressed exclusively in the prospective ventral cells. In both wing and leg discs, dorso-ventral and proximo-distal axes pattern depend upon *wg* and *dpp*.

Vestigial (*vg*), a nuclear protein, is expressed in both leg and wing imaginal discs (Fig. 4e). It is a known marker for leg (Fig. 4j) and wing imaginal discs, and are required for pattern formation along the proximal-distal axis in the adult. *vg* is a possible effector of growth induced by *dpp* signaling. *vg* is expressed in entire developing wing pouch. However its expression pattern in adult leg disc is none.

Comparative analyses of expression pattern of developmental genes in wing and leg discs are presented in Table 1. The molecular nature of the genes that they include basic metabolic and transporting functions, structural, cell

Table 1. Expression patterns of *eve*, *ftz*, *h*, *en*, *dpp*, *hh*, *ci*, *vg* and *wg* in leg and wing imaginal discs.

Gene	Classification	Molecular nature	Expression pattern in leg disc	Expression pattern in wing disc
<i>even skipped</i> (<i>eve</i>)	Pair rule	Homeodomain	Parasegment, almost entire area of disc	No expression
<i>fushi tarazu</i> (<i>ftz</i>)	Pair rule	PEST and homeodomain	Parasegment almost entire area of disc	Parasegment almost entire area of disc
<i>hairy</i> (<i>h</i>)	Pair rule	bHLH	Parasegment large area of the disc	Parasegment entire area of disc
<i>hedgehog</i> (<i>hh</i>)	Segment polarity	Secretory protein	Posterior compartment, co-expressed with <i>en</i>	Posterior compartment, co-expressed with <i>en</i>
<i>Cubitus interruptus</i> (<i>ci</i>)	Segment polarity	Transcription factor	Anterior compartment	Anterior compartment
<i>decapentaplegic</i> (<i>dpp</i>)	Segment Polarity	Morphogen (TGFB)	Dorso-ventral axis of the disc	Dorso-ventral axis of the disc
<i>wingless</i> (<i>wg</i>)	Segment polarity	Signal protein	Dorso-ventral compartment	Double circle in the disc
<i>engrailed</i> (<i>en</i>)	Segment polarity	Transcription factor	Posterior compartment	Posterior compartment
<i>vestigial</i> (<i>vg</i>)	—	Transcription factor	Almost entire area of disc	One circle in the wing disc

adhesive and signaling functions as well as transcriptional regulation. Data in Table 1 also indicate that wing discs have different organization than the leg discs although ventral leg and dorsal wing primordia appear to originate from a common primordium.

DISCUSSION

Subdivision of the primordia appendages into distinct compartments controls growth and patterning during development (Garcia-Bellido *et al.*, 1973). Short range interactions between compartment border cells triggers the expression of organizer signal molecules. Curiously, one of the most fascinating examples of unexpected expression of some pair rule genes, subsequent to cellularization in 'segment polarity' pattern of expression observed with gene products from *eve*, *h* and *ftz* (see Fig. 1a-i). This observation extends the role of pair rule genes, play during embryogenesis. In this context, it may be noted here that pair rule encodes a transcription factor that is expressed in regions corresponding to each gene's domain of function. Furthermore, expression pattern of *h* in leg discs is expected as the gene *h* is chiefly responsible for setting up periodic bristle pattern and as legs are covered with sensory bristles arranged in longitudinal rows in most segments. Similarly, as pair rule gene, *ftz* encodes a DNA binding homeodomain protein and as it is known to regulate segment polarity genes, its expression in the imaginal discs is expected. During normal wing disc development, *vg* expression is up-regulated in the mid-second instar stage (Williams *et al.*, 1993) through the *vg* boundary enhancer. The activation of the boundary enhancer is controlled by signaling interactions at D/V boundary of the wing disc, specifically by Notch signaling acting through Suppressor of Hairless, a transcription factor that binds to the boundary enhancer (Kim *et al.*, 1996). As expected, *eve*'s pair rule patterning was not observed in the wing disc although Eve is a homeodomain protein besides being a transcription repressor of a number of developmental genes. It is possible that Eve repression is required in the wing imaginal disc for both the odd and even

numbered *en* stripes in the wing imaginal disc. At any rate, our data reveal that some pair rule genes were expressed in the wing and the leg imaginal discs. However, we do not know why *ftz* was expressed in the salivary gland cells. The future molecular analysis of the Ftz may explain the results.

Furthermore, our data reveal that in both wing and leg discs a similar inductive mechanism operate to establish anterior-posterior and dorso-ventral specific compartments through expression of *en*, *wg*, *dpp*, *vg* and *ci* genes although the expression pattern of the genes were different in two types of the discs.

En and *hh* expression in leg and wing imaginal disc localize the posterior compartment. This conclusion is based on the coincident expression of *en* in adult wing (see Fig. 5a). Previous studies have also indicated that the activation of the *en* gene in all of the posterior (P) founder cells divides every segment of *Drosophila* into anterior and posterior compartment (Kornberg *et al.*, 1985). The P-cells that express *en* programme, help the cells to transcribe and secrete Hedgehog (Hh, Tabata *et al.*, 1995). This is true for leg disc. The *en* gene is a positive regulator of *hh* expression and it negatively regulates *patched* (*ptc*) and *dpp* in the posterior compartment (Tabata *et al.*, 1992). The *hh* gene is coexpressed with *en* (see Fig. 4) and all the organizing activity of *en* is mediated through *hh* (Tabata and Kornberg, 1994). Hh is also known to organize many aspects of wing development indirectly by inducing Dpp protein (Basler and Struhl, 1994; Zecca *et al.*, 1995). In wing and leg imaginal discs, *dpp* is expressed along the entire anterior margin of *en* and is believed to define the anterior-posterior compartment boundary (Lecuit and Cohen, 1997). Active Dpp acts as a long range morphogen to control growth and patterning in both the compartments (Basler and Struhl, 1994; Blair, 1995; Lecuit *et al.*, 1996; Nellen *et al.*, 1996).

ci is expressed in anterior compartment. *ci* controls the transcription of the *dpp*, which as a consequence, is expressed only in a thin strip

of the anterior cells along the A/P boundary. *dpp* encodes a member of the transforming growth factor B (TGFB) super family which induces the expression of target genes in a concentration dependent manner in both compartments. The stable and precise positioning of the Dpp morphogen source is crucial for growth and patterning of the entire wing and leg discs. Wingless has a role in the establishment of different cell fates, working within and between the anterior and posterior compartments of segments. Wingless also patterns the wing by acting as long range morphogen (Struhl and Basler, 1993; Brook *et al.*, 1996).

By following the patterns of segment polarity gene expression in the two discs we have been able to reconstruct the complex domain of morphological movement of disc cells. The A/P compartments act as engines to produce positional information in both disc. Posterior cells express the selector gene *en* which directs these cells to secrete the short-range signaling molecule Hh and at the same time makes P cells refractory to the Hh signal. *wingless* has a role in establishment of different cell fates working within and between the anterior compartments of segments. Ci and En are both DNA binding proteins known to act as transcription factors, indicating that they control cell segregation by regulating the expression of target genes. The Dpp and Wg signals confer ventralizing and dorsalizing properties to the cells surrounding respective expression domains. The establishment of a proximal-distal axis in wing and leg discs is believed to play a role in limb formation (Cohen 1993). Mutual repression of Wg and Dpp signaling system generates a stable regulatory

circuit by which each gene maintains its own expression in a spatially restricted domain.

In summary, from disc-to-disc comparison it may be concluded that discrete differences exist in expression pattern of developmental genes in wing and leg discs. The common functions of the developmental genes and many other genes in regulating gene expression suggest that developmental fates are manifested in part of the transcripts that different cell types produce from physically distinct areas of the imaginal discs. We lack sufficient understanding of the specific process in most cell types to interpret the significance of the genes that they specifically express. The recent release of the *Drosophila* genome sequence (Adams *et al.*, 2000; <http://flybase.bio-indiana.edu/>) and the demonstration that cDNA microarrays can be used to catalogue the transcriptome of both unicellular and multicellular organisms (White *et al.*, 1999; Klebes *et al.*, 2002) opens up a new approach. Hybridization of mRNA pools to DNA microarrays can potentially identify the differences in gene activity that define every developmental state. Thus, transcription regulators and their downstream targets can be identified simultaneously. We look forward to further enhancement in resolution that can be achieved by combining cell-sorting techniques with microarray analysis for assessing the expressing profiling of *Drosophila* imaginal discs.

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LITERATURE CITED

- ACHARYYA, M. and CHATTERJEE, R. N. 2001. Expression pattern of developmental genes in male and female reproductive system in *Drosophila melanogaster*. *Entom.*, 26 (Spl. Issue) 164-172.
- ADAMS, M. D., CEINIKER, S. E., HOLT R. A., EVANS C. A., GOCAYNE J. D, AMANATIDES, P. G., SCHERER, S.E., LI, P. W., HOSKINS, R. A. and GALLE, R. F. *et al.*, 2000. The genome sequence of *Drosophila melanogaster*. *Science*, 287 : 2185-2195.

- AKAM, M. 1987. The molecular basis of metameric pattern in the *Drosophila* embryo. *Development* **101**, 1-22.
- ASHBURNER, M. 1989. *Drosophila*. A laboratory manual. 2nd edn. Cold Spring Harbor Laboratory Press. Cold Spring Harbor, NY.
- BASLER, K. and STRUHL, G. 1994. Compartment boundaries and the control of *Drosophila* limb pattern by *hedgehog* protein. *Nature*, **368** : 208-214.
- BERKLEY *Drosophila* Genome Project resources [<http://www.fruitfly.org/about/methods/ampUniGene.html>]
- BLAIR, S. S. 1995. Compartments and appendage development in *Drosophila*. *Bioessays*, **17** : 299-309.
- BROOK, W. J. and COHEN, S. M. 1996. Antagonistic interactions between *wingless* and *decapentaplegic* responsible for dorsal-ventral pattern in *Drosophila* leg. *Science*, **273** : 1373-1377.
- BROOK, W. J., DIAZ-BENJUMEA, F. J. and COHEN, S. M. 1996. Organizing spatial pattern in limb development. *Ann. Rev. Cell Dev. Biol.*, **12** : 161-180.
- BRYANT, P. J. 1978. Pattern formation in imaginal discs. In 'The genetics and biology of *Drosophila*' (eds M. Ashburner and T. R. F. Wright), Academic Press, London : 229-335.
- CAMPBELL, G., WEAVER, T. and TAMLINSON, A. 1993. Axis specification in the developing *Drosophila* appendages : The role of *wingless*, *decapentaplegic* and *homeobox* *aristaless*. *Cell*, **74** : 1113-1123.
- COHEN, S. N. 1993. Imaginal disc development in *Drosophila* development. (eds. A. Arias and M. Bate) Coldspring Harbor press : 747-841.
- DUNCAN, I. 1987. The *bithorax* complex. *Ann. Rev. Genet.*, **21** : 285-319.
- Fly Base, a data base of *Drosophila* genome. [<http://flybase.bio.indiana.edu/>]
- FREELAND, D. M. and KUHN, D. T. 1996. Expression patterns of developmental genes reveal segment and parasegment organization of *Drosophila melanogaster* genital discs. *Mech. Dev.* **56** : 61-72.
- GARCIA-BELLIDO, A., RIPOLL, P. and MORATA, G. 1973. Developmental compartmentalization of the wing disc of *Drosophila*. *Nature New Biology*, **245** : 251-253.
- HAMA, C., ALI, Z., and KORNBERG, T. B. 1990. Region specific recombination and expression are directed by portions of the *Drosophila engrailed* promoter. *Genes Dev.*, **4** : 1079-1093.
- HELD, L. I. JR., and HEUP, M. A. 1996. Genetic mosaic analysis of *decapentaplegic* and *wingless* gene function in the *Drosophila* leg. *Dev. Genes Evol.*, **206** : 180-194.
- KIM, J., SEBRING, A., ESCH, J.E., KRAUS, M.E., VORWERK, K., MAGEE, J. and CARROLL, S. B. 1996. Integration of positional signals and regulation of wing formation and identity by *Drosophila vestigial* gene. *Nature* **382** : 133-138.
- KLEBES, A., BIEHS, B., CIFUENTES, F. and KORNBERG, T. B. 2002. Expression profiling *Drosophila* imaginal discs. *Genome Biology*, **3** : 0038-0038.16
- KLINGENBERG, C. P., MCINTYRE, G. S. and ZAKLAN, S. D. 1998. Left-right asymmetry of fly wings and the evolution of body axes. *Proc. R. Soc. Lond B, Biol. Sci.*, **265** : 1255-1259.
- KORNBERG, T., SIDEN, I., O'FARRELL, P. and SIMON, M. 1985. The *engrailed* locus of *Drosophila* : *In situ* localization of transcripts reveals compartment specific expression. *Cell*, **40** : 45-53.

- LAWRENCE, P. A., and STRUHL, G. 1996. Morphogens compartments and pattern : Lessons from *Drosophila*. *Cell*, **85** : 951-961.
- LECUIT, T., BROOK, W. J., NG, M., CALLEJA, M., SUN, H., and COHEN, S. M. 1996. Two distinct mechanisms for long range patterning by *decapentaplegic* in the *Drosophila* wing. *Nature*, **381** : 387-393.
- LECUIT, T., and COHEN, S. M. 1997. Proximal-distal axis formation in the *Drosophila* leg. *Nature*, **388** : 139-145.
- LINDSLEY, D.L. and ZIMM, G.G. 1992. The genome of *Drosophila melanogaster*. Academic Press, New York.
- MANN, R. S., and MORATA, G. 2000. The development and molecular biology of genes that subdivide the body of *Drosophila*. *Ann. Rev. Cell. Dev. Biol.*, **16** : 243-271.
- MARTINEZ-ARIAS, A., and LAWRENCE, P. A. 1985. Parasegments and compartments in the *Drosophila* embryo. *Nature*, **313** : 639-642.
- NELLEN, D. BURKE, R., STRUHL, G. and BASLER, K. 1996. Direct and long range action of DPP morphogen gradient. *Cell*, **85** : 357-368.
- NUSSLEIN-VOLHARD, C. 1979. Maternal effect mutations that alter the spatial coordinates of the embryo of *Drosophila melanogaster*. In 'Determination of Spatial Organization' (eds. S. Subtelny and I. R. Kornberg), Academic Press, New York.
- RAY, M., ACHARYYA, M., and CHATTERJEE R. N. 2001. Expression of *engrailed* and *wingless* genes in the imaginal discs of *Drosophila melanogaster*- *D. simulans* hybrids. *Entom.*, **26** (Spl. Issue) : 159-163.
- STRUHL, G., and BASLER, K. 1993. Organizing activity of the *wingless* protein in *Drosophila*. *Cell* **72** : 527-540.
- TABATA, T. and KORNBERG, T. B. 1994. *Hedgehog* is a signaling protein in *Drosophila*. *Cell* **72** : 527-540.
- TABATA, T., EATON, S., AND KORNBERG, T. B. 1992. The *Drosophila hedgehog* gene is expressed specifically in posterior compartment cells and is a target of *engrailed* regulation. *Genes Dev.*, **6** : 2635-2645.
- TABATA, T., SCHWARTZ, C., GUSTAVSON, E., ALI, Z. and KORNBERG, T. B. 1995. Creating a *Drosophila* wing *de novo*, the role of *engrailed* and compartment border hypothesis. *Development*, **121** : 3359-3369.
- WILLIAMS, J. A., PADDOCK, S. W., and CARROLL, S. B. 1993. Pattern formation in a secondary field: a hierarchy of regulatory genes subdivides the developing *Drosophila* wing disc into discrete sub-regions. *Development*, **117** : 571-584.
- WHITE, K. P., RIFKIN, S. A., HURBAN, P. and HOGNESS, D. S. 1999. Microarray analysis of *Drosophila* development during metamorphosis. *Science*, **286** : 2179-2184.
- ZECCA, M., BASLER, K., and STRUHL, G. 1995. Sequential organizing activities of *engrailed*, *hedgehog* and *decapentaplegic* in the *Drosophila* wing. *Development*, **121** : 2265-2278.

THE ANTISTRESS ACTIVITIES OF BLACK TEA (WORLD BLEND) POLYPHENOL, THEAFLAVINS, IN *DROSOPHILA MELANOGASTER*

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ABSTRACT

Tea is one of the most popular beverage in the world. Black tea is the rich source of thearubigins (TRs) and theaflavins (TFs) due to the oxidative polymerization of green tea polyphenols. In order to know the role of tea polyphenol, TFs, in 'stressful' situation of an organism, we used *Drosophila* as a trial run stuff for doing the same thing in human. We analyzed the puffing activity pattern of heat and cold shocked larval salivary glands of *D. melanogaster* followed by *in vitro* treatment of different concentration of TF. Results revealed that some stress puffs of the larval salivary chromosomes were induced considerably after *in vitro* treatment of heat and cold shock followed by treatment of 400ug/ml and 600ug/ml TF treatment. Expression pattern of polytene puffs after TF treatment clearly showed that tea polyphenol, TF, act as an anti-stress agent in the cells of *Drosophila*. The results of our study further indicate that a developmental puff, 74EF, had been induced considerably after temperature stressed followed by TF treatment. These data together provide evidences that tea polyphenol, theoflavins, act as anti-stress agent.

Key words : *Drosophila*, polytene puffs, Theaflavins.

INTRODUCTION

Tea is one of the most popular beverages, next to water. It is grown over thirty countries of tropical and subtropical zones. It is processed differently in different parts of the world, e.g. green, black and oolong tea. The tea contains various catechin derivatives including epicatechin, epigallocatechin, epicatechin gallate, epigallocatechin gallate (Pietta, 2000). Tea is also an important dietary source of flavanoids. The polyphenols, theaflavins (TFs) and thearubigins (TRs) are the fermented product of catechins. Black tea contains 15% dry weight of TRs. On the other hand, TFs account for about 2 gm per 100 gm of dried black tea extract.

Various lines of data, mostly obtained from short lived invertebrate organisms, *D.*

melanogaster, provide evidences that epigenetic repair system is induced in responses to stress conditions (Ritossa, 1962; Lakhota, 1987; Wallin *et al.*, 2002). Stress causes DNA damage, protein denaturation and misfolding by weakening of polar bonds and exposure of hydrophilic groups that are important targets of stress or induced damage (Schroder *et al.*, 1993, 1994). To encounter stress, cell produces stress proteins which protect the organisms, and for such protein encoding there are some regulatory genes present which are responsible for protecting the macromolecules and other cellular components. These elements are commonly known as heat shock elements (HSE). In *Drosophila*, heat shock factors (HSFs) are responsible for cell growth, development, and survival in stressed situation (Craig *et al.*, 1993; Wallin *et al.*, 2002). HSFs also involve

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in protecting organisms from damage as a result of exposure of heat or introduction of chemicals and other environmental stresses. In many situations, stress stimuli switch on an alternative metabolic pathway through posttranscriptional control of heat shock factor and protein – protein interaction *in vivo*. The genome wide identification of HSF target genes provides necessary information about the roles of HSFs in development, aging and in complex metabolic programming that occur in all living cells in response to stress (Rogina *et al.* 2000). Curiously, stress proteins also play an important role under non-stress condition at specific stages of development.

In addition to heat shock, a variety of other stimuli are also known to induce stress response (Ashburner and Bonner, 1979). The conditions are : (i) Environmental conditions, e.g. heavy metal, amino acid analogues, ethanol with nicotine, extra-cellular pH, detergents like NH40 and CHAPS, sodium salicylate, H₂O₂, urea etc., (ii) patho-physiological conditions e.g. fever and inflammation, viral infection, serum starvation, glucose starvation, intracellular calcium levels, intracellular pH etc. (iii) various developmental stages and cell cycle started (Morimoto *et al.*, 1994). It has been suggested that denatured proteins are the key components for pathogenic condition of stress by the cells (Ananthan *et al.*, 1986; Craig *et al.*, 1993). Unfortunately, we hardly know hitherto whether black tea polyphenols have antistress activities, although we consume black tea in heat or cold stress condition. In this context, it may be noted here that tea is the rich source of polyphenolic flavonoids which exhibit potent antioxidant activity *in vitro* and *in vivo* (Pietta, 2000). In view of these reasons, we have made an attempt to examine the effect of tea polyphenols, TFs, on *Drosophila* heat shock puffs as trail run stuff for assessing antistress activities of the polyphenols in human.

The advantages of *Drosophila* model for studying the antistress activities of TFs are numerous and include : (1) a relative short life span and easy maintenance, (2) adult cells that are post mitotic and fully differentiated,

eliminating confounding problems from cell replacement, (3) powerful molecular and genetic techniques, (4) abundant information and accessible manipulation of genetic environmental factors in aging fruit flies, (5) availability of fly lines with specific gene alterations required to facilitate stress and aging studies, (6) simple and well studied anatomy, allowing for consistent identification of specific individual cells in every animal, and (7) the techniques of enhancer trap and reporter genes which allow for the qualitative and quantitative examination of gene expression in whole animal (Bier *et al.*, 1989).

An additional advantage for the use of *Drosophila* as a model system relates to its relevance to humans and other vertebrates. One of the most amazing features that has emerged from the work on development of *Drosophila* is that many of the underlying molecular mechanisms of development in *Drosophila* turn out to be remarkably similar to those used in human. Not only many of the master regulatory molecules are structurally homologous between these two systems, but in a series of extraordinary experiments, the use of human homologue in the fly has shown that they appear to be functionally interchangeable (Halder *et al.*, 1995, Adams *et al.*, 2000).

The present experiment was designed to assess the protective effect of TFs on chromosomal level in heat and cold stressed animals, using *Drosophila* as a model system. Our data provide evidences that tea polyphenol, TFs, might help the organism who is in stress by modulating expression pattern of hidden stresser and developmental genes.

MATERIALS AND METHODS

A. Fly stock and their culture system

We used Oregon R strain of *D. melanogaster* for our experiment. The strain of *D. melanogaster*, maintained in our laboratory since 1957. The flies were cultured in a BOD incubator at 24° + 1°C at standard *Drosophila* food medium, supplemented with live yeast for

better nourishment. The food free third instar larvae were used for the experiments.

B. Synchronization of larval age

To obtain larvae of similar of group, eggs were collected in bottles containing *Drosophila* medium at 2 hrs interval. Adult flies as well as larvae were reared on standard agar-corn meal-brown sugar-yeast food medium at $24^{\circ} + 1^{\circ}\text{C}$. For better nourishment larval cultures were supplemented with live yeast.

C. Cytological preparations

Salivary glands were dissected out from third instar larvae in buffered Ringer's solution (pH 7.2, Ashburner, 1989) and treated according to the experimental purposes. The salivary glands were thereafter, fixed in aceto-ethanol (1 : 3 v/v) and stained in 2% aceto-orcin for 5 min. Thereafter, the glands were thoroughly washed in 50% acetic acid and squashed in lacto-aceto-orcin (Chatterjee and Mukherjee 1981). The slides thus prepared were stored overnight in a refrigerator for maturation of stain. TF solution of 200 $\mu\text{g}/\text{ml}$, 400 $\mu\text{g}/\text{ml}$ and 600/ μg ml were prepared freshly. The larvae were treated at different temperature viz. 16°C (cold shock), 29°C (mild heat shock) and 37°C (heat shock) for two hours. Thereafter, the animals were sacrificed and excised salivary glands were cultured in Poel's *Drosophila* media (Poel, 1972). For TF treatment, the salivary glands were treated for half an hour in Poel's media containing 200 $\mu\text{g}/\text{ml}$, or 400 $\mu\text{g}/\text{ml}$ or 600 $\mu\text{g}/\text{ml}$ TF. Salivary gland chromosomes were then prepared and puffing activity pattern was measured using ocular and stage micrometers as described by Chatterjee and Mukherjee (1971).

RESULTS

Figure-1a-f show that polytene chromosome puffing patterns of *D. melanogaster* prepared after treatment of different concentration of TF. As it appears from the photomicrographs presented in Fig. 1b, heat shock (37°C) induces at least eight puffs in salivary chromosomes of *Drosophila*. The puffs 63BC, 64F, 67B, 70A, 87A, 87C, 93D and 95D, are located in different arms

of the polytene chromosomes. When animals were treated at 16°C for 2 hours, majority of the stress puffs were also induced considerably (Fig. 1d). Similar situation was noted when glands were treated in mild heat shock (29°C) (Fig. 1c). However, when heat stressed salivary glands (37°C) were further treated with TFs for 30 min, considerable changes in puffing pattern were observed. Most of the heat shock puffs were induced except the 93D puff which was regressed in response to TFs in heat shocked salivary glands. On the other hand, some additional puffs were induced. For example, the 74EF puff site had been induced considerably after treatment of heat plus TF treatment (Fig. 1e) although it is a developmental puff. Similar was the situation when cold shock (16°C) treated salivary glands were treated with 400 $\mu\text{g}/\text{ml}$ TFs (Fig. 1f). It, therefore, appears that tea polyphenol, TF, not only induces heat stressed puffs considerably but also alters cellular physiology of the animals to help the organism to adapt to the harsh or unpredictable environments.

Our data further support the fact that when the heat shock and/or cold shock salivary glands were treated with TFs for 30 min, considerable induction of the stress puffs were induced (Tables 1, 2 and 3). These results together have been interpreted to have suggested that the TF stimulate the rescue effect of heat and cold shock of the cellular environment of *Drosophila*. It may thus be presumed that as heat shock puffs produced heat shock RNAs and consequently heat shock proteins, these puffs are necessary to protect from the stressful situation of the animals. Thus, the TF plays a protective role in critical physiological stress situation.

DISCUSSION

All stressful situations may be harmful to the biological organization. In many animals, some regulatory genes are present to protect macromolecule, recycle irreversible damaged cellular components, and facilitate appropriate adaptive responses until more affordable conditions are realized (Pardue *et al.*, 1987;

Table-1. Salivary gland chromosome puffing pattern of *Drosophila melanogaster* at 37°C heat shock (H.S.) followed by treatment with 200 µg, 400 µg, 600 µg TF.

Puff Sites	H.S. + Ringer Control Mean Puffing Activity + S.E.	H.S. + TF treat. (200 µg/ml) Mean Puffing Activity ± S.E.	H.S. + TF treat. (400 µg/ml) Mean Puffing Activity ± S.E.	H.S. + TF treat. (600 µg/ml) Mean Puffing Activity ± S.E.
63BC	1.57 ± 0.07 (18)	1.57 ± 0.04 (20)	1.66 ± 0.02 (18)*	1.65 ± 0.07 (17)*
64F	1.30 ± 0.04 (20)	1.43 ± 0.03 (20)	1.47 ± 0.03 (19)	1.46 ± 0.05 (20)
67B	1.45 ± 0.06 (20)	1.32 ± 0.02 (19)	1.41 ± 0.03 (19)*	1.50 ± 0.04 (18)
70A	1.47 ± 0.04 (17)	1.43 ± 0.02 (19)	1.53 ± 0.03 (18)	1.51 ± 0.03 (18)
87A	1.45 ± 0.03 (19)	1.36 ± 0.03 (19)	1.56 ± 0.05 (19)*	1.54 ± 0.07 (17)*
87C	1.49 ± 0.04 (20)	1.50 ± 0.04 (20)	1.62 ± 0.06 (19)*	1.65 ± 0.05 (17)*
93D	1.58 ± 0.07 (21)	1.42 ± 0.05 (20)	1.61 ± 0.03 (18)	1.62 ± 0.06 (18)
95D	1.61 ± 0.07 (17)	1.48 ± 0.05 (19)	1.61 ± 0.03 (17)	1.65 ± 0.05 (19)
74EF	1.38 ± 0.03 (18)	1.71 ± 0.07 (20)*	1.72 ± 0.07 (19)*	1.64 ± 0.05 (19)*
71EF	1.41 ± 0.03 (20)	–	1.78 ± 0.97 (17)	–

* Indicate significant at 0.05 level

Number in the parenthesis indicate the number of observation

Table-2. Salivary gland chromosome puffing pattern of *D. melanogaster* at 29°C heat shock (H.S.) followed by treatment with 200 µg, 400 µg, 600 µg/ml TF.

Puff Sites	H.S. + Ringer (Control) Mean Puffing Activity + S.E.	H.S. + TF Treat. (200 µg/ml) Mean Puffing Activity + S.E.	H.S. + TF Treat. (400 µg/ml) Mean Puffing Activity + S.E.	H.S. + TF Treat. (600 µg/ml) Mean Puffing Activity + S.E.
63BC	1.46 ± 0.05(19)	1.50 ± 0.05 (20)	1.51 ± 0.05(21)	1.55 ± 0.06(18)
64F	1.38 ± 0.03(18)	1.45 ± 0.02 (20)	1.48 ± 0.05(19)	1.54 ± 0.06(19)
67B	1.51 ± 0.05(20)	1.47 ± 0.05 (20)	1.59 ± 0.04 (18)*	1.53 ± 0.06(20)
70A	1.50 ± 0.05 (18)	1.52 ± 0.05 (21)	1.42 ± 0.06(18)	1.44 ± 0.03(19)
87A	1.47 ± 0.05 (19)	1.50 ± 0.05 (21)	1.51 ± 0.07(17)	1.60 ± 0.06(21)*
87C	1.41 ± 0.04 (19)	1.52 ± 0.04 (21)*	1.47 ± 0.07(18)	1.55 ± 0.05(19)
93D	1.51 ± 0.05 (20)	1.55 ± 0.08 (21)	1.50 ± 0.04(17)	1.59 ± 0.07(20)
95D	1.41 ± 0.04 (19)	1.45 ± 0.04 (20)	1.57 ± 0.05(18)*	1.61 ± 0.07(17)*
74EF	1.45 ± 0.06 (18)	1.52 ± 0.08 (22)	1.63 ± 0.05(16)*	1.68 ± 0.09(19)*
71EF	1.35 ± 0.02 (16)	–	1.52 ± 0.08(19)	

* Indicate significant at 0.05 level

Number in the parenthesis indicate the number of observation

Table-3. Salivary gland chromosome puffing pattern of *Drosophila melanogaster* at 16°C cold shock (C.S.) followed by treatment with 200 µg, 400 µg, 600 µg TF.

Puff Sites	C.S. + Ringer (Control) Mean Puffing Activity ± S.E.	C.S. + TF Treat. (200 µg/ml) Mean Puffing Activity ± S.E.	C.S. + TF Treat. (400 µg/ml) Mean Puffing Activity ± S.E.	C.S. + TF Treat. (600 µg/ml) Mean Puffing Activity ± S.E.
63BC	1.60 ± 0.05 (19)	1.39 ± 0.04 (19)	1.68 ± 0.06 (18)*	1.59 ± 0.07 (17)
64F	1.45 ± 0.06 (20)	1.56 ± 0.07 (20)	1.60 ± 0.06 (19)	1.53 ± 0.06 (20)
67B	1.60 ± 0.08 (18)	1.52 ± 0.06 (20)	1.51 ± 0.07 (19)	1.60 ± 0.05 (20)*
70A	1.50 ± 0.07 (19)	1.43 ± 0.04 (17)	1.47 ± 0.07 (18)	1.61 ± 0.06 (20)*
87A	1.51 ± 0.08 (17)	1.49 ± 0.05 (21)	1.67 ± 0.08 (19)*	1.69 ± 0.06 (20)*
87C	1.63 ± 0.09 (18)	1.46 ± 0.04 (22)	1.67 ± 0.06 (18)*	1.66 ± 0.06 (18)*
93D	1.53 ± 0.08 (20)	1.48 ± 0.06 (20)	1.67 ± 0.04 (18)*	1.50 ± 0.03 (17)*
95D	1.59 ± 0.08 (18)	1.55 ± 0.07 (20)	1.57 ± 0.05 (20)	1.64 ± 0.05 (19)*
74EF	1.43 ± 0.03 (19)	1.66 ± 0.06 (19)*	1.65 ± 0.07 (17)*	1.72 ± 0.06 (20)*
71EF	—	—	1.76 ± 0.11 (16)	—

* Indicate significant at 0.05 level

Number in the parenthesis indicate the number of observation

The data presented here provide further evidence that tea polyphenol, TFs, induces some stress puffs in *Drosophila* in stressful situation. These puffs reached the highest level after treatment of 400 µg/ml TF treatment. This may imply that the actual magnitude of health benefits of black tea is establishment of safe range of tea consumption. However, potential mechanisms of its action require investigation. Curiously, regression of one of major heat shock puff, 93D, was noted after TF treatment. The 74EF puff site has also been induced considerably after treatment of heat and TF treatment although it is a developmental puffs. The reason for such type of gene activation in *Drosophila* is not yet clear. It may be possible that the induction of the 74EF puff is necessary for buffering the development of animal under heat stressful condition. Our data indicate that TF may buffer against expression of hidden stresser genes. This view is further strengthened when we observed that 93D, a major heat shock puff is regressed in TF treatment. In this context, it may be noted here that 93D locus synthesizes noncoding RNAs (Sengupta and Lakhota, 2006).

In summary, our results on *Drosophila* model

system provide strong evidences that tea polyphenols flavonoids exhibit potential antistress activities. The induction of stress puffs in *Drosophila* may also be considered as bio-marker of antistress activities of tea polyphenols. However not all heat shock puffs are induced after heat treatment followed by TF treatment. This may suggest that the TF induces alternative metabolic pathway to buffer stress response. Earlier studies have shown that TFs act as a protecting agent from cancer (Sohal *et al.*, 1990; Weisburger *et al.*, 1996; McKay and Blumberg, 2002). Our data provide strong evidences that TF acts not only as a antocarcinogenic agent, but also as an antistress agent. Further research in this lines may provide valuable insights into the molecular mechanisms of repair of stress, toxicity damage, identification of target macromolecules and evolution of physiological state of cells after treatment of tea polyphenol, TFs.

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LITERATURE CITED

- ADAMS, M.D., CEINIKER, S.E., HOLT, R.A., EVANS, C.A., GOCAYNE, J.D, AMANATIDES, P.G., SCHERER, SE, LI, P. W., HOSKINS, R.A, GALLE, R.F. *et al.*, 2000. The genome sequence of *Drosophila melanogaster* *Science*, **287** : 2185-2195.
- ANANTHAN, J., GOLDBERG, A. L. and VOELLMY, R. 1986. Cooperative binding of heat shock transcription factor to the *hsp 70* promoter *in vivo* and *in vitro*. *J. Biol. Chem.*, **269** : 4804-4811.
- ASHBURNER, M. 1989. *Drosophila* : a laboratory Hand book. Cold Spring Harbor Laboratory Press, New York
- ASHBURNER, M. and BONNER, J. J. 1979. The induction of gene activity in *Drosophila* by heat shock. *Cell.*, **17** : 241-254.
- BIER, E., VASSIN, H., SHEPHARD, S., LEE, K., MCCALL, K., BARBEL, S., ACKERMAN, L., CARRETTO, R., UEMURA, T., GRELL, E., JAN, L.Y., and JAN, Y.N. 1989. Searching for pattern mutation in the *Drosophila* genome with a *P-lacZ* vector. *Genes and Dev.*, **3** : 1273-1287.
- CHATTERJEE, S. N. and MUKHERJEE, A. S. 1971. Chromosomal basis of dosage compensation in *Drosophila* V. Puffwise analysis of gene activity in the X chromosome of male and female *Drosophila hydei*. *Chromosoma*, **36** : 46-59.
- CHATTERJEE, R. N., and MUKHERJEE, A. S. 1981. Chromosomal basis of dosage compensation in *Drosophila*. X. Assessment of hyperactivity of the male X *in situ*. *J. Cell Sci.*, **47** : 295-309.
- CRAIG, E.A., GAMBIL, B.D. and NELSON, R.J. 1993. Heat shock proteins-molecular chaperones of protein biogenesis. *Microbiol. Rev.*, **57** : 402-414.
- GETHING, M.J. and SAMBROOK, J. 1992. Protein folding in the cell. *Nature*, **355** : 33-45.
- GOERING, P.L., FISHER, B.R., CHAUDHARY, P.P. and DICK, C.A. 1992. Relationship between stress protein induction in rat kidney by mercuric chloride and nephrotoxicity. *Toxicol Appl Pharmacol.*, **113** : 184-191.
- HALDER, G., CALLAERTS, P. and GEHRING, W. J. 1995. Induction of ectopic eyes by targeted expression of the *eyeless* genes in *Drosophila*. *Science*, **267** : 1788-1792.
- HATTORI, H., KANEDA, T., LOKESHWAR, B., LASZIO, A. and OHTSUKA, K. 1993. A stress-inducible 40 kDa protein (*hsp 70*) : purification by modified two dimension gel electrophoresis and co-localization with *hsp 70* in heat-shock HeLa cells. *J. Cell Sci.*, **104** : 629-638.
- LAKHOTIA, S. C. 1987. The 93D heat shock locus in *Drosophila*: a review. *J. Genet.* **66** : 139-157
- MCKAY, D.L. and BLUMBERG, J. 2002. The role of tea in human health : An update. *J. Nutrition*, **21** : 1-13.
- MORIMOTO, R. I., TISSIAERES, A. and GEORGOPOULOS, C. 1994. The biology of heat shock proteins and molecular chaperones. Cold Spring Harbor Laboratory Press, NY.
- PARDUE, M. L., BENDENA, W.G. and GRABE, J. C. 1987. Heat shock puffs and response to environmental stress. In "*Results and Problems in Cell Differentiation*" (Ed. W. Henning) Heidelberg: Springer-Verlag, Berlin, **14** : 121-131.
- PIETTA, P. G. 2000. Flavonoids as antioxidants. *J. Nat. Pro.*, **63** : 1035-1042.

- POELS, C. L. M. 1972. Mucopolysaccharides secretion from *Drosophila* salivary gland cells as a consequence of hormone induced gene activity. *Cell Diff.*, 1 : 63-78.
- RITOSSA, F. 1962. A new puffing pattern induced by heat shock and DNP in *Drosophila*. *Experientia*. 18 : 571-573.
- ROGINA, B., REENAN, R.A., NILSEN, S. P., and HELFAND, S.L. 2000. Extended life span conferred by co-transporter gene mutations in *Drosophila*. *Science*, 290 : 2137-2140.
- SANDERS B.M. 1993. Stress proteins in aquatic organisms : an environmental perspective. *Crit. Rev. Toxicol.*, 23 : 49-75.
- SANDERS B.M., NGUYEN J., DOUGLASS T.G., and MILLER S. 1994. Heat inducible proteins that react with antibodies to chaperonin 60 are localized in the nucleus of fish cell line. *Biochem. J.*, 297 : 21-25.
- SCHRODER H., LANGER T., HARTL, F. U. and BUKAU, B. 1993. DnaK, DnaJ and GrpE from a cellular chaperon machinery capable of repairing heat-induced protein damage. *EMBO J.*, 12 : 4137-4144.
- SENGUPTA S., and LAKHOTIA, S.C. 2006. Altered expression of the noncoding hsrw gene enhances poly-Q-induced neurotoxicity in *Drosophila*. *RNA Biol.*, 3 : e1-e8.
- WEISBURGER, J.H., HARA, Y., DOLAN, L., LUO, F. Q., PITTMAN, B. and ZANG, E. 1996. Tea polyphenols as inhibitors of mutagenicity of major classes of carcinogens. *Mutat. Res.*, 371 : 57-63.
- WALLIN, R.P.A., LUNDQVIST, A., MORE, S.H., BONIN, A. V., KIESSLING, R., and LJUNGGREN H.G. 2002. Heat shock proteins as activators of the innate immune system. *Trend. In Immu.*, 23 : 130-134.

ANTI-ANGIOGENIC THERAPY-NEW AVENUE FOR CANCER TREATMENT

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ABSTRACT

Metastatic process and tumour growth are angiogenesis dependent. As a primary tumour grows, it needs to develop a blood supply that can support its metabolic needs—a process called angiogenesis. Angiogenesis appears to be one of the crucial steps that triggers the transition of a tumour from a small usually harmless cluster of abnormal or mutated cells to a large, malignant growth, capable of spreading to other organs.

Generally, patients diagnosed with any type of cancer typically rely on surgery or radiation to remove the tumour and on follow-up radiation or chemotherapy, or both, to try to eradicate any remaining cancerous cells in the body.

But the objective of the antiangiogenic therapy is quite different in comparison to other therapeutic approaches. Antiangiogenic drugs stop new vessels from forming around a tumour and break up the existing network of abnormal capillaries that feeds the cancerous mass.

Tumour angiogenesis process is regulated by enhanced secretion of growth factors. Among several tumour angiogenic factors, vascular endothelial growth factor (VEGF) has been recognized as a prime regulator of tumour angiogenic process.

Different types of antiangiogenic compounds effective in animal studies have been developed, in many cases, however, the basis of their activity is uncertain and thus their efficacy in human subjects remains to be confirmed.

2-Methoxyestradiol (2-ME), once considered an inactive end metabolite of estradiol, has recently emerged as a very promising agent for cancer treatment. It indicates significant antiangiogenic properties that prevent tumour nourishment. 2ME was reported to elicit both stimulation and inhibition of tumour angiogenesis and growth depending on the dosage used. The present study was undertaken to determine the dose dependent effect of 2ME on VEGF mRNA in GH₃ cell line and to correlate with cell proliferation. m-RNA was determined by Northern blot analysis. Cell proliferation and death rates were measured using H³ thymidine incorporation into 2ME treated and untreated cells. A dose-dependent biphasic effect of 2ME on VEGF m-RNA and cell proliferation was found in GH₃ cell line. A trend of decreasing expression of VEGF m-RNA and rate of cell proliferation was noted with higher (5–10 μ M) 2ME concentrations. So the results of these studies indicate that 2ME is a novel therapeutic drug for cancer.

Keywords : metastasis, angiogenesis, 2-Methoxyestradiol, antiangiogenic therapy

INTRODUCTION

The main clinical problem of cancer is metastasis, the migration in the blood and lymph system of tumour cells that give rise to

tumours elsewhere in the body. When cancer is detected at an early stage, before it has spread, it can often be treated successfully by surgery or local irradiation, and the patient will

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be cured. However, when cancer is detected after it is known to have metastasized, treatments are much less successful. So metastases, rather than primary tumours, are responsible for most cancer deaths.

Angiogenesis is required for metastasis

Metastatic process and tumour growth are angiogenesis dependent (Fig. 1). Angiogenesis, the sprouting of new blood vessels, plays a critical role in a variety of normal physiological events including embryonic development, endometrial proliferation, corpus luteum formation, wound healing etc. (Blood and Zetter, 1990). However, many pathological

processes are also characterized by abnormal vascular development such as arthritis, diabetic retinopathy, psoriasis, atherosclerosis, tumour growth as well as metastasis (Folkman, 1989). Judah Folkman, Professor of Harvard Medical School, U.S.A., advocated that cancer cells or tumours will not grow to a dangerous size (a diameter of 0.4 mm to 1 mm) without blood vessels to nourish them (Folkman, 1989). In fact, angiogenesis or neovascularization appears to be one of the crucial steps in tumour's transition from a small usually harmless cluster of abnormal or mutated cells (known as *in situ* tumour) to a large, malignant growth, capable of spreading to other organs. Tumour

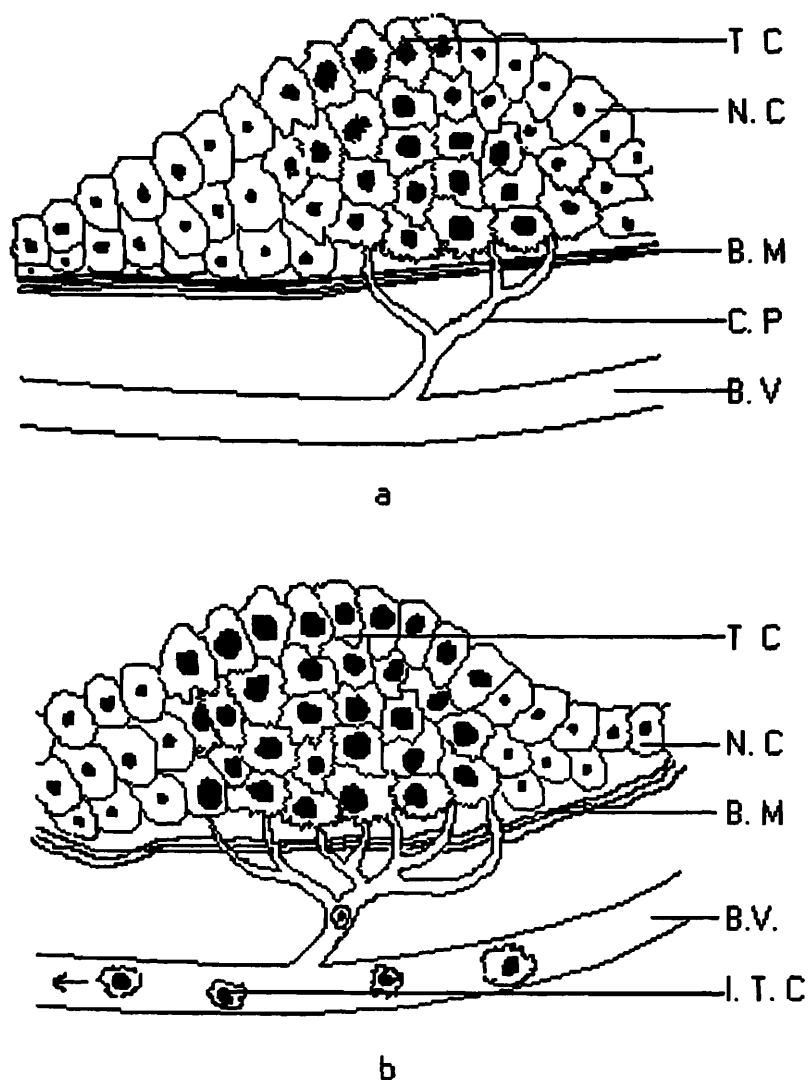


Fig. 1. Tumour development and metastasis process : a = Initiation of tumour formation and capillaries proliferate allowing blood to flow to the tissue; b = Tumour cells detach from the primary site and migrate (metastasis) from blood vessel to a new organ.

T.C = Tumour Cell; N.C = Normal Cell; B.M = Basement membrane, C.P = Capillaries Proliferate; B.V = Blood Vessel; I.T.C = Invasive Tumour Cell.

angiogenesis or neovascularization supports tumour growth by allowing passage of nutrients, oxygen and waste products through a ever increasing population of cells. The complexity of the angiogenic process, which involves both positive and negative regulators, provides a number of targets for therapy.

Vascular endothelial growth factor (VEGF) as critical growth factor of angiogenesis process

Angiogenesis process is regulated by enhanced secretion of growth factors through cell migration, endothelial cell proliferation, proteolytic activity and capillary morphogenesis. Among several tumour angiogenic factors, vascular endothelial growth factor (VEGF) has been recognized as a prime regulator of angiogenic process. It stimulates the proliferation of endothelial cells for the formation of new blood vessels as well as increasing their permeability, which may also be important for the provision of nutrients to tumours (Dvorak *et al.*, 1999).

Current treatments of cancer

Generally, patients diagnosed with any type of cancer typically rely on surgery or radiation to remove the tumour and on follow-up radiation or chemotherapy, or both, to try to eradicate any remaining cancerous cells in the body. Surgical excision of a tumour is both quick and effective, and it accounts for the largest number of cures. Radiation therapy is preferable in many instances. But radiation treatments act either by inflicting genetic damage sufficient to kill cells directly or by inducing apoptosis (cellular suicide). Cancer of the cervix, uterus, larynx and early stages of both prostate cancer and Hodgkin's disease are well treated with radiotherapy. Chemotherapy is also preferable in many cases. Chemotherapeutic drugs act on human cells in different ways. Generally they prevent cells from multiplying by interfering with their ability to replicate DNA and sometimes, it can induce apoptosis in cancerous cells.

These forms of treatments have several shortcomings. i) Sometimes cancer grips vital

organs that cannot be surgically removed. ii) Sometimes radiotherapy proves inadequate, because it fails to eradicate all the cancer cells of a tumour. iii) Whole body radiation exposures destroy some delicate, vital tissues. iv) Generally, the available chemotherapeutic drugs often kill healthy cells of the body during treatment and create serious side effects like anemia, diarrhoea, nausea, hair loss, weakness and loss of appetite. v) The majority of the most common cancers (breast, lung, colorectal and prostate cancer) are not yet curable with chemotherapy alone. But the objective of the antiangiogenic therapy is quite different in comparison to other therapeutic approaches.

Antiangiogenic therapy–New strategy for cancer treatment

Antiangiogenic drugs stop new vessels from forming around a tumour and break up the existing network of abnormal capillaries that feeds the tumour (Fig. 2). In 1989 the first clinical trial of an anti-angiogenic agent – interferon alpha-began for the treatment of life threatening hemangioma (a noncancerous blood vessel tumour found primarily in infants). By 1992 the first anti-angiogenic drug for cancer patients, TNP-470 (a synthetic analogue of the substance fumagillin), entered clinical trials, which were restricted to a few kinds of tumours. Later on, a number of anti-angiogenic compounds effective in animal studies have been developed, in many cases, however, the basis of their activity is uncertain and thus their efficacy in human subjects remains to be confirmed. During the past several years, researchers have identified at least 15 different compounds found in the body that can trigger blood vessel growth and several others that can halt it.

2-Methoxyestradiol (2-ME), once considered an inactive end metabolite of estradiol, has recently emerged as a very promising agent for cancer treatment. It is synthesized by sequential hydroxylation of the parent compounds followed by methylation in the liver (Brueggemeier and Singh, 1989). It is orally active in a wide range of tumour models with

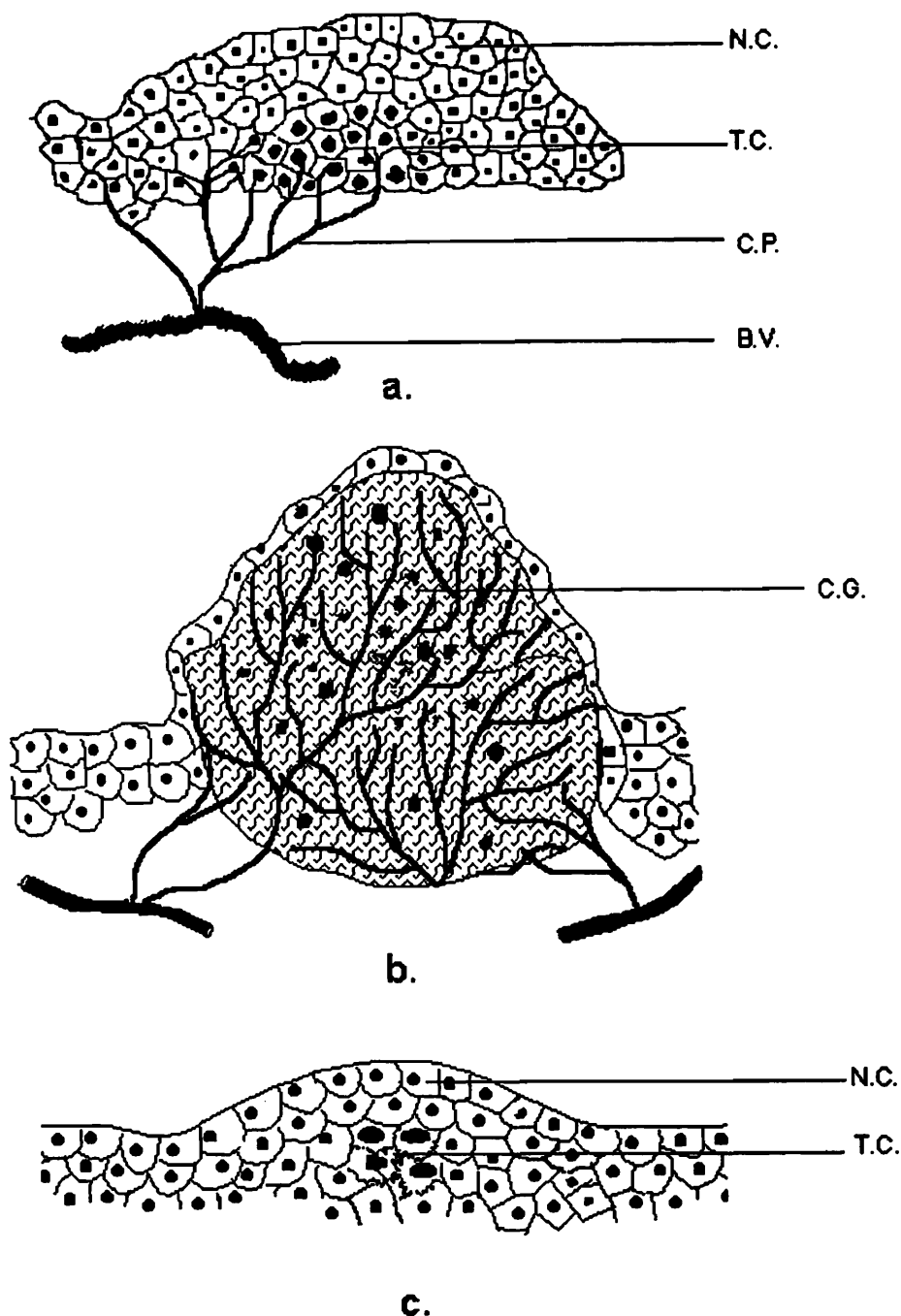


Fig. 2. Regulation of angiogenesis process : a = Initiation of tumour with few tumour cells; b = Proliferation of new blood vessels and capillaries during angiogenesis and cancerous mass continues to expand; c = Tumour size reduces with angiogenesis inhibitors treatment.

N.C = Normal Cell; T.C = Tumour Cell; C.G = Cancerous Growth; C.P = Capillaries Proliferate; B.V = Blood Vessel.

showing no clinical signs of toxicity. It also indicates significant antiangiogenic properties that prevent tumour nourishment. The antiangiogenic properties of 2ME and a mechanism by which it exerts its activity, were first identified by Robert D' Amato and others in 1994 (D'Amato *et al.*, 1994). 2ME targets rapidly growing cells with relatively high specificity

and does not kill non-dividing cells. Moreover, 2ME has been shown to inhibit the proliferation of estrogen responsive cells (Fotsis *et al.*, 1994; Lottering *et al.* 1996; Zoubine *et al.*, 1999) and also blocks endothelial cell proliferation *in vitro* and angiogenesis *in vivo* (Fotsis *et al.*, 1994, Klauber *et al.*, 1997). Therefore, the present study was aimed to investigate the dose-

dependent effect of 2ME on VEGF expression in GH₃ rat pituitary tumour cell line and to correlate these results with angiogenesis inhibition.

MATERIAL AND METHODS

2-Methoxyestradiol (Sigma, U.S.A), an anti-angiogenic end metabolite of estradiol, was used. A stock solution of 2-ME was prepared by the method already in practice in the laboratory (Banerjee *et al.*, 2003). The present study was undertaken to determine the dose dependent effect of 2ME (1, 5 and 10 μ M) on VEGF-mRNA in GH₃ cell line and to correlate with cell proliferation. m-RNA was determined by Northern blot analysis as described previously (Banerjee *et al.*, 2003). Cell proliferation and death rates were measured using H³ thymidine incorporation into 2ME treated and untreated cells.

RESULTS AND DISCUSSION

A dose-dependent biphasic effect of 2ME on VEGF m-RNA and cell proliferation was found in GH₃ cell line. A trend of decreasing expression of VEGF m-RNA and rate of cell proliferation was noted with higher (5–10 μ M) 2ME concentrations. Despite the potential anticancer effect of 2ME, our studies have revealed dose-dependent dual effects of this compound. For example, 1 μ M dose of 2ME exhibit proliferative effects in GH3 tumour cells. In contrast, a trend of decreasing expression of VEGF mRNA and rate of cell proliferation was noted with higher (5–10 μ M) 2ME concentrations. So the results of these studies indicate that 2ME is a novel therapeutic drug for cancer.

Our present and earlier (Banerjee *et al.*, 2001, 2002, 2003, 2005) observations suggested that the mechanism of action of 2ME on tumour growth and angiogenesis may be mediated through down regulation of VEGF.

Effect of 2ME in combination with Cyclophosphamide (CP) in mouse tumour

We have also extended our studies to *in vivo*

mouse model to evaluate the efficacy and safety of 2-ME in combination with Cyclophosphamide (CP). 5mg/kg body wt. dose of 2ME in combination with CP (20mg/kg body wt.) not only gave protection to bone marrow chromosomes of mouse but also induced solid tumour regression (Banerjee *et al.*, 2006). The results of these studies indicate that 2ME (in combination with CP) is a novel therapeutic drug for cancer.

CONCLUSION

As several new anti-angiogenic compounds enter into clinical trials, in many cases the basis of their activity is uncertain and their efficacy in human subjects remains to be confirmed. 2-Methoxyestradiol—the first orally active small molecule drug candidate, acts as a potent inhibitor of angiogenesis.

Additional advantages for considering 2-Methoxyestradiol (in combination with CP) as novel prominent anti-angiogenic and anticancer agents include :

It shows to inhibit the growth of several metastatic and primary cancerous tumours with low or no toxicity at therapeutically effective doses.

It is a naturally occurring metabolite in humans.

It targets rapidly growing cells with relatively high specificity and does not kill non-dividing cell.

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LITERATURE CITED

- BANERJEE, J., MUKHERJEE, P., GUPTA, S. and BANERJEE, S.N. 2006. Inhibition of Tumour growth in response to anti-angiogenic therapy. *Persp. Cytol & Genet.*, **12** : 479-484.
- BANERJEE, S., SAXENA, N., SENGUPTA, K and BANERJEE, S. K. 2003 .17 α -estradiol-induced VEGF-A expression in rat pituitary tumour cells is mediated through ER independent but PI3K-Akt dependent signaling pathway. *Biochem.Biophys. Res. Commun.*, **300** : 209-215.
- BANERJEE, S.N., BANERJEE, S., LAVALLEE, T.M. and BANERJEE, S.K. 2001. The dose dependent biphasic effects of 2-methoxyestradiol on VEGF₁₆₅ expression in tumour cells may modulate cellular proliferation and death. *Stowers Institute Symposium from Gene and Genetics to Molecular Medicine*, Oct 30-31, 2001, Missouri, USA Abs-2, pp-2.
- BANERJEE, S.N., BANERJEE, S. and BANERJEE, S.K. 2002 Involvement of VEGF in 2-Methoxyestradiol induced cell proliferation inhibition in MCF-7 and GH₃ tumour cell lines. *National Seminar on Recent Advances in Molecular Physiology*, 4-6 Feb, 2002, Univ. of Kalyani, WB, India. pp-14.
- BANERJEE, S.N., SENGUPTA, K.K., BANERJEE, S., SAXENA, N.K. and BANERJEE, S.K. 2003. 2-Methoxyestradiol exhibits a biphasic effect on VEGF-A in Tumour cells and upregulation is mediated through ER- α : A possible signaling pathway associated with the impact of 2-ME₂ on proliferative cells. *Neoplasia*, **5**(5) : 417- 426.
- BANERJEE, S.N., BANERJEE, S. and BANERJEE, S.K. 2005 Role of VEGF-A in 2-Methoxyestradiol-induced tumour cell proliferation. *Ind. J Med Res. (Suppl)*, **121** : 52.
- BLOOD, C. H. and ZETTER, B. R. 1990. Tumour interactions with the vasculature : angiogenesis and tumour metastasis. *Biochem Biophys Acta*, **1032** : 89-118.
- BRUEGGEMEIER, R.W. and SINGH, U. 1989. Inhibition of rat liver microsomal estrogen 2-hydroxylase by 2-methoxyestrogens. *J. Steroid Biochem*, **33** : 589-593.
- D'AMATO R J., LIN, CM., FLYNN, E., FOLKMAN, J. and HAMEL, E. 1994. 2-Methoxyestradiol, and endogenous mammalian metabolite, inhibits tubulin polymerization by interacting at the colchicine site. *Proc. Natl Acad Sci., USA*, **91** : 3964-3968.
- DVORAK, H. F., NAGY, J.A., FENG, D., BROWN, L.F. and DVORAK, A.M. 1999. *Curr. Top. Microbiol. Immunol.*, **237** : 97-132.
- FIDLER, I. J. and ELLIS, L M. 1994. The implications of angiogenesis for the biology and therapy of cancer metastasis. *Cell*, **79** : 185-188.
- FOLKMAN, J. 1989. What is the evidence that tumours are angiogenesis-dependent ? *J. Natl. Canc. Inst.*, **82** : 4-6.
- FOTSIS, T., ZHANG, Y., PEPPER, M.S., ADLERCREUTZ, H. MONTESANO, R., NAWROTH, P. P. and SCHWEIGERER, L. 1994. The endogenous oestrogen metabolite 2-methoxyestradiol inhibits angiogenesis and suppresses tumour growth. *Nature*, **368** : 237- 239.
- KLAUBER, N., PARANGI, S., FLYNN, E., HAMEL, E. and D'AMATO, R.J. 1997. Inhibition of Angiogenesis and breast cancer in mice by the microtubule inhibitors 2-methoxyestradiol and Taxol. *Cancer Res.*, **57** : 81-86.
- LOTTERING, M.L. DE KOCK, M., VILJOEN, T.C. GROBLER, C.J. and SEEGER, J.C. 1996. 17 beta estradiol metabolites affect some regulators of the MCF-7 cell cycle. *Cancer Lett.*, **110** : 181-186.
- ZOUBINE, M.N., WESTON, A.P., JOHNSON, D.C., CAMPBELL, D.R. and BANERJEE, S.K. 1999. 2-methoxyestradiol-induced growth suppression and lethality in estrogen responsive MCF-7 cells may be mediated by down regulation of p34cdc2 and cyclinB1 expression. *Int. J. Oncol.*, **15** : 639-646.

PARASITE AND DISEASES

PATHOLOGICAL STUDY OF TUBERCULOSIS IN SPOTTED DEER IN WEST BENGAL

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ABSTRACT

A survey was conducted to know the mortality of spotted deer that showed the lesions of tuberculosis at different National Parks, Sanctuaries and Deer Parks in West Bengal from January 1997 to December 2000. In the present study *Mycobacterium tuberculosis* of human types was the important isolate from the spotted deer while bovine types of *M. tuberculosis* were observed in some impression smears. Grossly, grayish white pea sized tubercle formation was observed in almost all the cases. Histopathologically, the lungs and lymph nodes showed typical mixed granulomatous inflammation consisting of central caseation and calcification followed by an area of necrosis and a zone of epithelioid cells, lymphocytes, eosinophils and peripheral fibrosis. Acid fast bacilli were demonstrated in tissue sections by Zeihl Neelson's staining.

Keywords : Tuberculosis, Spotted deer, pathology, mortality

INTRODUCTION

Wild life has played immense and fruitful cultures since the first appearance of man on this earth. Life on earth is a delicate balance and they are so closely interlinked that disturbances in one, threatened the existence of others. Deer population in India is a great hope for the naturalist amidst unexpected habitat destruction since the denizens are conscious of their survival and have a major role to save the forest and grass land ecosystem. Though the deer are prolific in nature yet some species are endangered. Although deer species are better resistant than that of domestic ruminants but the death toll has been increased due to different contagious and infectious disease of bacterial, viral, fungal origin, drowning, predator bite and translocation. Among all the diseases, tuberculosis, paramphistomiasis, pneumonia and fasciolosis

are the major diseases in spotted deer in both the free living and in captivity. The prevalence of tuberculosis in both captive and free living deer is not uncommon in India and abroad (Mc Diarmid, 1967; John, 1979; Rathore and Khera, 1982; Rodger and Bhattacharjee, 1986 and Shah *et al.*, 1986). Considering the exigency of problem mainly due to diseases, the present study was conducted to know the mortality of spotted deer and pathological changes due to tuberculosis at different National Parks, Sanctuaries and Deer Parks in West Bengal during the period from January 1997 to December 2000.

MATERIALS AND METHODS

A state wide wild life survey was conducted to know the mortality of spotted deer at different National Parks, Sanctuaries and Deer Parks in West Bengal during the period from

January 1997 to December 2000. While studying the mortality of spotted deer at different places, the spotted deer that showed the lesions of tuberculosis constituted the material for the present study. Suspected lungs showing nodules at the time of postmortem examination were selected. The other organs like liver, kidney and lymph nodes were also collected. Samples were taken in two parts for transport to laboratory from different places. One part was preserved in 3% sodium borate solution for microbiological study and the other part in 10% formal saline for histopathological study.

Slides of tissue impression smears were prepared from the periphery of the caseated mass of the nodule in lungs and these smears were stained with Zeihl-Neelson's staining technique after heat fixing. Then the slides were examined under oil immersion microscope.

Representative portions of the organs were processed for paraffin sections of 5 micron thickness. Sections were stained in Mayer's haematoxylin and eosin for histopathological examinations. Sections were also stained by Zeihl-Neelson's method for identification of acid fast organisms.

RESULTS AND DISCUSSION

A total of 89 death are caused by tuberculosis which were confirmed by isolation of bacterial agent and/or clinico-pathological signs and lesions. Mortality percentage due to tuberculosis in spotted deer were 4.69% in Buxa National Parks, 6.33% in Gorumara N.P., 0.33% in Sundarban N.P., 8.64% in Mahananda W.L.S., 6.32% in Ballavpur W.L.S., 4.44% in Ramnabagan W.L.S., 6.38% in Kumari Kangshabati Deer Park, 9.75% in Adina D.P., 13.09% in Gorchumuk D.P. and 9.09% in Jhargram D.P. The mortality rate of tuberculosis is higher in Deer Park than that of Sanctuaries and National Parks. The mortality % of tuberculosis in spotted deer in the present study was in agreement with the findings of Arora and Goyal (1987), Acharjyo and Rao (1987), and Rao and Acharjyo (1992) who recorded

mortality upto 11.33% and 12% at Nandankanon Biological Park. Grossly, grayish white, pea-sized tubercle formation was observed in almost all the cases.

In some cases, lungs were hard and caseated having small nodular structures from 1- 5 cm in diameter throughout the lung parenchyma. This findings were in closely resemblance with the findings of Basak *et al.* (1975) in deer, Singh *et al.* (1986) and Upadhyay *et al.* (1986) in spotted deer, Arora and Goyal (1987) in captive cervids and Acharyo and Rao (1991) in spotted deer and wild ruminants. Pleura was thick and the cavity was congested. Histopathologically, the lungs and lymph nodes showed typical mixed granulomatous inflammation consisting of central caseation and calcification followed by an area of necrosis and a zone of epitheloid cells, lymphocytes, eosinophils and peripheral fibrosis. A few giant cells were also seen around the caseated area in most of the cases. Fibrous encapsulation was not well marked. This observation simulated with the findings of Basak *et al.* (1975) and Singh *et al.* (1986) in deer, Rao *et al.* (1982), Shah *et al.* (1986), Upadhyay *et al.* (1986) and Chakraborty *et al.* (1993). Kidney showed a focal area of caseation and a few haemorrhagic foci surrounded by aggregation of macrophages, intertubular fibrosis causing atrophy and dilatation of tubules with desquamation of tubular epithelial lining was seen. This finding in the kidney was in close resemblance with the findings of Shah *et al.* (1986). A few focal necrosis in seminiferous tubules without any granulomatous reaction were observed in testis in rare cases. Acid fast bacilli were demonstrated in tissue section by acid fast staining. In the present study, *M. tuberculosis* of human types was the important isolate from the spotted deer while bovine types of *M. tuberculosis* were observed in some impression smears.

It can at least be summarized from the present study that Tuberculosis has become a common disease in wild animals particularly those are closely associated with man and environment.

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LITERATURE CITED

- ACHARJYO, L.N. and RAO, A. T. 1987. Mortality pattern in some Indian captive wildruminants. *Ind. J. Anim. Sci.*, **54**(5) : 430-435.
- ARORA B.M. and GOYAL, J. P. 1987. Mortality in captive cervids. *Ind. J. Anim. Sci.*, **57**(5) : 426-428.
- BASAK, D.K., CHATTERJEE, A., NIOGI, M.K. and SAMANTA, D.P. 1975. Tuberculosis in captive deer. *Ind. J. Anim. Hlth.*, **14** : 135-136.
- CHAKRABORTY. A., SHARMA, D.K. and CHAUDHURY, B. 1993. Tuberculosis in captive herbivores. *Ind. J. Vet Pathol.*, **17**(2) : 58-60.
- JOHN, H. 1979. Tuberculosis in deer. *New Zealand Vet. J.*, **27**(8) : 151.
- MCDIARMID, A. 1967. A list of bovine tuberculosis in fellow deer. *J. Brit. Soc.*, **1** : 78.
- RAO, AT., ACHARJYO, L. N. and NAYAK B.C. 1982. Tuberculosis in some ungulates and primates in Nandankanan Biological Park. *Ind. J. Vet. Path. and Microbiol.*, **25** : 199-202.
- RAO, A.T. and ACHARJYO, L.N. 1992. Mortality in some Indian deer at Nandankanan. *Ind. J. Vet. Pathol.*, **16** (2) : 120-121.
- RATHORE, S. S. and KHERA, S. S. 1982. Tuberculosis in wild animals and birds in captivity and free living state. *Vet. Bull.*, **53** : 371.
- RODGERS, W. A. and BHATTACHARJEE, K. K. 1986. Tuberculosis in wild chital at Ranthambore National Park, Rajasthan. *Zoos Print.*, **10** : 7-8.
- SHAH, N. M., DHOLAKIA, P. M., HERANJAL, D. D., PRAJAPATI, K. S., GANJOPADHAYAYA, R. M. and BHUVA, C. N. 1986. Incidence of tuberculosis in black buck and white spotted deer. *Ind. J. Anim. Sci.*, **56** : 1141-1142.
- SINGH, C. D., N., PRASAD, L. N. and THAKUR, H. N. 1986. Some observation on tuberculosis in deer. *Ind. Vet. J.*, **63** : 867-868.
- UPADHAYAYA, J. N., RAHMAN, H., PATHAK, D. C., BARUAH D.K. and BARUAH G., K. 1986. Tuberculosis in captive deer. *Ind. Vet. J.*, **63** : 865-866.

STUDY ON THE RATE OF AMMONIA EXCRETION IN *ISOPARORCHIS HYPSELOBAGRI* (BILLET, 1898)

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ABSTRACT

Ammonia is detected as excretory product in *Isoparorchis hypselobagri*. The amount of excretion of ammonia is lower when the flukes are kept *in vitro* in the incubation media without glucose (control) than in the incubation media with glucose. The amount of excreted ammonia shows highly significant values than that of control in *in vitro* condition. In the swim bladder of host *Wallago attu* ammonia is also present in significant amount.

Keywords : ammonia excretion, swim bladder, *Isoparorchis*, excretory product.

INTRODUCTION

Isoparorchis hypselobagri (Billet, 1898) is a widely distributed common digenetic piscine trematode parasite harbouring in swim bladder of *Wallago attu*. The excretory organs appear to be the major route for the elimination of metabolic wastes, although there is little precise knowledge of this route in this parasite. In trematodes some 90% of excreted nitrogen comes from the α -aminonitrogen of aminoacids, the remainder originating from the breakdown of purines and pyrimidines (Barret, 1981). In parasitic helminthes the major excretory product is ammonia which usually constitutes 80% of the total excretory nitrogen. This is a toxic compound and is an end product in aquatic organisms (Barret, 1981).

MATERIALS AND METHODS

Healthy adult *Isoparorchis hypselobagri* were collected from the swim bladder of *Wallago attu*. These flukes were washed several times with PBS (pH 7.0) and kept in conical flasks (Taylor and Baker, 1978, Bera and Manna, 2007). Conical flasks containing 4 parasites with 40

ml PBS were considered as control condition and conical flasks containing 4 parasites in 40 ml PBS with 40 mg glucose (1gm/litre) were considered as nutrient treated condition. Both in control and nutrient glucose treated condition, 10 sets were prepared for ammonia estimation. Adult flukes were incubated in PBS without glucose (control) and with glucose (treated) up to 300 hours. Washing of swim bladder of host in which these flukes harbour naturally were also used for ammonia estimation. The method of Conway and Cooke (1939) was followed for ammonia estimation. The results were analysed with suitable statistical programme.

RESULT

The ammonia content in control condition is recorded highest after 12 hours of incubation and lowest after 144 hours of incubation (Fig. 1).

In glucose treated condition, the highest ammonia content is found after 36 hours of incubation and lowest after 192 hours of incubation. Thus, the amount of excreted ammonia in *in vitro* condition shows highly

significant value at 5% level in treated with that of control condition (table 1).

The amount of excreted ammonia in the swim bladder of *W. attu* differs with the number of parasites harbour. The highest amount of ammonia is recorded when the number of parasites is above eight and lowest when the number of parasites below six. The highest value is 43.845 mg/ml and the lowest value is 5.853 mg/ml (Table 2, Fig. 2)

DISCUSSION

The adult *Isoparorchis hypselobagri* harbours in the swim bladder of *Wallago attu*, an oxygen

rich environment (Siddiqi and Nizami, 1974, 1975, Rahaman and Manna, 1992). Excessive accumulation of ammonia in the media would undoubtedly be harmful. Ammonia and its derivatives are essentially the true end products of protein utilization (Goil, 1958, Senft, 1963, Moss, 1970, Kurelec and Rijavec, 1966). The excretion of ammonia is reported in different groups of helminthes. The trematodes are ammonotelic and ammonia can be formed by the action of several enzymes in *Schistosoma mansoni* (Smyth, 1966, Nimmo-Smith and Raison, 1968). *Ascaris lumbricoides* excreted 39 mg of nitrogen per 100 gm of wet weight of body of which 79% is ammonia (Savel, 1955) while *Trichinella spiralis* larvae excrete 208 mg

Table 1. Ammonia content of the incubation media PBS (pH 7.0) without glucose (control), with glucose (treated) and rate of change of excretory ammonia in treated condition

Study Group	Ammonia Content (mg /ml)(control)	Ammonia Content (mg /ml)(treated)	Rate of Change	5% level of significance
12 h (10)	4.739 ± 0.163 [H]	44.785 ± 0.129	89.418 %	(+ +)
24 h (10)	3.43 ± 0.186	40.601 ± 0.174	91.551 %	(+ +)
36 h (10)	3.437 ± 0.189	45.347 ± 0.187 [H]	92.42 %	(+ +)
48 h (10)	2.54 ± 0.123	43.6 ± 0.182	94.182 %	(+ +)
60 h (10)	1.633 ± 0.184	28.684 ± 0.191	94.306 %	(+ +)
72 h (10)	4.462 ± 0.215	36.365 ± 0.126	87.729 %	(+ +)
84 h (10)	2.411 ± 0.135	21.502 ± 0.182	88.787 %	(+ +)
96 h (10)	2.518 ± 0.172	31.496 ± 0.171	92.005 %	(+ +)
108 h (10)	1.406 ± 0.119	43.6 ± 0.146	96.777 %	(+ +)
120 h (10)	1.675 ± 0.101	15.597 ± 0.153	89.26 %	(+ +)
132 h (10)	1.77 ± 0.116	23.586 ± 0.136	92.495 %	(+ +)
144 h (10)	1.299 ± 0.094 [L]	18.387 ± 0.151	92.935 %	(+ +)
156 h (10)	3.511 ± 0.156	26.796 ± 0.168	86.897 %	(+ +)
168 h (10)	2.34 ± 0.137	32.629 ± 0.066	92.828 %	(+ +)
180 h (10)	4.539 ± 0.205	20.671 ± 0.197	78.041 %	(+ +)
192 h (10)	2.831 ± 0.1	13.704 ± 0.115 [L]	79.341 %	(+ +)
204 h (10)	2.635 ± 0.187	43.275 ± 0.141	93.911 %	(+ +)
216 h (10)	2.3 ± 0.1	43.185 ± 0.108	94.674 %	(+ +)
228 h (10)	1.805 ± 0.126	45.237 ± 0.104	96.009 %	(+ +)
240 h (10)	2.211 ± 0.08	34.536 ± 0.126	93.597 %	(+ +)
252 h (10)	2.173 ± 0.105	44.656 ± 0.193	95.133 %	(+ +)
264 h (10)	2.243 ± 0.1	44.625 ± 0.157	94.973 %	(+ +)
276 h (10)	1.387 ± 0.195	43.336 ± 0.228	96.799 %	(+ +)
288 h (10)	1.307 ± 0.079	40.466 ± 0.145	96.77 %	(+ +)
300 h (10)	2.131 ± 0.119	38.492 ± 0.169	94.463 %	(+ +)

* Results are expressed as Mean ± S.D.

* Figure in the parentheses indicates the times of analysis

* P <0.001 highly significant (+ +)

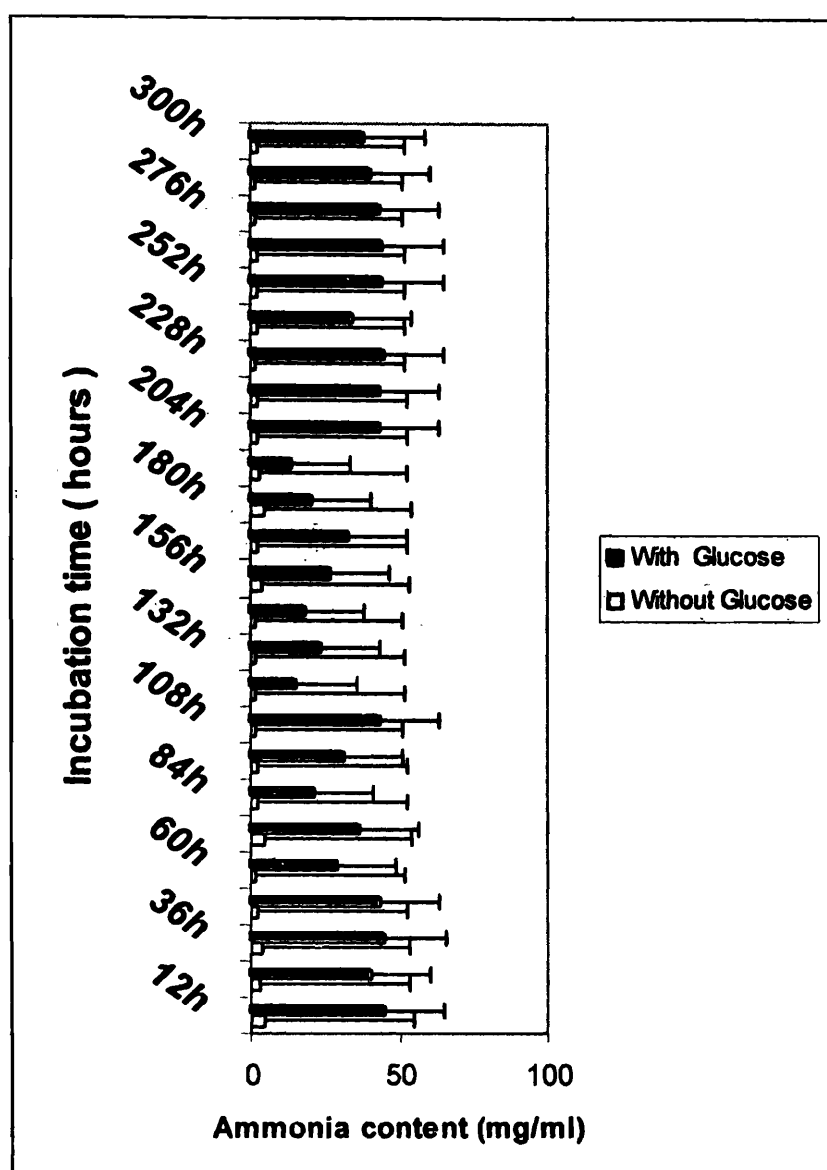


Fig. 1. Ammonia content in incubation media (40 ml PBS) of adult *I. hypselobagri*

Table 2. Ammonia content in the swim bladder washing of *W. attu* with 40 ml PBS (pH 7.0)

Study Group	Weight range of parasite(mg)	Ammonia content (mg/ml)
1 No. of Parasite present (6)	150-350	22.616 $\pm$ 0.099
2 No. of Parasite present (6)		36.391 $\pm$ 0.174
3 No. of Parasite present (6)		29.398 $\pm$ 0.129
5 No. of Parasite present (6)		10.85 $\pm$ 0.112
6 No. of Parasite present(6)		5.853 $\pm$ 0.14 [L]
7 No. of Parasite present (6)		11.16 $\pm$ 0.104
9 No. of Parasite present (6)		43.845 $\pm$ 0.123 [H]
11 No. of Parasite present (6)		11.106 $\pm$ 0.067
13 No. of Parasite present (6)		18.89 $\pm$ 0.109
17 No. of Parasite present (6)		14.626 $\pm$ 0.069

* Results are expressed as Mean $\pm$ S.D.

*Figure in the parentheses indicates the number of swim bladder washings analysed

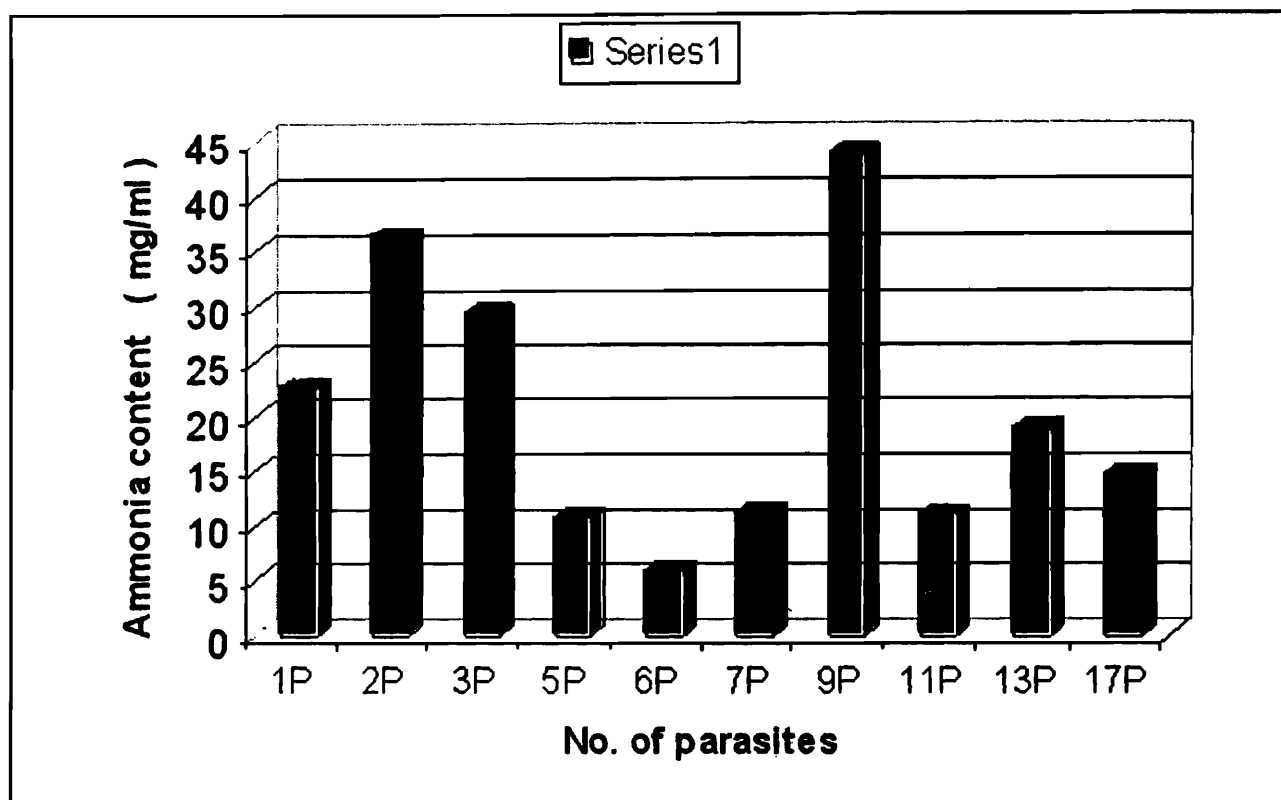


Fig. 2. Ammonia content in swim bladder washing with PBS, harbouring *I. hypselobagri*

of nitrogen per 1 mg of wet body weight of which 33% is ammonia (Haskins and Weinstein, 1957). The analysis of incubates of *Taenia taeniaeformis* larvae showed 17.5% ammonia nitrogen in the excretory products (Haskins and Oliver, 1958). Fairbrain *et al.* (1961) reported 30% of ammonia in the excretory products of *Hymenolepis diminuta*. Goil (1958) reported the end products of protein metabolisms in three flukes *Paramphistomum explanatum*, *P. gigantea* and *Gastrothylax crumenifer*. About 3.95% of total body nitrogen was excreted in the form of ammonia in a period of 12 hours under aerobic conditions in *P. explanatum*, 2.9% of total body nitrogen as ammonia under identical conditions in *G. crumenifer*, and 3.04% of total body nitrogen as ammonia in a period of 12 hours in *Isoparorchis hypselobagri* (Srivastava & Gupta, 1976, Nizami & Siddiqi, 1976).

In the present observation quantitative analysis of excreted ammonia up to 300 hours in both control and glucose treated condition is done. In the present study, in both control and glucose treated condition, the ammonia excretion is very high within 12 to 36 hours of incubation. Then the amount of ammonia

excretion decreased and reach its lowest in both control and treated condition within 144 to 192 hours of incubation. When these parasites are in host's swim bladder they also excrete ammonia. The amount of ammonia present in the swim bladder depends on the number of parasites present and body weight of the parasite. Thus a comparison of ammonia excretion in natural condition and in *in vitro* control and glucose treated condition is made in the present study. The highest amount of ammonia excretion in glucose treated condition is closely similar to the highest amount of ammonia in host's swim bladder. Based on this observation, it can be assumed that the parasites remain in full metabolic activity up to 36 hours in *in vitro* culture after which they become torpor and decay gradually thus metabolic activity become at its lowest level. Obviously ammonia excretion become gradually lowered.

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The authors are deeply indebted to K. L. Mukherjee, former Professor and Head,

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LITERATURE CITED

- BARRET, J. 1981. *Biochemistry of Parasitic Helminths*. McMillan Publishers., London : 140–141.
- BERA, B. and MANNA, B. 2007. Pyruvate Kinase and Phosphoenol pyruvate Carboxykinase activity in adult *Isoparorchis hypselobagri* (Digenea : Trematoda). *Research Journal Parasitology (Academic Journal)*, 2(1) : 51–56.
- CONWAY, E. J. and COOKE, R. 1939. Estimation of ammonia. *J. Biochem.*, 33 : 457–459.
- FAIRBRAIN, D., WERTHEIM, G., HARPUR, R. D. and SCHILLER, E. L. 1961. Biochemistry of normal and irradiated strains of *Hymenolepis diminuta*. *Exp. Parasit.*, 11 : 248–263.
- GOIL, M. M. 1958. Protein metabolism in trematode parasites. *J. Helminth.*, 32 : 119–124.
- HASKINS, W. T. AND WEINSTEIN, P. P. 1957. Nitrogenous excretory products of *Trichinella spiralis* larvae. *J. Parasit.*, 43 : 19–24
- HASKINS, W. T. and OLIVER, L. 1958. Nitrogenous excretory products of *Taenia taeniaeformis* larvae. *J. Parasit.*, 44 : 569–573.
- KURELEC, B. and RIJAVEC, M. 1966. Amino acid pool of the liver fluke (*Fasciola hepatica* L.) *Comp. Biochem. Physiol.*, 24 : 403–416.
- MOSS, G.D. 1970. The excretory metabolism of the endoparasitic digenean *Fasciola hepatica* and its relation to its respiratory metabolism. *Parasitology*, 66 : 1–19.
- NIMMO-SMITH, R.H., and RAISON, C.G. 1968. Monoamine oxidase activity of *Schistosoma mansoni*. *Comp. Biochem. Physiol.*, 24 : 403–416.
- NIZAMI, W. A. and SIDDIQI, A. H. 1976. Qualitative analysis of substances excreted by *Isoparorchis hypselobagri* (Trematoda) during aerobic *in vitro* culture. *Z. Parasitenk.*, 50 : 53–56.
- RAHAMAN, A. and MANNA, B. 1992. Daily egg-output capacity of adult *Isoparorchis hypselobagri* (Billet, 1898), *in vitro*. *J. Parasit Appl. Anim. Biol.*, 1(2) : 111–118.
- SAVEL, J. 1955. Etudes sur la Constitution et le metabolisme proteques d' *Ascaris lumbricoides* Linné, 1758. É. & Ī *Rev. Path. Comp.*, 55 : 213–282.
- SENFT, A.W. 1963. Observations on amino acid metabolism of *Schistosoma mansoni* in a chemically defined medium. *Ann N. Y. Acad. Sci.*, 113 : 272–288.
- SIDDIQI, A. H. and NIZAMI, W. A. 1975. Gas content of swim bladder of *Wallago attu* and oxygen consumption in *Isoparorchis hypselobagri* (Trematoda). *Z. Parasitenk.*, 47 : 263–268.
- SMYTH, J. D. 1966. *The Physiology of Trematodes*. Oliver & Boyd. Edinburgh : pp. 34–38.
- SRIVASTAVA, M. and GUPTA, S. P. 1976. Protein metabolism in *Isoparorchis hypselobagri*. *Z Parasitenk.*, 49 : 179–182.
- TAYLOR, A.E.R. and BAKER, J. R. 1978. *Methods of Cultivating Parasites in vitro*. Academic press, New York, : pp. 11–12.

HOOKWORM INFESTATION AND ANAEMIA AMONG PRIMARY SCHOOL CHILDREN

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ABSTRACT

In this epidemiological study, stool samples and blood samples were collected from two primary schools in Burdwan District, West Bengal, one situated in rural belt and the other in urban belt. The children are of age group between 5-10 years. The study has been carried out to draw a relationship between hookworm (*Ancylostoma duodenale*, *Necator americanus*) infestation anaemia and hypoproteinemia. It has been observed that the hookworms are the leading cause of iron-deficiency anaemia in children of the above slum communities. Heavy infection leads to gastric problem causing Vitamin B₁₂ malabsorption leading to protein bound malnutrition

Keywords : *Ancylostoma duodenale*, *Necator americanus*, infestation, epidemiology, anaemia, hypoproteinemia, malnutrition, malabsorption

INTRODUCTION

Hookworm infestation is the common public health problem in India. The two species that most commonly infect human beings are *Ancylostoma duodenale* and *Necator americanus* (Garekar 2002). According to World Health Organization, 1 billion people are hookworm infected worldwide of which 200 million are estimated to be infected in India.

A single adult *A. duodenale* causes about 0.2 ml blood loss per day (Chatterjee 1976, Garekar 2002). The development of clinical symptomatology depends on several factors including warm burden, preexisting iron stores and the nutritional status of the host.

The present study has been carried out to ascertain the prevalence of hookworm infection and to clarify whether hookworms are an important cause of iron deficiency anaemia in primary school going children of rural and urban slum communities.

MATERIAL AND METHODS

The study has been carried out among the children of two primary schools in Burdwan district. One of the school named Fakirpur Primary School, situated in rural belt and the other named Lakshmipur Math Primary School situated in urban belt. The children are of age group 5-10 yrs. The number of children in the schools situated in rural belt and urban belt are 151 and 139 respectively.

Early morning stool samples were collected from the children in provided containers. Stool samples were examined under light microscope by preparing smear in normal saline following the method of Yadla *et al.*, 2003. In the positive slides the number of eggs of the entire slide was recorded to provide a rough estimate of warm burden.

The blood samples from each and every child has also been collected and haemoglobin percentage has been estimated by Sahli's Haemoglobinometer.

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The weight of the children was measured under common weighing machine.

OBSERVATIONS AND RESULTS

After examining the stool samples it has been observed that 29.7% of the children in rural belt and 35.9% in urban belt are free of any intestinal infection. Of the infected ones 36.7% children in rural belt and 46.0% in urban belt are infected with hookworm species (*Ancylostoma duodenale*, *Necator americanus*) whereas 63.2% in rural belt and 54.0% in urban belt are infected with other gastrointestinal parasites such as, *Ascaris lumbricoides*, *Giardia* sp and *Entamoeba* sp etc. (Plate I, Fig. 1).

The haemoglobin percentage recorded was between 7.9-9.9 in 7.8% of rural children and 10.7% of urban ones, between 10.0-12.0 in 49.6%

of rural children and 47.7% of urban ones and between 12.1-14.2 in 42.3% of rural and 41.7% of urban ones (Plate I, Fig. 2).

The children those who are free of any gastrointestinal infection have the average haemoglobin of 13.2% in rural area and 13.4% in urban area. The children those who are infected with hookworm (*Ancylostoma duodenale*, *Necator americanus*) have the average haemoglobin of 7.9% both in rural and urban areas. The children those who are infected with other gastrointestinal parasites (*Ascaris lumbricoides*, *Giardia* sp, *Entamoeba* sp) the average haemoglobin recorded was 10.1% in rural and 10.3% in urban areas (Plate I, Fig. 3, 4).

Normal average weights recorded among children from 5-10 years are presented in Table I. It has been observed that children having

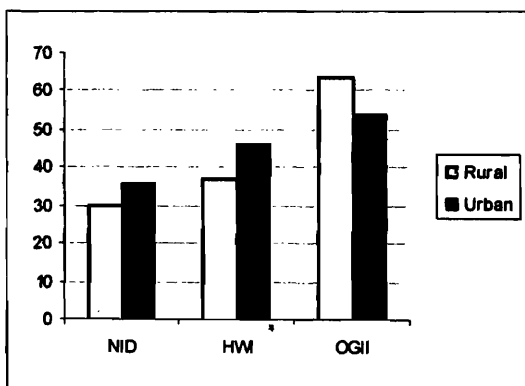


Fig. 1. Prevalence rate in Rural and Urban areas

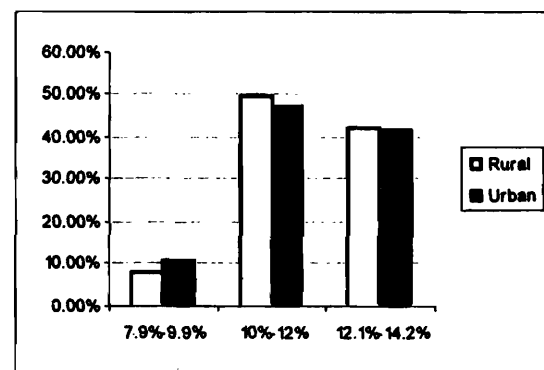


Fig. 2. Range of Hb% in Rural and Urban areas

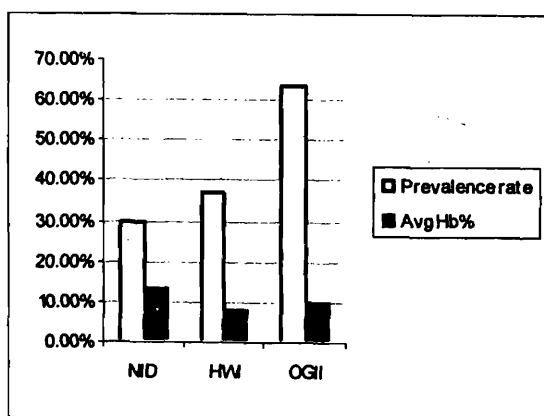


Fig. 3. Comparison between prevalence rate and Average Hb% in Rural area

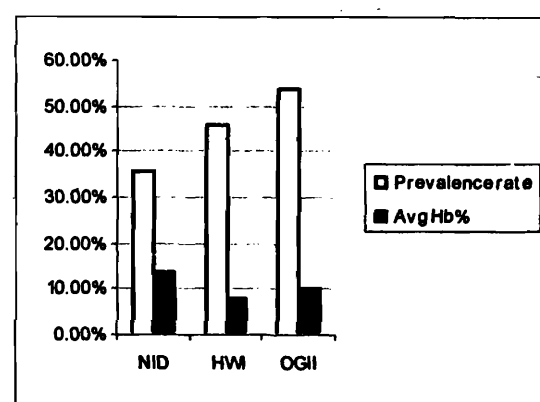


Fig. 4. Comparison between prevalence rate and average Hb% in Urban area

NDI = No Infection Detected
 HWI = Hookworm Infection
 OGII = Other Gastro Intestinal Infection

moderate infection loss a weight of 1-2kg where as children with heavy infection loss 4Kg-4.5Kg weight. (Table I).

DISCUSSION

The hookworm infection is a common and significant burden on health of rural and urban children in Burdwan District. It has been observed that the hookworms are the leading cause of iron deficiency anaemia in these children. The timing of anaemia onset depends on the child's preexisting iron stores. As iron is required for the biosynthesis of neurotransmitters, anaemia affects cognitive development. Delay in growth and development has been observed among the children having significant anaemia (Plate II, Table I).

Significant weight loss has been detected among the children with heavy infection (Table I) as the child losing RBC and plasma. Malabsorption as a result of hypoproteinemia aggravates malnutrition. Due to heavy hookworm infection gastric problem occurs which leads to Vitamin B12 malabsorption in chronic state causing protein bound malnutrition. Anaemia and Protein Energy Malnutrition occur together in many cases. (Plate II).

MANAGEMENT

Hookworm disease cannot be eradicated but

new tools and understanding make better control possible.

- i) Mass deworming activities on the health of target populations.
- ii) Use of proper and continued shoe wear and proper disposal of sewage is necessary.
- iii) Development of Information Education and Communication Programme helped us to combat with hookworm infection and anaemia related with malabsorption.

Management also need iron therapy, complemented by appropriate diet. The diet should be rich in iron and protein. Dietary supplementation of ascorbic acid increases iron absorption.

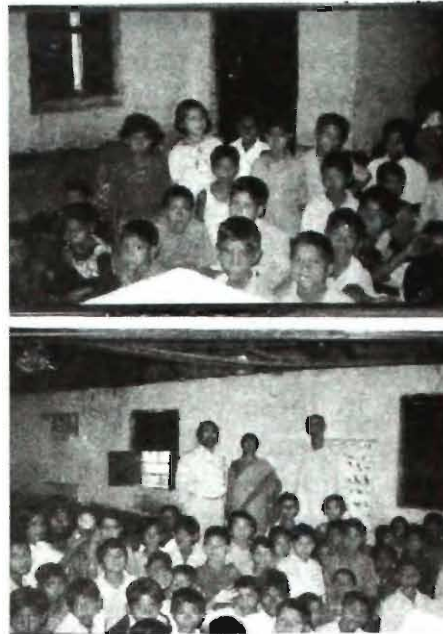
As the area is of high endemism the recommended strategy for disease control is the periodical application of recommended drugs (World Health Organization, 2002) twice a year. Particular attention has been given to the children who are considered as the risk group for the morbidity due to hookworms.

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Thanks are due to the Department of Community Medicine for providing the laboratory. We also express our gratitude to the Headmaster of Fakirpur Primary School and Lakshmipur Math Primary School for assisting us in various aspects.

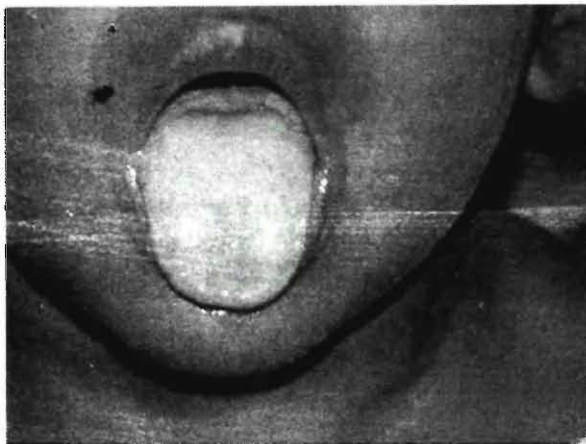
Table I. Comparative study of weights of children i) with no infection ii) with moderate infection iii) with severe infection

Age in year	No Infection (i)	Moderate Infection (ii)	Severe Infection (iii)
5	20 kg	18-19 kg	16 kg
6	21kg	19-20 kg	17 kg
7	22kg	20-21 kg	17.5 kg
8	23kg	21-22 kg	18.5 kg
9	24.5g	22-23 kg	20 kg
10	25.5kg	23-24 kg	21 kg



SCHOOL CHILDREN

SYMPTOMS OF ANAEMIA AND MALABSORPTION



Lips and tongue show extreme pallor



Pale plump child



Malabsorption leads to protein bound malnutrition



Detected learning disabilities and lower IQ

LITERATURE CITED

- ALBONICO, M, SMITH, PG, HALL, A, *et al.* 1994. A randomized controlled trial comparing mebendazole and albendazole against *Ascaris*, *Trichuris*, and the hookworms. *Trans. R. Soc. Trop. Med. Hyg.*; **88** : 585-9.
- BAHADER SM, ALI, GS, SHAALAN, AH and KHALIL, NM. 1995. Effects of *Enterobius vermicularis* infection in intelligence quotient (IQ) and anthropometric measurement of Egyptian rural children. *J. Egypt Soc. Parasitol.*, **25**(1) : 183-94.
- BRADLEY, M, CHANDIWANA, SK. and BUNDY, DAP. 1993. The epidemiology and control of hookworm infection in the Burma Valley area of Zimbabwe. *Trans. R. Soc. Trop. Med. Hyg.*, **87** : 145-7.
- CHATTERJEE, JB. 1967. Some aspects of nutritional anaemias in India. *Proc. Nutr. Soc. India*, **2** : 67-80.
- CHWANG, LC, SOEMANTRI, AG, and POLLITT, E. 1988. Iron supplimentation and physical growth of rural Indonesian children. *Am. J. Clin. Nutr.*, **47** : 496-501.
- GAREKAR, S. 2002. Ancylostoma infection. *Med. Sec.* 1-10 of Sec. 10.
- HOTEZ, PJ, 1989. Hookworm disease in children. *Pediatr. Infect. Dis. J.*, **8** : 516-20.
- KIGHTLINGER, LK, SEED, JR, and KIGHTLINGER. 1995. The epidemiology of *Ascaris lumbricoides*, *Trichuris trichura* and hookworm in children in the Ranomafana rainforest Madagascar. *J. parasitol.*, **81**(2) : 159-69.
- KILPATRICK, ME, TRABOLSI, B, and FARID, Z. 1981. Levamisole compared to mebendazole in the treatment of *Ancylostoma duodenale* in Egypt. *Trans. R. Soc. Trop. Med. Hyg.*, **75** : 578-579.
- WATKINS, WE, CRUZ, JR, POLL WITT, E. 1996. The effects of deworming on indicators of school perfoemance in Guatemala. *Trans. R. Soc. Trop. Med. Hyg.*, **90**(2) : 156-161.
- YADLA, S. 2003. An epidemiological study of Ancylostomiasis in a rural area of Kanpur District, Uttar Pradesh, India. *Indian Journal of Public Health*. Vol. XXXXVII No. **2** : 53-60.

NEUROSECRETORY INNERVATIONS IN A PARASITIC NEMATODE *ASCARIDIA GALLI*

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ABSTRACT

Neuromuscular junctions of *Ascaridia galli* are studied ultramicroscopically. It reveals existence of discrete synapses where indications for nerve endings and muscle cell extensions are available. Strikingly, incidence for neurosecretory innervations due to the presence of demonstrable stream of elementary granules that penetrate the hypodermal plasma membrane has been established. A few mitochondrial bodies and vesicles of larger dimension are also detected within these extensions. Such condition otherwise provides evidence for direct neurosecretory innervations to the muscle fibres likely to amplify the muscular activation emerging from parasitic mode of life.

Keywords : Nematode, Neuromuscular junctions, Nerve endings, Neurosecretory innervation, *Ascaridia galli*.

INTRODUCTION

The nervous system of nematodes has been studied by several investigators (Strote *et al.*, 1996, Endo and Trpis, 1997, Hoschitz *et al.*, 2001). Morphoanatomically the nervous system in nematodes is comprised of a circumoesophageal nerve ring endowed with three ganglionic swelling at the dorsal, ventral and lateral regions. Strikingly, involvement of nervous system to constitute the neuromuscular junctions generally in majority of nematodes has unique features due to the fact that such junctions are formed by specialized branches of muscle cells (muscle arms) extending to the nerve cords and not by neurites as such (Stretton *et al.*, 1978). Such feature of neuromuscular junction may have variations. The aim of this investigation is to probe these neuromuscular junctions in case of *A. galli* with a view to identify deviation in the general make up for having diversified parasitic adaptation to the host.

MATERIAL AND METHODS

Full-grown live worms were collected from the alimentary canal of the decapitated chickens. Immediately after collection from the host, the anterior portion of the worm were quickly dissected out to ensure proper penetration of the fixative and fixed in 2% paraformaldehyde and 4%glutaraldehyde in 0.1M cacodylate buffer, pH 7.2 for overnight at 4°C. The samples were post fixed in 1% osmium tetroxide and processed following standard technique. The ultrathin sections were examined in Philips Morgagni 268 electron microscope operated at 80 kV.

RESULTS AND DISCUSSION

The nerve ring of *A. galli* is located at about 250-300 µm from the anterior end encircling the pharynx with thickness of about 40µm. Peripherally the nerve ring is made up of numerous axonal processes. The neurosecretory cells (NSCs) are round to ovoid with distinct

nuclei and cytoplasmic inclusions (Fig. 1). In the ventral ganglionic half of the nerve ring, the cytoplasm of such cells possess nuclei and inconspicuous chromatin granules (Fig. 1). The cytoplasmic region shows bubbling appearance interspersed with cytoplasmic contents including secretory materials and some of the contents appear to concentrate along the axonal hillock on their way towards respective axonal processes. Moreover, impressions of intracytoplasmic fibres may be found in some

of the cells of larger dimension. The latter feature may demonstrate deployment of axoplasmic flow initiated from perikarya of origin. Furthermore, distinct microtubular structures are demonstrable at the axon-hillock (Fig. 2) region. These microtubules bear some structures and bodies, which are comparable with secretory inclusions of variable contours. Such criteria reflect tunneling of secretory material through homogenous axoplasmic substances. Sometimes glycogenous contents

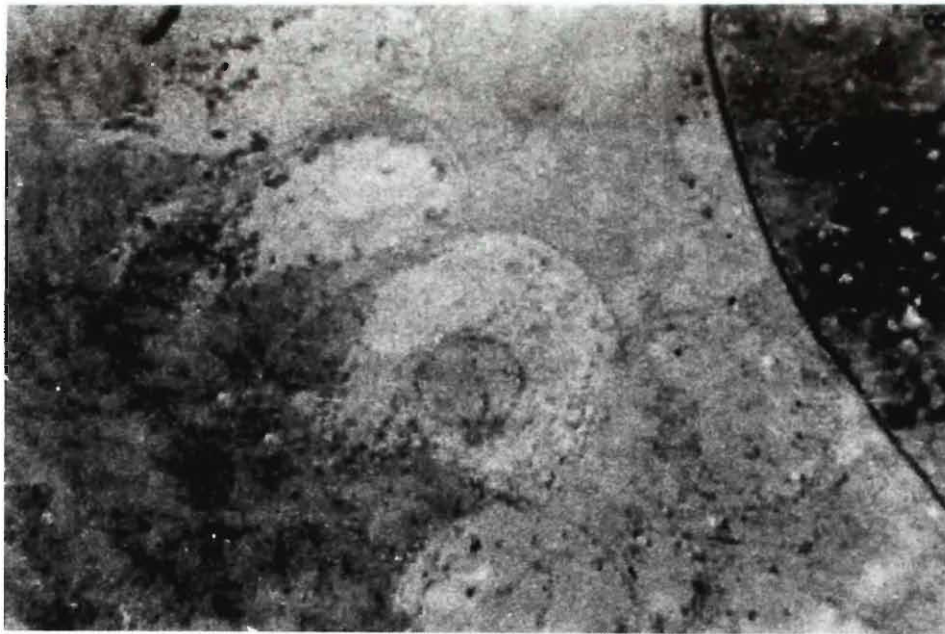


Fig. 1. Ultramicroscopic view of semithin section showing discrete cytomorphic anatomy of ventral ganglionic NSCs. Note nuclear configuration and cytoplasmic characteristics endowed with secretory inclusions within the perikarya and their streaming on way to axonal process. (arrow head) $\times 1500$



Fig. 2. Section showing portion of the axon hillock region to show distribution of microtubules along the axonal process via axon hillock. Bar = 2 μm .

are also found to aggregate at the mesial profile of the axonal prolongations. Such situation may have a bearing for the metabolic mediation of axoplasmic flow in the transportation of neurosecretory material (NSM) amongst the NSCs in particular. Incidentally, the distal end of the axonal region is often found to contain aggregation of dense granules. Overall profile of the neuropile and their confluence with the

muscle fibres provide evidence for neurosecretory innervations to the surrounding muscles or hypodermal cord. This is further strengthened by the fact of penetration of 'moniliform' axons within the hypodermal plasma membrane (Fig. 3). A few mitochondrial elements and large vesicles are present within this prolongation (Fig. 4).

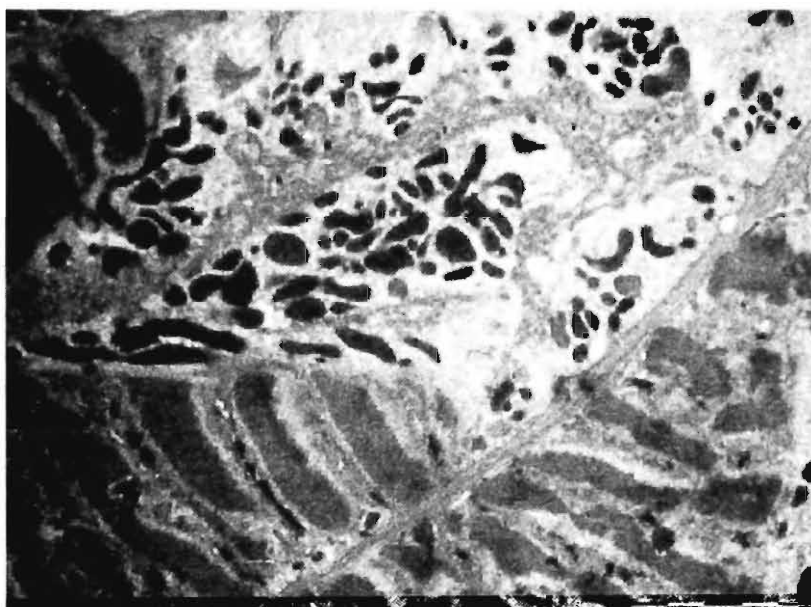


Fig. 3. TEM view of extension of axonal process innervating the adjacent muscle layers. Bar = 5 μm .

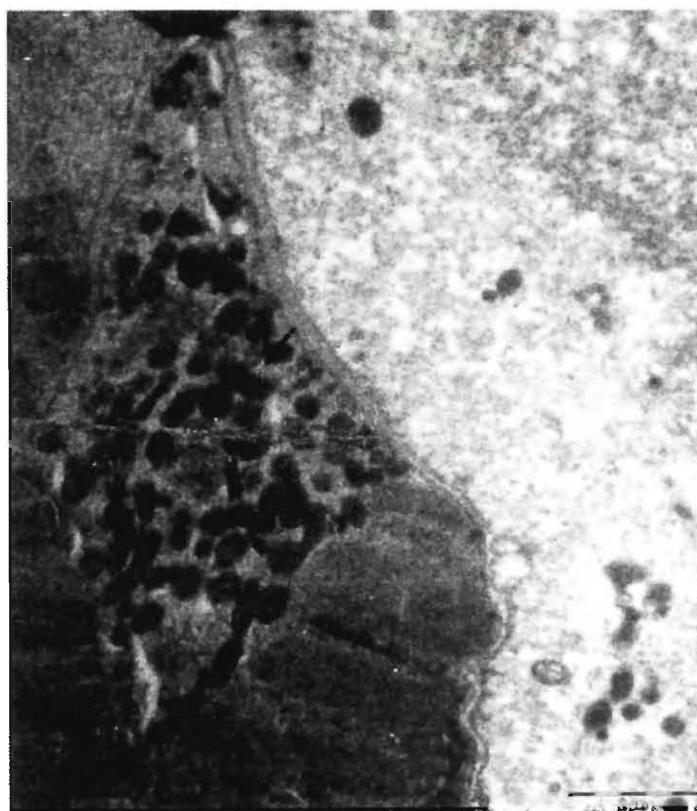


Fig. 4. Same as above showing aggregation of mitochondria (arrow). Bar = 2 μm .

The morphological features of the nervous system and its cytomorphic nature in *Ascaridia galli* elicit basic pattern of the nervous systems in nematodes. The existence of the three important ganglia (dorsal, ventral, lateral) in the anterior nerve ring region has been assessed and consistent with other species like *Ascaris lumbricoides* (Gersch and Scheffel, 1958; Ishikawas, 1961, Davey, 1964, 1966), *Phocanema decipiens* (Davey and Kan, 1967, 1968), *Thalastoma*, *Cephalobellus*, and *Rhabditis oxycerca* (Bird, 1971), *Gangulaterakis spumosa* (Kulkarni and Deshmukh, 1991), *Dicrofilaria immitis* (Delves *et al.*, 1989). Indeed, there exists resemblance of such components in other free-living nematode like *Caenorhabditis elegans* (White *et al.*, 1986).

Apart from these studies the foregoing observation provides that the questionable neuromuscular junction in this species under reference is obvious as and when their confluence with oesophageal region has been referred to. Such findings do not subscribe the contention of Kulkarni and Deshmukh (1991) who noted otherwise that is the muscle fibres receive nerve fibres and the usual 'innervation' has not been prevalent in *Gangulaterakis spumosa* (parasitic) and simulates the pattern as found in free-living nematode, *C. elegans* (Ware *et al.*, 1975). In *Ascaridia galli* the ground is more strengthened by the fact that stained neurosecretory granules (NSGs) are found, along the axonal processes as reported earlier in *Dipetalonema* (McLaren, 1972) and *Haemonchus contortus* (Rogers, 1968).

Characteristically, availability of coated vesicles with granular contents in the neuropile network has implication in the release of neurosecretion from axon terminals. Incidentally, earlier report (Reger, 1965) supports the occurrence of dimorphic neurosecretory vesicles (synaptic vesicles and dense core vesicles). Indeed, the former facilitate the synaptic cleft whereas the latter transport, store and release hormones, proteins and neuropeptides. Such understandings have bearings of the key molecular mechanisms that underlie cargo release from these two types of vesicles with reference to regulation of quantal release (Scalettar, 2006). The latter is reasonably assumed to constitute incipient neurosecretion pool so as to deploy the material to the adjoining concerned muscles. In addition, evidence for direct neurosecretory innervations to the hypodermal plasma membrane furnishes scope for amplifying the muscular activation in case of parasitic mode of life as and when efficacy of neuromuscular physiology is referred to.

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LITERATURE CITED

- BIRD, A. F. 1971. *The Structure of Nematodes*. Academic Press, Inc., New York.
- DAVEY, K. G. 1964. Neurosecretory cells in a nematode, *Ascaris lumbricoides*. *Can. J. zool.*, **42** : 731-734.
- DAVEY, K. G. 1966. Neurosecretion and moulting in some parasitic nematodes. *Amer. Zool.*, **6** : 243-249.
- DAVEY K. G. and KAN S. P. 1967. An endocrine basis for ecdysis in a parasitic nematode. *Nature*, **214** : 737-738.
- DAVEY, K. G. and KAN, S. P., 1968. Moulting in a parasitic nematode *Phocanema decipiens*. IV. Ecdysis and its control. *Can. J. Zool.*, **46** : 893-896.

- DELVES, C. J., WEBB, R. and HOWELLS, R. E. 1989. Neurosecretory like material in 3rd–4th stage *Dicrofilaria immitis* larvae (Nematoda : Filarioidea). *Parasitology*, **99** : 99-104.
- ENDO, B.Y. and TRPIS, M. 1997. Ultrastructure of infective larvae (L3) of *Onchocerca volvulus* (Nematoda : Filarioidea) developed in *Simulium yahense* in Liberia. *J. Parasitol.*, **83**(3) : 344-362.
- GERSCH, M. H. and SCHEFFEL, L. 1958. Sekretorisch tätige Zellen in Nervensystem Von Ascaris. *Naturwissenschaften*, Berlin, **45** : 345-346.
- HOSCHITZ, M., BRIGHT, M. and OTT, J. A. 2001. Ultrastructure and reconstruction of the pharynx of *Leptonemella juliae* (Nematoda, Adenophora). *Zoomorphology*, **121**(2) : 95-107.
- ISHIKAWA, M. 1961. On the secretory phenomenon of nerve cell of *Ascaris*. *Jap. J. Parasitol.*, **10** : 1-5 [In Japanese].
- KULKARNI, N. V. and DESHMUKH, P. G., 1991. Histology of the nervous system and neurosecretion in the male of the parasitic nematode, *Gangulaterakis spumosa* (Schnider, 1968) Lane, 1914, *Acta Parasitol. Pol.*, **36**(4) : 191-194.
- McLAREN D. J., 1972. Ultrastructural and cytochemical studies on the sensory organelles and nervous system of *Dipetalonema vitae* (Nematoda : Filarioidea). *Parasitology*, **65** : 507-524.
- REGER, J. R. 1965. The fine structure of neuromuscular junctions and contact zones between body wall muscle cells of *Ascaris lumbricoides*. *Z. Zellforsch. Mikrosk. Anat.*, **67** : 196-210.
- ROGERS, W. P. 1968. Neurosecretory granules in the infective stage of *Haemonchus contortus*. *Parasitology*, **58** : 657-662.
- STROTE, G., BONOW, I. and ATTAH, S. 1996. The ultrastructure of the anterior end of male *Onchocerca volvulus*: papillae, amphids, nerve ring and first indication of an excretory system in the adult filarial worm. *Parasitology*, **113**(pt-I) : 71-85.
- SCALETAR, B.A. 2006. How neurosecretory vesicles release their Cargo. *Neuroscientist.*, **12**(2) : 164-76.
- WARE, R. W., CLARK, D., CROSSLAND, K, and RUSSELL, R. L. 1975. The nerve ring of the nematode *Caenorhabditis elegans*. *J. Comp. Neurol.*, **162** : 71-100.
- WHITE, J. G., SOUTHGATE, E., THOMSON, J. N. and BRENNER, S. 1986. The structure of the nervous system of the nematode *Caenorhabditis elegans*. *Phil. Trans. Roy. Soc. Lond.*, B **314** : 1-340.

**ECOLOGY, BEHAVIOUR
AND
ANIMAL PLANT INTERACTION**

AGONISTIC BEHAVIOUR OF BLACKBUCK-AN OBSERVATION IN SEMI-NATURAL HABITAT OF GANJAM DISTRICT, ORISSA, INDIA

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ABSTRACT

Blackbuck (*Antilope cervicapra* Linn. 1758) is a gregarious, territorial antelope belong to the family bovidae and endemic to Indian sub-continent. Ecologically, *Antilope cervicapra*, a grazer prefers open area and shows remarkable kind of social organization and behaviour scrutinizes through the course of evolution. The Social behaviour and agonistic interaction of *Antilope cervicapra* was observed in semi-natural habitat, Ganjam district, Orissa, India during a 2-year behaviour study. Analysis of agonistic interactions like Walk towards, Body push, Forcing to stand up, Supplanting, Dominance display, Ear threat, Horn or Frontal threat, Charge, Butting, Sparring, Fight and Chasing between male-male, male-female and female-female individuals. Most agonistic encounters occur between members of the same age, sex and social class. The frequency of buck-buck agonistic encounter was highest (52%), while doe-doe encounter remained lowest. Agonistic interaction likes dominance display (16%), threats (18.31%) and chasing (20%) are very common in between bucks, while walk towards (18%) and body push (42%) are very common among does. It was found that, the agonistic interactions were maximum in winter season (40.3%) in comparison to summer (32%) and monsoon (27%). The degree of aggression was more between the similar age, sex and social categories individuals. Agonistic interaction between territorial males and adult bachelor males were increased during rutting season. Also observed that the fight was very frequent among the adult bachelor males. Fight between territorial males are linked with territory establishment and maintenance.

Keywords : Blackbuck, Agonistic behaviour, Semi-natural, Ganjam, Orissa

INTRODUCTION

The *Antilope cervicapra* Linn. 1758 is a gregarious, terrestrial antelope, belongs to the family bovidae of the order artiodactyla and threatened animal endemic to Indian sub-continent, commonly called Blackbuck or Indian Antelope (Prater, 1971) and locally known as "Krushnasara Mriga", Kar (2001). Ecologically, *Antilope cervicapra*, a grazer prefers open area and shows remarkable kind of social organization and behaviour scrutinizes through the course of evolution. The study of intraspecific variation in activities can provide insights into the evolution and maintenance of behavior (Kavita, 2005). Aggression has been a

favorite topic of scientific research since the Second World War, since aggressive behaviour is nearly universal among animals, including human being (Bakker, 1986). Agonistic behaviour is defined as "a physical act or threat of action by which one individual, reduce the freedom or genetic fitness of another" (Wilson, 1975). In many species of animal, dispute between individuals are common which express by different types of aggressive display. Also agonistic displays are means of obtaining or retaining a resource (Enquist, 1985). Lorenz (1968) categorized aggression in terms of three main situations in which it may occur : Social or intra-specific aggression, predator aggression and anti-predator aggression.

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Previous ethological study on blackbuck by Dubost and Feer (1980) examined its agonistic behaviour quantitatively but that study was concentrated to the male and in captive condition. A detailed description on the social behaviour of blackbuck presented by Schaller (1967), Nair (1976), Mungall (1978), Srivastava *et al.* (1991) and Chhangani (2006), but quantitative data on agonistic behaviour patterns are limited. The present study describes the variation in social or intra-specific agonistic interaction of blackbuck in according to the age, sex and season.

MATERIALS & METHODS

The study was conducted at Proposed Community Reserve, Ganjam district, Orissa, India, a semi-natural habitat around local community. The habitat is predominantly open grassland (25%), woodland (10%) and cultivated land (65%) and the climate is dry-deciduous. Topographically the area is undulating with scattered hills ranging an elevation from 200-350 msl. Field observations were conducted from November 2004 to December 2006, 6-8 days per month with 200 h of observations. Binocular were used for identification of the individual and for observation of behaviour patterns. More than 10 groups and 12 territorial males were identified as individual through natural marking such as broken horn, numbers of spiral in horn and face coloration when present. Observation for a single group of blackbuck was continuously from 1 h to 6 h. Most data were collected all hours between 6 : 00 to 18 : 00 h.

Agonistic behaviour was sampled by scan sampling method (Altman, 1974) and when interaction were recorded also noting the time of occurrence, sex, relative size and identity of both the individual that initiated the interaction and the recipient. Three sex classes of participants in agonistic encounter are considered 1) encounter between males (male-male) 2) encounter between females (female-female) 3) encounter between male and female (male-female), Koutnik (1981).

RESULTS

Agonistic behaviour is that associated with conflict and fighting between two conspecific, and includes patterns of threat, fighting and submission (Scott and Fredericson, 1951). Agonistic behaviour in the strict sense i.e., fight, threat and chase according to different social status of the individual of the species. This behaviour patterns are obviously important for social life of the species (Walther, 1978). Most of the agonistic behaviour patterns under discussion are considerably differed in frequencies and degree of aggressiveness between social classes, age classes and in season. An ethogram of aggressive display classified according to Dubost and Feer (1980) were observed in the blackbuck in the study area is presented below :

1. **Walk towards (WT)** : approach movement served as a threat.
2. **Body push (BP)** : the signaler approached the recipient from behind and pushed its body
3. **Forcing to stand up (FS)** : refers to an animal force another to stand up by simply approaching in a certain posture like threatening with ears, presenting horns from the front or rear, or giving the light tap with the horns on the head, horns or rump.
4. **Supplanting (S)** : an animal attaches itself to another of inferior rank and follow it relentlessly at a normal walk or dominance display, thereby forcing it to continually yield in front of him. The animal followed is unable to stop and walk or circle among the herd, with tail down and head and ears raised.
5. **Dominance display (DD)** : the animal displaying dominance in the herd, drops his ears vertically as in threat, and hold his tail curled over his back. His body is straight, head raised; chin horizontal and pre-orbital gland open.
6. **Ear threat (ET)** : refers to letting the ears hang down on the side of the neck. This display an individual forces another to

move aside, or to stand up. By this display mother defending their young, are especially common, as in other ruminants.

7. **Horn or frontal threat (HT)** : the animal presents its horns towards the recipient as a ritualized intension movement for fighting.
8. **Charge (Cg)** : it is a violent and rapid threat designed to drive a conspecific away, consist of rushing at an opponent with horn ready to hit. It was found frequently in mixed herd and mostly in territorial males towards the same or opposite sex of any age classes.
9. **Butting (B)** : an individual drive off a rival or make her stand up with lowered ear butt another on her side or shoulder. It was very common in females of all ages and younger bachelor males.
10. **Sparring (Sp)** : refers, head to head pushing, without any mutual harm. It was very common among the individuals of bachelor males. Sparring between adult male was much longer and more violent.
11. **Fight (F)** : refers to any kind of horn contact between the opponents. This is

quite frequent between territorial and bachelor male, while less frequent in between females. It was observed that the reciprocal threat leads to fight.

12. **Chasing (Ch)** : when one individual run towards another individual and the challenged animal flees drawing pursuit from the aggressor. Also occurs at the end of fight when one of the two opponents is defeated and has turned for flight. It very mostly initiated by territorial male chase the other adult male, younger bachelor male and sometime sub-adult female of the mixed herd.

The frequency of above all observed aggressive interaction varied upon the sex of the participant (Fig. 1). The overall frequency of agonistic interactions challenged by male was more then five times greater then that of the interactions challenged by female, a significantly higher frequency. The frequencies of male-male agonistic interaction were 52% of total interaction observed in the study period, and are frequent with most dangerous. Among the agonistic behaviour dominance display (16%), threats (18.31%) and chasing (20%) are very common in between males, while walk towards (18%) and body push (42%) are very common among females. Agonistic behaviour like walk towards (15%), supplanting (12%),

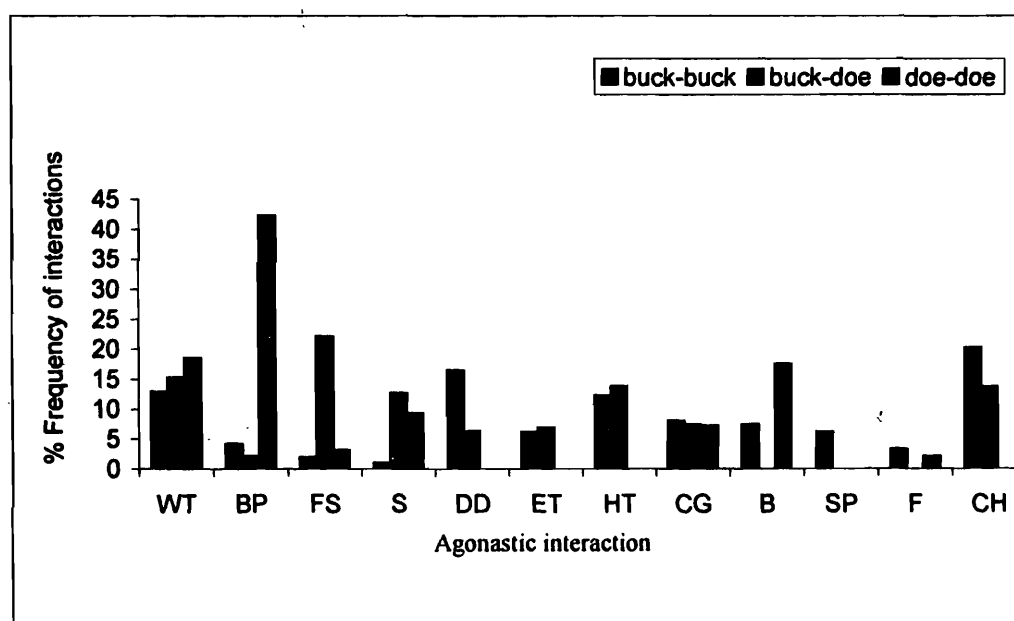


Fig. 1. Showing frequencies of agonistic interaction between individual of different sex of Blackbuck at Ganjam, Orissa, India.

threats (20%) and chasing (13%) were common in between male and female. The frequency of agonistic interaction changed markedly throughout the year (Fig. 2) and differed between the sexes. The monthly mean of agonistic interaction of male-male was 25.9% (S.D. = 15.08), male-female 15.83% (S.D. = 7.58) and female-female was 8.08% (S.D. = 2.63). The frequency of aggressive encounters initiated by males and directed towards females was low throughout the year. The average agonistic behaviour initiated by male were varied (Fig. 3) and maximum in winter (40.3%) i.e. pre-rut period and progress towards rut period and least in the summer (24.6%).

DISCUSSION

The agonistic behaviour enforces the maintenance of individual distance, especially among females, function in the establishment and maintenance of territories in case of male and co-ordination of group activities (Walther, 1974). *Antelope cervicapra* is a social species and its whole life is passed among conspecific with which it share its space and time. The activities of the members of a herd are highly synchronized, a characteristic of many other gregarious species (Dubost & Feer, 1980).

The differences in frequency of agonistic interaction in different seasons depends upon the food availability, food quality, rut period and establishment of territories by males. Also the present study area is a semi-natural habitat and most of the parts are cultivated land so factors like public interference by involvement in agricultural activities influences on the social behaviour and on the seasonal variation on agonistic interaction. As a result in the monsoon season most of the blackbuck population drive away towards the small pockets of grassland and due to this the frequency of agonistic interaction increases because of food competition by population pressure. However, when the agricultural activities over in the month of December i.e. pre-rut season, the frequency and degree of agonistics interaction increases significantly among males.

Blackbuck agonistic behaviour closely associated with social organization. Most of the encounter between individual are on same age, sex or social class. As there is different type of social organization and herd so unequal intensity and frequency of encounters between members of the herd. In cases where the herd is composed of one age class, there is minimum chance of encounter with individuals of other

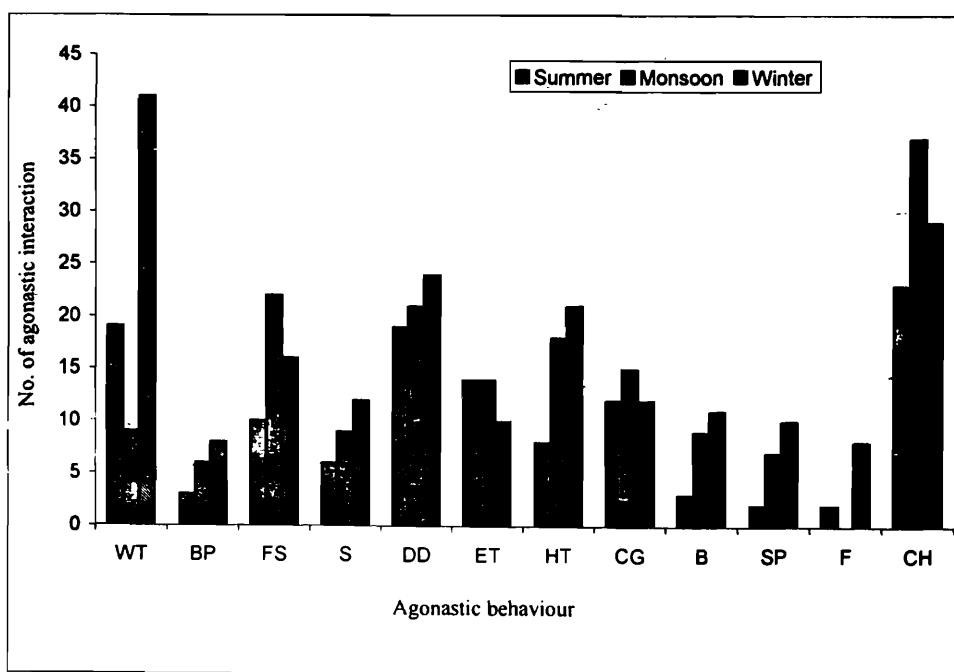


Fig. 2. Seasonal variation in the frequencies of agonistic interaction challenged by buck in Ganjam district, Orissa, India.

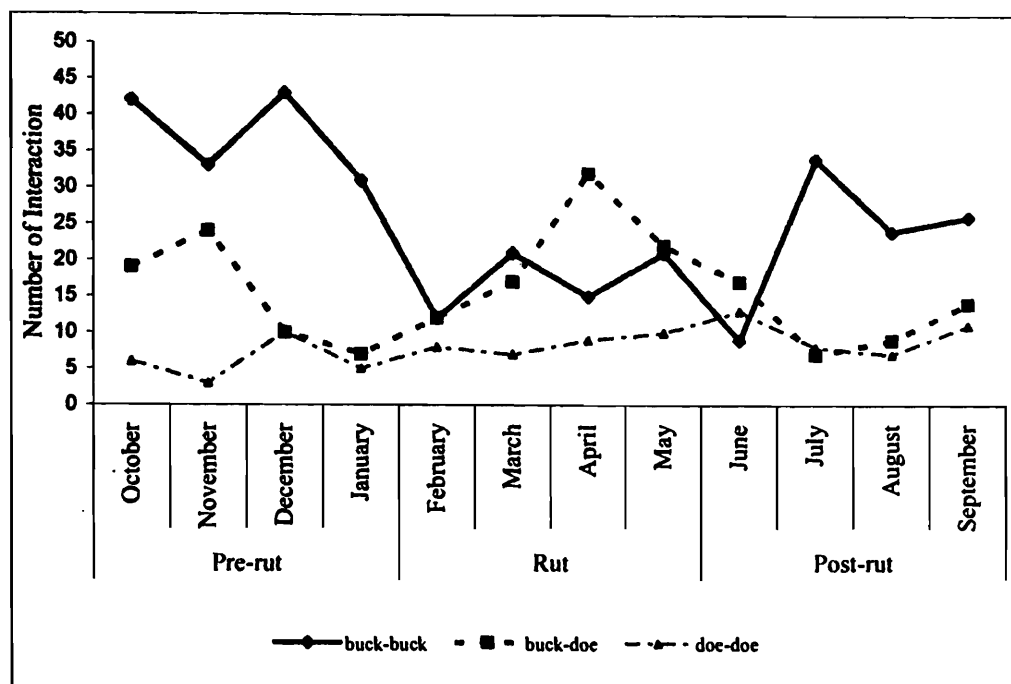


Fig. 3. Seasonal variation in agonistic interaction of Blackbuck (*Antelope cervicapra*) at semi-natural habitat of Ganjam district, Orissa, India.

classes like in female herd. However bachelor herds containing males of several ages there is a maximum chance for the encounter between individuals of equal ages. This type of encounters found in other ungulates like *Axis axis* (Schaller, 1967). Certain agonistic displays like fight, chase, charge and butting are mostly found among the same age classes are less frequent but more aggressive while others agonistic display found among different age classes are more frequent but less aggressive.

Blackbucks live in herds comprising an old male and several females and fawns, while younger males stay away avoiding competition with the old ones, but as the breeding season approaches, the males form bachelor groups interacted aggressively to defend a territory individually (Mungall, 1978; Nocon, 1999). Adult males are highly territorial in nature and there territories are adjacent so the male-male interactions are very frequent possibly due to holding the ownership of the areas, which are rich in term of food resources, and female groups graze through these territories. The more frequent and high degree of agonistic interaction by intra sexual competition in males is possibly due to high reproductive success which monopolies all the females of the herd (Srivastava and Srivastava, 1991) which is

supported by the present result that the agonistic interaction challenged by males are increase in pre-rut season. But the male-male interaction decreases in rutting season possibly due to development of tolerance during the breeding season. It was observed that well-established males tended to fight less with males on adjacent territories then with new comers trying to find a territory. The other bucks without territories, and young males, form their own all male groups and are less interacted except the fight. Youngster is placed at the bottom of the social hierarchy, which gives him a particular social role typified by few agonistic interactions (Dubost and Feer, 1980).

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LITERATURE CITED

- ALTMANN, J. 1974. Observational study of behaviour : sampling methods. *Behaviour*, **49** : 227-267.
- BAKKER, T. C. M. 1986. Aggressiveness in sticklebacks (*Gasterosteus aculeatus* L.) : a behaviour-Genetic study. *Behaviour*, **98** : 1-144.
- CHHANGANI, A. K. 2006. Ecology and socio-behaviour of Blackbuck (*Antilope cervicapra*) in Thar Desert. *Cheetal*, **42**(3&4) : 19-21.
- DUBOST, G. and F, F. 1980. The behaviour of the male *Antilope cervicapra* Linn., Its development according to age and social rank. *Behaviour*, **76** : 62-126.
- ENQUIST, M. 1985. Communication during aggressive interactions with particular reference to variation in choice of behaviour. *Anim. Behv.*, **33** : 1152-1161.
- JARMON, P. T. 1974. The social organization of Antelope in relation to the ecology. *Behaviour*, **46** : 215-266.
- KAR, S. 2001. Balipadar's Blackbuck (an insight into myth and reality of human-blackbuck). Wildlife wing, Forest Department, Govt. of Orissa Publ., Bhubaneshwar; Nov. 2001.
- KAVITA, I. 2005. Female grouping best predicts lekking in blackbuck (*Antilope cervicapra*). *Behavioral Ecology and Sociobiology*, **57**(3) : 283-294
- KOUTNIK, L. D. 1981. Sex-related difference in the seasonality of agonistic behaviour in mule deer. *J. Mamm.*, **62**(1) : 1-11.
- LORENZ, K. 1966. On aggression. Harcourt, Brace and world, New York.
- MUNGALL, E. C. 1978. The Indian Blackbuck, antelope : a Texas view. Kleberg studies in Natural Resources, College Station, TX, No. 3, 184 pp.
- NAIR, S.S. 1976. A population survey and observation on the behaviour of the Blackbuck in the, Point Calimere Sanctuary. *J. Bomb. Nat. Hist. Soc.*, **73**(2) : 304-310.
- NOCON, W. 1999. "*Antilope cervicapra*" (On-line), Animal Diversity Web. Accessed December 17, 2006 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Antilope_cervicapra.html.
- PRATER, S. H. 1971. The book of Indian Animals. Bombay Natural History Society, Oxford University Press, Bombay, 3rd ed. : 270-271.
- SCHALLER, G. B. 1967. The deer and tiger. Chicago University Press. Chicago
- Scott, J. P., Fredericson, L. E. 1951. The case of fighting in mice and rats. *Physiol. Zool.*, **24** : 273-309.
- SRIVASTAVA, A. and SRIVASTAVA, M., 1991. Some aspect of ecology and social behaviour of Blackbuck (*Antilope cervicapra*) around Luni basin. *Geobios*, **18** : 64-68.
- WALTHER, F. R. 1978. Quantitative and functional variations of creation behaviour patterns in male Thomson's gazelle of different social status. *Behaviour*, **65** : 212-240.
- WILSON, E. O. 1975. Sociability a new synthesis—the Belknap press of Harvard Uni. Press, Cambridge, Mass.
- WALTHER, F. R. 1974. Some reflection on expression of behaviour in combats and courtship of horned ungulates. In : *The behaviour of ungulates and its relation to management* (Ed. by V. Giest & F. Walther), pp. 56-106. Morges, Switzerland. IUCN Publications new series, No. 24.

ECOLOGICAL STUDY OF ROTIFERA AND ITS APPLICATION FOR BIOMONITORING OF FRESHWATER RIVERINE ENVIRONMENT OF SOUTH WEST BENGAL, INDIA

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ABSTRACT

Environmental monitoring is meant for programmed process of measurement and collection of information about the existing status of environment and can be done by physicochemical and biological methods. Physicochemical monitoring deals with quantitative estimation of physical and chemical parameters of environment. On the other hand, employing of biological parameters for assessing environmental perturbation is termed as biomonitoring. It has been emphasized that the nature and degree of pollution of any water body may be judged from the occurrence, abundance and composition of the inhabiting organisms. The use of indicator organisms in the assessment of water quality depends upon a in-depth knowledge of the ecological tolerance of the concerned organisms. A biological indicator representing a useful biological measure is sensitive enough and can be used for diagnosis, control, prevention and reclamation. Rotifera, being an important faunal components of freshwater lotic as well as lentic zooplanktonic community, have attracted attention of several workers globally, with reference to their significance as bio-indicators of water quality, and also as an indicator of saprobity. In the present study, all total 46 species of Rotifera were recorded from 9 study sites in some freshwater riverine systems of South West Bengal viz. Dwarkeswar, Shilabati and Kansai. The temporal and spatial distribution patterns were studied in relation to major ecological parameters pertaining to riverine ecosystem. All the documented rotifera species were categorized as per the established scheme for bioindicator species viz. eutrophic species; oligotrophic species; acidophilic species; mixohaline species; alkaline mesotrophic species; taxa preferring special water; temperate species; worm stenothermal species; cold stenothermal species and eurythermal species. The physicochemical parameters of different study sites where the rotiferan bioindicator species inhabit were compared with the international standards for permissible limit to find out the relationship between the intensity of pollution and occurrence of rotifers.

Keywords : Biomonitoring, freshwater, river, Rotifera

INTRODUCTION

Detection of pollution status by physicochemical ways is not always easy but sometimes it appears to be very expensive. According to International Organization for Standardization (ISO), environmental monitoring is meant for programmed process for measurement and collection of information about the existing status of environment and can be done by physicochemical and biological methods. Physicochemical monitoring deals

with quantitative estimation of physical and chemical parameters of environment. On the other hand, employing of biological parameters for assessing environmental perturbation is termed as biomonitoring (Bartram and Helmer, 1996). Biomonitoring, by biological agent has now become a growing subject for research to assess pollution. Biological monitoring is an integral part of water quality monitoring. It however, includes two categories; i) The bioassays (early warning or alarm systems,

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ecotoxicological tests, bioaccumulation tests, eutrophication tests); and ii) bio-assessments (analysis of the biological communities). The former are experimental and the later are observational in approach. Both in turn, are linked to the choice of environmental policy makers concerning the updating of "water quality criteria" and "effluent standards". Biomonitoring or application of biological variables in environmental monitoring activities has often resulted in different interpretations relating to 'biological variables' and caused a lot of confusion on 'activities' relating to this aspects (Zwart and Trivedi, 1994). A biological indicator is meant to give a useful biological measure, which is sensitive enough and can be used for diagnosis, control, prevention and reclamation (Ghetti and Revera, 1994). It has been emphasized that the nature and degree of pollution of any water body may be judged from the occurrence, abundance and composition of the inhabiting particular biotic organisms. The use of indicator organism requires a knowledge of the ecological tolerance and requirements of acute and chronic pollutants (Gaufin and Gaufin, 1966). The presence of certain species, with information on associations or groups, is a relatively reliable indication that pollution has not exceeded to a threshold limit during their life cycle within a given reach (Wilhm, 1975).

Zooplankton species successions and spatial distributions are results of differences in ecological tolerance to various abiotic and biotic environmental parameters. Among different zooplankton, due to high population turnover rates, rotifers are particularly sensitive to changes in water quality. Their community structure not only allows estimates of the level of pollution, but also can indicate the trend of general conditions over time (Sladeczek, 1983). Different putrescible organic matter are decomposed by aquatic microorganisms forming different biotic communities in the aquatic ecosystem. These organisms have been named as saprobes and water quality could be categorized as per saprobity (Datta, 2001). Rotifera comprised of an important faunal component of littoral and limnetic invertebrate

communities in freshwater environments. Rotifera has been considered as good indicators of saprobity (= organic pollution manifested in BOD₅, dissolved oxygen content and specific communities of indicator species). They have attracted attention of several workers globally, notably those of Hakkari (1972), Radwan (1976), Fuller *et al.* (1977), Donner (1978), Gannon and Stemberger (1978), Pejler (1981, 1983), Karabin (1983), Maemets (1983) and Sladeczek (1983), with regard to their significance as bioindicators of water quality, trophic status and environmental toxicity studies.

In fact, Rotifera were first used as indicators by Kolkwitz and Marsson (1902, 1909). Kolkwitz and Marsson (1902) set up "Saprobien system" to define the quality of surface waters mainly on the presence of indicator species belonging to the plankton and periphyton community. In fact, this system is still the basis for a series of biological indices (De Pauw *et al.*, 1992).

Subsequently Kolkwitz (1935) listed some species as polysaprobic, alpha mesosaprobic, beta-mesosaprobic and oligosaprobic. Wetzel (1959) listed two polysaprobic, one beta-mesosaprobic and four oligosaprobic species. Sladeczek (1983) provided an excellent account of 625 species of Rotatoria found in Czechoslovakia as indicators of water quality with remarks on saprobity, saprobic valence, indicative weight of different species, saprobic index and pollution. In addition, other valuable contributions dealt with the role of Rotifera as bioindicator have been in relation to pH (Berzins and Pejler, 1987), temperature (Berzins and Pejler, 1989a), trophic degree (Berzins and Pejler, 1989b), oxygen content (Berzins and Pejler, 1989c), water color (Berzins and Pejler, 1989d), and substrate and habitat (Pejler and Berzins, 1989, 1993).

Sladeczek (1956) considered 82 species of Rotifera as good indicators. The observations of Indian Rotifera as bio-indicators were initiated as preliminary remarks by Arora (1961, 1966). Since then, this aspect has attracted attention of several workers from this country including useful reports by Arora (1961, 1966); Rao and Mohan (1977); Sampath *et al.* (1979);

Sharma (1986, 1992); Saksena and Kulkarni (1986); Saksena (1987), Sharma and Dudani (1992); Sharma and Naik (1996); and Sharma & Sharma (1999, 2001). In the present study, all total 46 species of Rotifera were recorded from 9 study sites in some freshwater riverine systems of South West Bengal viz. Dwarkeswar, Shilabati and Kansai. The temporal and spatial distribution patterns were studied in relation to major ecological parameters pertaining to riverine ecosystem. All the documented rotifera species were categorized as per the established scheme for bioindicator species viz. eutrophic species; oligotrophic species; acidophilic species; mixohaline species; alkaline mesotrophic species; taxa preferring special water; temperate species; worm stenothermal species; cold stenothermal species and eurythermal species. The physicochemical parameters of different study sites where the rotiferan bioindicator species inhabit were compared with the international standards for permissible limit to tally the intensity of pollution and occurrence of rotifers.

METHODOLOGY

The present investigation has been carried out in three rivers viz. Dwarkeswar, Shilabati and Kansai of South West Bengal during July 2001 to June 2003. In Dwarkeswar river, the study site-1 is situated at Rajgram, upstream to Bankura municipality (23°17'N; 87°10'5"E) and study site-2 was located at Ekteswar, downstream to Bankura municipality (22°54'N; 87°46'54"E) and study site-3 was located in the Kalipur (near Arambag town) (22°54'N; 87°56'43"E). In river Shilabati, study site-4 (22°54'N; 87°12'E) was located near Garbeta subdivision, study site-5 (22°40'N 87°40'21"E) was situated near Ghatal municipality and study site-6 was situated near Bandar, (22°42'N; 87°49'5"E) 4 miles down to the Ghatal municipality. In the river Kansai, study site-7 was situated near Dherua (22°26'N; 87°12'E), study site-8 was situated near Midnapore municipality (22°26'30"N; 87°15'E) and study site-9, was situated 12 miles below Midnapore town, near Pathra (22°28'N; 87°37'5"E)(Fig. 1 of West Bengal).

The rotiferan as well as other zooplankton samples were collected at an monthly intervals during 8 a.m. to 10 a.m. from July 2001 to June 2003 from 9 study sites of three rivers. Zooplankton samples were randomly collected by filtering 100 liters of water through the bolting nylon cloth (No. 25, mesh size 54 m) and were preserved in 5% buffered formalin (APHA, 1995). The zooplankton species have been identified following Sharma 2001; Needham and Needham, 1962; Edmondson, 1959 and Battish, 1992. The number of the rotifers were counted under Phase Contrast Microscope (Model No.-Carl Zeiss, Germany-912311) using "Sedgwick Rafter Cell" and the values were expressed in Number per liter (No./L). Collected water samples were analyzed following standard methods (APHA, 1995; Trivedy and Goel, 1984). Some additional analyses like - index of dominance (Simpson, 1949), species richness index or variety indices (Menhinick, 1964), Shannon species diversity index (Shannon and Weaver, 1949) and species evenness index (Pielou, 1966) were also computed. On the basis of observation of diversity index (Table -7), the range of polluted and unpolluted streams were categorized as three undermentioned categories (Wilhm and Dorris, 1968).

$\bar{H}$ (Shannon index of diversity)	Condition of water
> 3	clean water
1 – 3	moderately polluted
<1	heavily polluted

RESULTS AND DISCUSSION

All total 46 species of Rotifera belonging to two (2) orders, eleven (11) families and fifteen (15) genera have been found (Table 1). The results of different physicochemical parameters have been shown in Table 2. The zooplankton productivity of a river is proportional to the age of its water and inversely proportional to its current (Reinhard, 1931; Eddy, 1934). In the present study, the Rotifera population registered a highly significant inverse

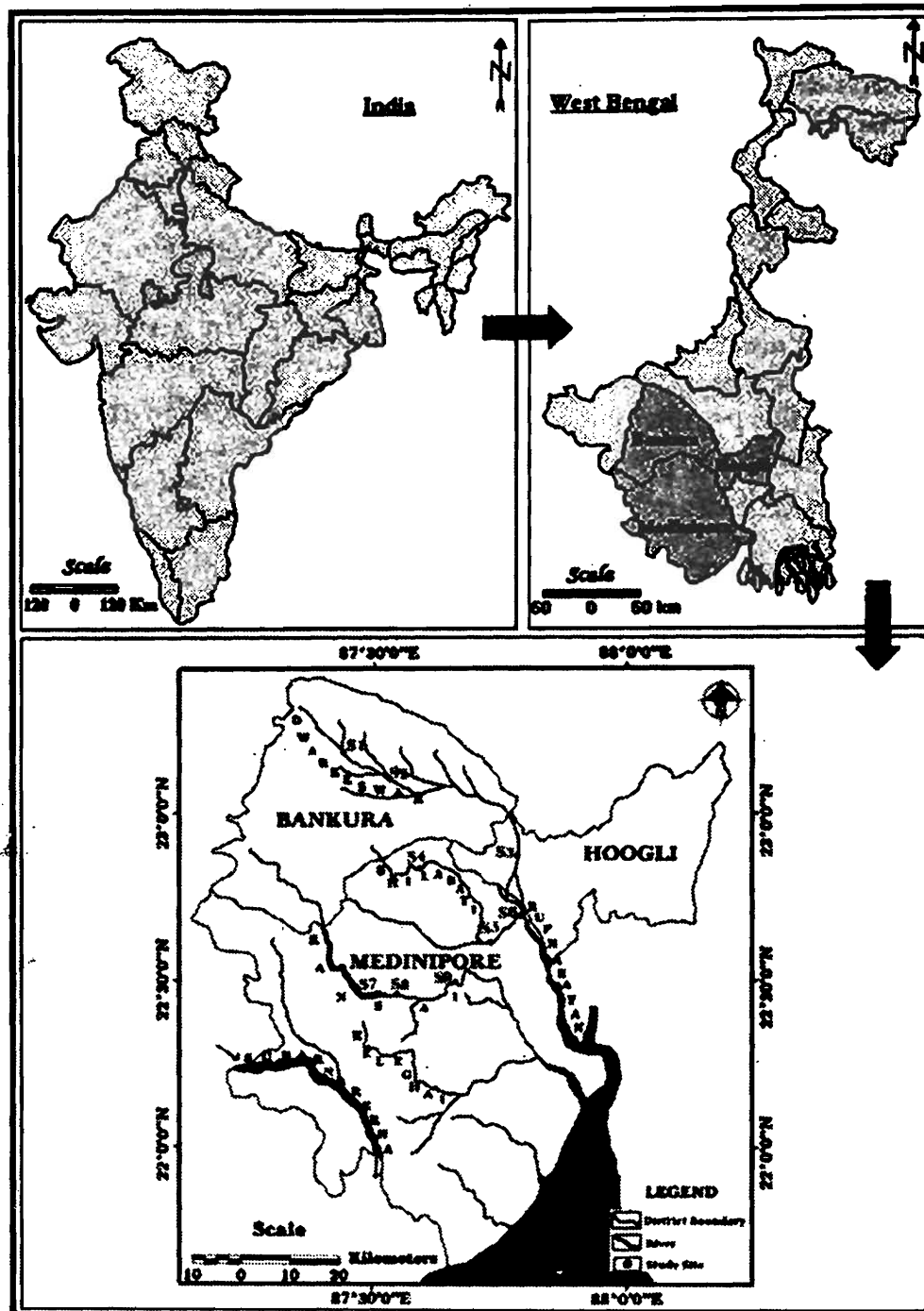


Fig. 1. Location map of the study sties

relationship with water current ($r = -0.931; -0.954; -0.893; -0.867; -0.544; -0.626; -0.828; -0.755$ and -0.844) for the nine study sites (study site-1 to study site-9) respectively which corroborated the findings with Reinhard, 1931; and Eddy, 1934 (Table 3,4 and 5). Hofmann (1977) opined that temperature exerts a significant influence on population dynamics of rotifer not only because of its direct control on embryonic development but also because, it

is an important characteristic of the determinative situation of the environment. In the present study, temperature ranged from 16°C – 36°C at 9 study sites of three rivers, which were neither extreme cold nor excess hot and that's why here temperature did have little effect on rotifer population. The correlation between Rotifera and temperature showed positive relationship ($r = 0.364; 0.243; 0.372; 0.339; 0.301; 0.361; 0.15; 0.23$ and 0.22) for the

Table-1. Occurrence and distribution of different rotifer species at nine study sites (study site 1 to 9) of three rivers during the study period (July, 2001 to June, 2003).

S. No.	Family and Species	Dwarkeswar			Silabati			Kansai		
		S1	S2	S3	S4	S5	S6	S7	S8	S9
	Phylum ROTIFERA									
	Super class EUROTATORIA Bartos, 1959									
	Class MONOGONONTA Wesenberg-Lund, 1889									
	Order PLOIMIDA Delage, 1897									
	Family ASPLANCHNIDAE Haring and Myers, 1926									
1	<i>Asplanchna priodonta</i> Gosse, 1850	+	+	+	+	+	+	+	+	+
	Family BRACHIONIDAE Wesenberg-Lund, 1899									
2	<i>Brachionus angularis</i> Gosse, 1851	+	+	+	+	+	+	+	+	+
3	<i>B. bidentata bidentata</i> Anderson, 1889	+		+						
4	<i>B. bidentata jirovci</i> (Bartos, 1964)	+	+	+	+	+	+	+		+
5	<i>B. calyciflorus f. amphiceros</i>	+	+	+						
6	<i>B. calyciflorus f. anuraeiformis</i> (Brehm, 1909)	+	+	+				+	+	+
7	<i>B. calyciflorus f. borgerti</i> (Apstein, 1907)	+	+	+						
8	<i>B. calyciflorus f. dorcus</i> (Gosse, 1851)	+	+	+						
9	<i>B. caudatus personatus</i> (Ahlstrom, 1940)	+	+	+	+	+	+	+	+	+
10	<i>B. falcatus</i> Zacharias, 1893	+	+	+	+	+	+	+	+	+
11	<i>B. forficula minor</i> (Voronkov 1913)					+	+	+	+	+
12	<i>B. patulus patulus</i> Muller, 1776	+	+	+	+	+	+		+	+
13	<i>B. quadridentatus brevispinus</i> (Ehrenberg, 1832)	+	+	+						
14	<i>B. quadridentatus quadridentatus</i> Hermann, 1783	+	+	+	+	+	+			
15	<i>B. quadridentatus rhenanus</i> (Lauterborn, 1893)	+	+	+		+	+	+		+
16	<i>B. rubens</i> Ehrenberg, 1838	+	+	+	+	+	+	+	+	+
17	<i>Keratella cochlearis</i> (Gosse, 1851)	+	+	+	+	+	+			
18	<i>Keratella tropica</i> Apstein, 1907	+	+	+	+	+	+	+	+	+
19	<i>Platylabus quadricornis</i> (Ehrenberg, 1838)				+		+		+	+
	Family COLURELLIDAE Bartos, 1959									
20	<i>Colurella uncinata</i> (Muller, 1773)	+	+	+	+	+	+			
21	<i>Lepadella (Lepadella) ovalis ovalis</i> (Muller, 1786)	+		+						
	Family EUCHLANIDAE Bartos, 1959									
22	<i>Beauchampiella eudactylota</i> (Gosse, 1886)				+	+	+		+	+
23	<i>Euchlanis dilatata</i> Ehrenberg, 1832	+	+	+	+	+	+			
	Family LECANIDAE Bartos, 1959									
24	<i>Lecane (Lecane) crepida crepida</i> Haring, 1914				+		+		+	

Table-1. Contd.

S. No.	Family and Species	Dwarkeswar			Silabati			Kansai		
		S1	S2	S3	S4	S5	S6	S7	S8	S9
25	<i>L. (L) curvicornis curvicornis</i> (Murray, 1913)	+		+						
26	<i>L. (L) hastata</i> (Murray, 1913)		+	+						-
27	<i>L. (L) hornemanni</i> (Ehrenberg, 1834)		+							
28	<i>L. (L) leontina</i> (Turner, 1892)	+	+	+	+	+	+	+	+	+
29	<i>L. (L) luna luna</i> (Mullar, 1773)		+							
30	<i>L. (L) nana</i> (Murray, 1913)	+	+	+	+	+	+	+	+	
	Family: LECANIDAE Bartos, 1959									
31	<i>L. (L) papuana</i> (Murray, 1913)	+	+	+	+	+	+	+	+	+
32	<i>L.(L) ungulata</i> (Gosse, 1887)	+	+	+	+	+	+	+	+	+
33	<i>Lecane (Monostyla) bulla</i> (Gosse, 1851)	+	+	+	+	+	+	+	+	+
34	<i>L. (M) decipiens</i> (Murray, 1913)	+		+						
35	<i>L. (M) hamata</i> (Stokes, 1896)	+		+						-
36	<i>L.(M) lunaris lunaris</i> (Ehrenberg, 1830)	+	+	+		+	+	+	+	+
37	<i>L. (M) pyriformis</i> (Daday, 1905)	+	+	+	+	+		+	+	+
38	<i>L. (M) stenroosi</i> (Meissner, 1908)	+	+	+	+		+	+	+	+
	Family NOTOMMATIDAE Remane, 1933									
39	<i>Cephalodella gibba</i> (Ehrenberg, 1832)	+	+	+						
	Family SYNCHAETIDAE Remane, 1933									
40	<i>Polyarthra vulgaris</i> Carlin, 1943	+	+	+	+	+	+	+	+	+
	Family TRICHOCERCIDAE Remane, 1933									
41	<i>Trichocerca(Trichocerca) elongata braziliensis</i> (Murray, 1913)	+	+	+	+					
42	<i>T. (T) rattus</i> (Muller, 1776)	+	+	+	+	+				
	Family TRICHOTRIDAE Bartos, 1959									
43	<i>Trichotria tetractis</i> (Ehrenberg, 1832)			+	+					
	Order GNESIOTROCHA De Beauchamp, 1965									
	Family TESTUDINELLIDAE Bartos, 1959									
44	<i>Pompholyx sulcata</i> Hudson, 1885								+	
	Family FILINIDAE Bartos, 1959									
45	<i>Filinia longiseta</i> (Ehrenberg, 1834)	+	+	+	+	+	+	+	+	+
46	<i>F. terminalis</i> (Plate, 1886)	+	+	+	+		+	+	+	+

nine study sites (study site-1 to study site-9) respectively (Table 3,4 and 5). The pH governed the distribution, transport and fate of heavy metals in an aquatic system (Whitton and Say, 1975). The alkaline pH was favorable for the growth of aquatic vegetation (Westlake, 1975). Comparatively lower pH during summer months was supposed to be due to higher decomposition activities of organic matter coupled with higher temperature and lower

water depth. In the present study, pH did not show any definite seasonal trend and pH values ranged from 6.1 to 7.9, and thus in most cases, it remained to either in acidic or in alkaline range and Rotifera expressed both significant and insignificant direct and indirect correlation with pH as revealed from correlation coefficient analysis (Table-3,4 and 5). According to Berzines and Pejler, 1987, pH had no direct effect on rotifers even though it appeared to be as an

Table-2. Mean SE and range of different physicochemical parameters of waters at study sites S1 to S9 of three rivers during study period.

		Dwarkeswar			Shilabati			Kansai		
		S1	S2	S3	S4	S5	S6	S7	S8	S9
Sl. No.	Physicochemical parameters	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range	Mean $\pm$ SE Range
1	Water Current (cm/min)	44.71 $\pm$ 4.87 8.00-82.00	42.88 $\pm$ 5.03 5.00-81.00	44.25 $\pm$ 5.24 7.00-88.00	40.58 $\pm$ 3.11 16.00-71.00	42.38 $\pm$ 2.45 28.00-68.00	39.08 $\pm$ 2.32 28.00-65.00	42.83 $\pm$ 5.76 7.00-89.00	42.00 $\pm$ 5.40 8.00-83.00	39.08 $\pm$ 5.09 7.00-80.00
2	Water Temp.(°C)	27.85 $\pm$ 1.10 16.50-34.00	27.38 $\pm$ 1.03 16.00-34.00	27.17 $\pm$ 1.04 16.00-35.00	27.92 $\pm$ 1.05 16.00-35.00	27.42 $\pm$ 1.03 17.00-32.50	27.13 $\pm$ 0.98 17.00-32.00	27.13 $\pm$ 0.99 18.00-33.00	28.23 $\pm$ 1.06 17.00-36.00	27.42 $\pm$ 0.98 18.00-34.00
3	pH	7.09 $\pm$ 0.07 6.50-7.50	7.17 $\pm$ 0.08 6.50-7.80	7.10 $\pm$ 0.03 6.80-7.40	7.04 $\pm$ 0.09 6.10-7.90	7.14 $\pm$ 0.08 6.50-7.85	7.03 $\pm$ 0.04 6.70-7.40	7.18 $\pm$ 0.06 6.70-7.90	7.09 $\pm$ 0.08 6.40-7.90	7.04 $\pm$ 0.03 6.60-7.30
4	Alkalinity (mg/l)	108.51 $\pm$ 10.20 50.00-185.0	102.58 $\pm$ 15.16 35.00-320.0	83.75 $\pm$ 7.98 35.00-180.0	57.50 $\pm$ 2.74 35.00-85.00	59.38 $\pm$ 3.60 30.00-95.00	56.67 $\pm$ 3.32 35.00-85.00	59.79 $\pm$ 2.24 45.00-80.00	66.46 $\pm$ 2.42 40.00-90.00	63.33 $\pm$ 1.82 45.00-80.00
5	D.O.(mg/l)	7.17 $\pm$ 0.38 4.18-10.54	7.96 $\pm$ 0.46 4.04-12.97	6.90 $\pm$ 0.23 4.25-9.25	7.62 $\pm$ 0.29 4.46-9.93	7.77 $\pm$ 0.37 5.20-11.35	7.42 $\pm$ 0.30 4.65-9.58	7.60 $\pm$ 0.34 4.86-10.40	8.11 $\pm$ 0.31 5.43-10.40	7.93 $\pm$ 0.23 6.28-9.58
6	B.O.D.(mg/l)	2.53 $\pm$ 0.20 0.73-4.46	2.61 $\pm$ 0.27 1.15-6.89	2.20 $\pm$ 0.16 1.25-3.25	1.48 $\pm$ 0.17 0.13-3.24	1.68 $\pm$ 0.17 0.12-3.25	1.68 $\pm$ 0.21 0.28 -3.56	1.98 $\pm$ 0.13 1.21-3.24	2.00 $\pm$ 0.16 0.43-3.25	1.49 $\pm$ 0.10 0.75-2.56
7	Total Kjeldahl Nitrogen(mg/l)	2.83 $\pm$ 0.40 0.28 7.29	3.18 $\pm$ 0.56 0.29 9.18	1.93 $\pm$ 0.28 0.14 4.35	2.83 $\pm$ 0.48 0.53 -9.35	2.61 $\pm$ 0.46 0.41 -10.50	1.69 $\pm$ 0.19 0.45 -3.50	1.79 $\pm$ 0.28 0.28 -4.66	3.25 $\pm$ 0.62 0.43 -14.87	1.70 $\pm$ 0.22 0.25 -4.40
8	Total Phosphate Phosphorus (mg/l)	0.37 $\pm$ 0.08 0.06 1.41	0.62 $\pm$ 0.16 0.01 - 3.79	0.26 $\pm$ 0.06 0.01 1.25	0.34 $\pm$ 0.10 0.002 -1.85	0.34 $\pm$ 0.08 0.004 -1.21	0.22 $\pm$ 0.08 0.001 -1.45	0.24 $\pm$ 0.05 0.02 -1.03	0.28 $\pm$ 1.61 0.02 -0.96	0.11 $\pm$ 0.01 0.01 -0.24

Table-3. Correlation between different groups of zooplankton and physicochemical parameters at study site -1 to study site-3 in Dwarkeswar river during the study period.

	Study site-1				Study site-2			Study site-3	
	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda
Water Current	-0.931**	-0.932**	-0.737**	-0.954**	-0.796**	-0.820**	-0.893**	-0.764**	-0.724**
Temp.	0.364	0.263	0.218	0.243	0.165	0.155	0.372	0.26	0.226
pH	-0.314	-0.498*	-0.382	0.224	-0.047	0.317	0.166	0.154	0.136
Alkalinity	0.450*	0.286	0.353	0.355	0.227	0.477*	0.269	0.27	0.145
D.O.	-0.271	-0.173	-0.148	-0.238	-0.171	0.114	-0.222	-0.251	-0.022
B.O.D.	-0.309	-0.419*	-0.452**	-0.134	-0.06	-0.085	-0.242	-0.029	-0.085
Total Kjeldahl Nitrogen	0.067	-0.091	-0.038	0.19	0.212	0.263	0.19	0.17	0.066
Total Phosphate Phosphorus	0.603**	0.507*	0.115	0.488*	0.321	0.433*	0.681**	0.467*	0.256

** Correlation is significant at the 0.01level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table-4. Correlation between different groups of zooplankton and physicochemical parameters at study site -4 to study site-6 in Shilabati river during the study period

	Study site-5			Study site-6			Study site-7		
	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda
Water Current	-0.867**	-0.869**	-0.683**	-0.544**	-0.805**	-0.588**	-0.626**	-0.618**	-0.473*
Temp.	0.339	-0.032	-0.112	0.301	-0.28	0.034	0.361	-0.106	-0.018
pH	0.624**	0.222	0.233	0.732**	0.304	0.556**	0.550**	0.16	0.029
Alkalinity	0.685**	0.393	0.312	0.600**	-0.072	0.480*	0.717**	0.037	0.352
D.O.	-0.501*	-0.169	-0.062	-0.326	0.251	-0.127	-0.248	0.026	-0.412
B.O.D.	0.3	-0.009	0.009	0.235	-0.217	0.069	0.104	0.157	0.303
Total Kjeldahl Nitrogen	-0.071	0.194	0.347	-0.002	0.237	0.135	-0.059	0.21	0.061
Total Phosphate Phosphorus	-0.166	-0.262	0.11	0.442*	0.136	0.218	-0.301	-0.155	-0.349

** Correlation is significant at the 0.01level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table-5. Correlation between different groups of zooplankton and physicochemical parameters at study site-7 to study site-9 in Kansai river during the study period.

	Study site-7			Study site-8			Study site-9		
	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda
Water Current	-0.828**	-0.781**	-0.554**	-0.755**	-0.776**	-0.38	-0.844**	-0.854**	-0.345
Temp.	0.15	-0.247	-0.236	0.23	0.046	-0.287	0.22	-0.039	-0.232
pH	0.393	0.087	0.001	0.314	0.176	-0.269	0.183	0.085	-0.175
Alkalinity	0.618**	0.194	0.021	0.532**	0.264	-0.126	0.529**	0.279	0.211
D.O.	-0.583**	-0.328	-0.204	-0.586**	-0.41	-0.066	-0.182	0.07	0.181
B.O.D.	0.552**	0.252	0.015	0.491*	0.377	-0.012	0.286	0.288	0.006
Total Kjeldahl Nitrogen	0.171	0.355	0.249	-0.192	-0.025	0.082	0.403	0.570**	0.021
Total Phosphate Phosphorus	0.207	0.34	0.389	0.321	0.254	-0.041	-0.133	-0.069	-0.107

** Correlation is significant at the 0.01level (2- tailed)

* Correlation is significant at the 0.05 level (2- tailed)

important parameter in explaining the distribution of different species. Besides, species specific study, it was quite difficult to draw any definite trend between different zooplankton groups and pH. Species wise study of different rotifer species revealed that different species displayed different relationships with pH (Table-6). Alkalinity of the water in its capacity to neutralize a strong acid and is characterized by the presence of all the hydroxyl ions capable of combining with the hydrogen ion. Alkalinity in natural waters is due to free hydroxyl ions and hydrolysis of salts formed by the weak acids and strong bases (Trivedy and Goel, 1984). The number of milliequivalents of acid used in the titration to combine all the hydroxyl ions, is called as total

alkalinity (Trivedy and Goel, 1984). The species with well developed lorica such as *Brachionus* and *Keratella* built higher population during the period when the alkalinity was high (Dhanapathi 2000) but in the present observation, although the water conditions were neither acidic nor alkaline (Table-2), the genus *Brachionus* and *Keratella* exhibited positive relationship with alkalinity. Sharma (1992) stated that the Rotifera fauna of West Bengal included various acidophilic species i.e. *K. cochliaris* and *B. patulus*, whereas, *B. bidentata*, *B. rubens* and *Lecane lunaris* have been regarded by him as alkalophilic element. This study supported the findings of Michael (1968), Nayer, (1970), and Vasisht and Sharma (1976) relating to coincidence of Rotiferan abundance

Table-6. Correlation between different physicochemical parameters with different rotiferan species.

Rotifera species	WC	TEMP	pH	ALKA	DO	BOD	TKN	TPP
1 <i>Asplanchna priodonta</i>	-0.035	-0.652**	-0.387	-0.308	0.611**	-0.179	0.110	0.020
2 <i>Brachionus angularis</i>	-0.479*	0.171	0.157	0.570**	-0.268	0.193	0.122	0.044
3 <i>B.bidentata bidentata</i>	-0.508*	0.262	-0.085	0.212	0.240	0.123	0.109	0.200
4 <i>B.bidentata jirovci</i>	-0.601**	0.339	0.259	0.515*	-0.396	0.139	0.079	0.099
5 <i>B.calyciflorus f. amphiceros</i>	-0.871**	0.420*	-0.085	0.521**	-0.254	-0.355	0.307	0.654**
6 <i>B.calyciflorus f.anuraeiformis</i>	-0.611**	0.295	0.097	0.398	-0.434*	0.028	0.102	0.147
7 <i>B.calyciflorus f.borgerti</i>	-0.749**	0.572**	0.042	0.610**	-0.483*	-0.339	0.412	0.693**
8 <i>B.calyciflorus f.dorcus</i>	-0.773**	-0.035	-0.120	0.086	-0.031	0.045	0.119	0.254
9 <i>B. caudatus personatus</i>	-0.722**	0.332	0.291	0.451*	-0.365	0.218	0.065	0.208
10 <i>B.falcatius</i>	-0.576**	0.322	0.397	0.518**	-0.349	0.135	0.040	0.088
11 <i>B.forficula minor</i>	-0.622**	0.247	0.346	0.448*	-0.233	0.260	-0.009	0.320
12 <i>B. patulus patulus</i>	-0.545**	0.048	-0.066	0.387	-0.105	-0.069	0.247	0.072
13 <i>B. quadridentatus brevispinus</i>	-0.796**	0.557**	0.081	0.519**	-0.503*	-0.381	0.263	0.731**
14 <i>B. quadridentatus quadridentatus</i>	-0.446*	0.165	0.308	0.042	-0.025	-0.190	-0.062	0.097
15 <i>B. quadridentatus rhenanus</i>	-0.459*	-0.298	0.050	0.017	0.169	0.303	-0.006	0.178
16 <i>B. rubens</i>	-0.532**	0.312	0.529**	0.234	-0.263	0.322	-0.140	0.194
17 <i>Keratella cochlearis</i>	-0.328	-0.155	0.353	-0.129	0.130	0.115	-0.192	-0.002
18 <i>Keratella tropica</i>	-0.514*	0.264	0.142	0.624**	-0.339	0.151	0.193	0.110
19 <i>Platyias quadricornis</i>	-0.544**	0.194	0.378	0.334	-0.263	0.191	0.082	0.173
20 <i>Colurella uncinata</i>	-0.613**	0.033	0.140	0.051	0.056	-0.111	0.170	0.097
21 <i>Lepadella (Lepadella) ovalis ovalis</i>	-0.306	0.166	0.282	0.381	0.031	-0.211	0.202	0.214
22 <i>Beauchampiella eudactylota</i>	-0.579**	0.485*	0.687**	0.748**	-0.65**	0.442	-0.139	0.160
23 <i>Euchlanis dilatata</i>	-0.098	-0.81**	-0.52**	-0.381	0.669**	-0.266	0.052	-0.160
24 <i>Lecane(Lecane) crepida crepida</i>	-0.506*	0.259	0.397	0.313	-0.180	0.027	0.073	0.278
25 <i>L. (L) curvicornis curvicornis</i>	-0.621**	0.439*	-0.197	0.448*	-0.237	-0.217	0.332	0.648**
26 <i>L.(L) hastata</i>	-0.281	0.146	-0.395	0.017	-0.161	-0.134	0.000	-0.038

Table 6. Contd.

Rotifera species	WC	TEMP	pH	ALKA	DO	BOD	TKN	TPP
27 <i>L.(L) hornemanni</i>	-0.344	0.198	0.365	0.210	-0.167	-0.139	0.062	0.457*
28 <i>L.(L) leontina</i>	-0.467*	0.330	0.445*	0.073	-0.332	0.058	-0.154	0.098
29 <i>L.(L) luna luna</i>	-0.009	-0.281	0.009	-0.253	0.078	0.045	-0.370	-0.101
30 <i>L.(L) nana</i>	-0.702**	0.235	0.408	0.357	-0.283	0.221	-0.017	0.298
31 <i>L. (L) papuana</i>	-0.518**	0.308	0.330	0.050	-0.307	0.038	-0.072	0.027
32 <i>L.(L) unguolata</i>	-0.516*	0.326	0.487*	0.132	-0.397	0.032	-0.092	0.090
33 <i>Lecane(Monostyla)bulia</i>	-0.490*	0.313	0.476*	0.165	-0.285	0.020	-0.034	0.105
34 <i>L. (M) decipiens</i>	-0.421*	0.230	-0.110	0.095	-0.274	-0.133	0.063	0.419*
35 <i>L. (M) hamata</i>	-0.416	0.341	0.312	0.473*	-0.064	-0.157	0.266	0.855**
36 <i>L.(M) lunaris lunaris</i>	-0.645**	0.245	0.545**	0.162	-0.351	0.297	-0.070	0.208
37 <i>L.(M) pyriformis</i>	-0.654**	0.262	0.274	0.293	-0.357	0.079	0.018	0.151
38 <i>L. (M) stenroosi</i>	-0.624**	0.168	0.097	0.466*	-0.214	0.259	0.185	0.189
39 <i>Cephalodella gibba</i>	-0.802**	0.169	0.096	0.225	0.146	0.115	-0.056	0.504*
40 <i>Polyarthra vulgaris</i>	-0.552**	0.345	0.394	0.099	-0.336	0.111	-0.071	0.398
41 <i>Trichocerca(T) elongata</i> <i>braziliensis</i>	-0.016	-0.59**	-0.380	-0.231	0.437*	0.100	-0.170	-0.177
42 <i>T.(T) rattus</i>	-0.238	-0.456*	-0.167	-0.295	0.435*	-0.158	0.014	-0.006
43 <i>Trichotria tetractis</i>	-0.573**	0.292	0.594	0.755**	-0.480*	0.290	-0.032	-0.322
44 <i>Pompholyx sulcata</i>	-0.342	0.341	0.484	0.410	-0.377	0.505*	-0.240	-0.073
45 <i>Filinia longiseta</i>	-0.218	-0.667**	-0.395	-0.316	0.584**	-0.290	0.119	-0.058
46 <i>F. terminalis</i>	-0.248	-0.448*	-0.171	-0.173	0.343	-0.021	-0.018	-0.088

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

with higher total alkalinity. pH didn't reveal overall significant relationship with rotiferan population in most of the cases ($r = 0.450; 0.355; 0.269; 0.685; 0.600; 0.717; 0.618; 0.532$ and 0.529 for the 9 study sites, study site-1 to study site-9 respectively) (Table 4,5 and 6). with total diversity of Rotifera. Dissolved oxygen (DO) is probably the most widely analyzed chemical parameter in any water body. Apart from its direct effect on respiration of different biotic organisms, it controls directly or indirectly many limnological parameters of aquatic ecosystem. Dissolved oxygen plays an important role in determining the occurrence and abundance of rotifer communities (Dhanapathi 2000). Hofmann (1977) determined oxygen concentration as to be an important factor in determining seasonal, horizontal and vertical variations of rotifers, while Berzins and Pejler (1989b) noticed wider range of oxygen is required for the occurrence of these organisms.

In the present study, maximum D.O. during winter season followed by rainy season was supposed to be due to the flushing of water with atmosphere or as a result of increased water volume, depth and water current as well as due to higher growth of macro and microphytes. In this study, dissolved oxygen ranged from 4.04 to 12.97 mg/L. An inverse relationship ($r = -0.271; -0.238; -0.222; -0.501; -0.326; -0.248; -0.583; -0.586; -0.182$ for study site-1 to study site-3 of Dwarkeswar river, study site-4 to study site-6 of Shilabati river and study site-7 to study site-9 of Kansai river respectively) (Table 3,4 and 5) was noticed between rotifer abundance and dissolved oxygen which might be attributed to the respiratory activity of the rotifers and other zooplankton and also because of uptake of oxygen for decomposition of algal bloom (Berzins and Pejler, 1989b) (Table 3,4 and 5). Species that occur and prefer water with high

DO values such as of genus *Asplanchna*, showed significant positive correlation with dissolved oxygen ($r = 0.611$) (Table-6). Dhanapathi, 2000, also recorded this species from the water having high DO. Pejler (1957) and Pourriot (1965) pointed out that cold stenothermal forms are more tolerant of low oxygen content in the water than eurythermal species. Ellis *et al.* (1946) stated that the amount of total Kjeldhal nitrogen in unmodified natural waters are very less (less than 0.1mg/L), while more than 1.0 mg/L are indicative of organic pollution (Reid, 1961). The value of Total Kjeldahl Nitrogen ranged from 0.14 to 14.87mg/L and mean value were 2.83 ± 0.40 ; 3.18 ± 0.56 ; 1.93 ± 0.28 ; 2.83 ± 0.48 ; 2.61 ± 0.46 ; 1.69 ± 0.19 ; 1.79 ± 0.28 ; 3.25 ± 0.62 and 1.70 ± 0.22 for study site-1 to study site-9 respectively (Table 2). Total phosphate phosphorus level in the water body was recorded low at study sites- 1, 3 to 9 (0.37 ± 0.08 ; 0.26 ± 0.06 ; 0.34 ± 0.10 ; 0.34 ± 0.08 ; 0.22 ± 0.08 ; 0.24 ± 0.05 ; 0.28 ± 1.61 ; and 0.11 ± 0.01 respectively) but a sharp increase of this parameter in study site-2 (0.62 ± 0.16 ; range : 0.01–3.79) was thought to be due to sewage disposal. Higher values of total phosphate phosphorus suggested that there was a greater role of sewage draining from adjoining municipal areas causing such high concentration of phosphorus

Simple correlation coefficient analysis between different species of rotiferan community revealed both positive and negative relationships, which may be due to the adaptability of similar environmental conditions (Table 3,4 and 5). Considerable volume of data generated by the analysis of different physicochemical parameters of water which revealed that almost all parameters tended to remain within the permissible limit (comparing with international and national standard as shown in the Table 8) By virtue of their such concentration, the water of these study sites could be used for drinking with conventional treatment, propagation of wildlife and fisheries and for irrigation, industrial cooling and for controlled waste disposal and was not expected to pose any problem for the aquatic biota. In the present findings, environmental parameters

in relation to population dynamics assessed from correlation coefficient values, stated that there appeared no well marked effectiveness of any single environmental factor controlling the distribution of zooplankton.

Sladeczek (1983) provided an excellent account of 625 species of Rotatoria found in different water bodies of Czechoslovakia as indicators of water quality with remarks on saprobity, saprobic valence, and indicative weight of different species, saprobic index and pollution. The saprobien system as highlighted by Kolkwitz and Marsson (1908, 1909) is the earliest biotic index and this system is based on the observations in a river which has received a heavy input of sewage and shows different zones of decreasing pollution. These zones have been termed as polysaprobic, α mesosaprobic, β mesosaprobic and oligosaprobic zones in order to decreasing higher organic enrichment in a river. The presence or absence of indicator species in the said study sites were recorded in relation to species diversity index (H') (Table 7). This information is used to monitor the range of pollution.

Several indicator species of Rotifera recorded from Indian inland waters were categorized by Sharma (1996). Based on the affinity for specific water bodies following categories of Rotifera have been made.

1. **Eutrophic species** : Those species which are likely to inhabit in highly nutrient containing water bodies viz. *Brachionus angularis*; *B. bidentata*; *B. calyciflorus*; *B. caudatus personatus*; *B. falcatus*; *B. rubens*; *Keratella tropica*; *Asplanchna priodonta*; *L. (L) curvicornis curvicornis*; *Lecane (Monostyla) bulla*; *L. (M) lunaris*; *Polyarthra vulgaris*; *Pompholyx sulcata*; *Filinia longiseta*. Most of these species were designated as eutrophic indicators in India and elsewhere in the World (Sladeczek, 1983; Saksena, 1987; Sharma, 1996;). Out of these Rotiferan species, *Brachionus angularis*; *B. calyciflorus*; *B. rubens* and *Filinia longiseta* have been reported to inhabit in hypereutrophic water body (Sharma, 1996).

Table-7. Seasonal variation of community indices of Rotifera population at 9 study sites**Index of Dominance**

	Monsoon	Post mon	Pre mon	Monsoon	Post mon	Pre mon	Range	Mean	±SD
S1	0.158	0.232	0.302	0.233	0.211	0.271	0.158 - 0.302	0.234	±0.050
S2	0.178	0.210	0.240	0.292	0.288	0.286	0.178 - 0.292	0.249	±0.048
S3	0.243	0.238	0.300	0.321	0.347	0.340	0.238 - 0.347	0.298	±0.048
S4	0.130	0.095	0.138	0.112	0.085	0.121	0.085 - 0.138	0.113	±0.020
S5	0.204	0.133	0.168	0.217	0.077	0.110	0.077 - 0.217	0.152	±0.055
S6	0.362	0.159	0.227	0.235	0.089	0.148	0.089 - 0.362	0.203	±0.095
S7	0.067	0.072	0.065	0.106	0.081	0.082	0.065 - 0.106	0.079	±0.015
S8	0.072	0.087	0.064	0.104	0.076	0.073	0.064 - 0.104	0.079	±0.014
S9	0.102	0.087	0.076	0.100	0.107	0.123	0.076-0.123	0.099	±0.016

Species richness index

	Monsoon	Post mon	Pre mon	Monsoon	Post mon	Pre mon	Range	Mean	±SD
S1	3.270	2.626	1.710	2.175	2.184	1.580	1.580 - 3.270	2.257	±0.621
S2	2.872	2.044	1.794	2.070	1.872	1.492	1.492 - 2.872	1.980	±0.373
S3	2.823	3.181	2.120	2.685	2.299	1.682	1.682 - 3.181	2.465	±0.538
S4	3.719	2.530	2.034	4.111	2.736	1.828	1.828 - 4.111	2.826	±0.913
S5	2.514	2.547	1.605	2.540	2.558	1.800	1.605 - 2.558	2.261	±0.437
S6	2.893	3.029	2.162	4.035	3.242	2.470	2.162 - 4.035	2.972	±0.651
S7	4.826	2.408	1.853	3.203	2.750	1.957	1.853 - 4.826	2.833	±1.098
S8	3.702	2.630	2.216	4.950	3.136	1.968	1.968 - 4.950	3.100	±1.102
S9	4.726	3.410	2.569	4.146	3.871	2.375	2.375 - 4.726	3.516	±0.916

Species diversity Index (H')

	Monsoon	Post mon	Pre mon	Monsoon	Post mon	Pre mon	Range	Mean	±SD
S1	2.144	2.281	1.775	1.806	2.215	1.911	1.775 - 2.281	2.022	± 0.219
S2	2.017	2.208	2.058	1.666	1.915	1.800	1.666 - 2.208	1.944	± 0.194
S3	1.641	2.198	1.813	1.617	1.710	1.574	1.574 - 2.198	1.759	± 0.231
S4	2.223	2.539	2.592	2.498	2.713	2.649	2.223 - 2.713	2.536	± 0.171
S5	1.755	2.495	2.411	1.940	2.688	2.559	1.755 - 2.688	2.308	± 0.373
S6	1.057	2.285	2.216	2.022	2.596	2.433	1.057 - 2.596	2.102	± 0.548
S7	2.813	2.772	2.891	2.486	2.696	2.784	2.486 - 2.891	2.740	± 0.140
S8	2.722	2.753	2.931	2.427	2.780	2.870	2.427 - 2.931	2.747	± 0.175
S9	2.455	2.676	2.765	2.464	2.538	2.536	2.455 - 2.765	2.572	± 0.123

Species evenness Index

	Monsoon	Post mon	Pre mon	Monsoon	Post mon	Pre mon	Range	Mean	±SD
S1	0.812	0.678	0.499	0.704	0.651	0.533	0.499 - 0.812	0.646	±0.113
S2	0.841	0.695	0.584	0.615	0.603	0.519	0.519 - 0.841	0.649	±0.125
S3	0.843	0.683	0.514	0.571	0.519	0.450	0.450 - 0.843	0.597	±0.144
S4	0.927	0.896	0.805	0.864	0.906	0.834	0.805 - 0.927	0.872	±0.046
S5	0.902	0.833	0.769	0.781	0.913	0.816	0.769 - 0.913	0.836	±0.060
S6	0.962	0.824	0.697	0.714	0.916	0.787	0.697 - 0.962	0.817	±0.107
S7	0.955	0.941	0.949	0.877	0.915	0.914	0.877 - 0.955	0.926	±0.029
S8	0.961	0.891	0.935	0.919	0.913	0.915	0.891 - 0.961	0.922	±0.024
S9	0.930	0.893	0.923	0.934	0.847	0.833	0.833 - 0.934	0.893	±0.044

Table-8. Water Quality Parameters and Standards in respect of domestic/drinking water supplies (All values in ppm, unless specified otherwise).

Characteristic	ADSORBS	IIEE	USPH	ISI	WHO	ICZM
1. Temp.(°C)	Accept-able	Cause for rejection				<40
2. pH	7-8.5	<6.5& >9.2	7-8.5	6-8.5	6-9	6.5-8.5 5.5-9.0
3. Alkalinity.						
8. Dissolved Oxygen.	4-6			4-6		
10. Biochemical Oxygen Demand.	2-3					<30
11. Total Kjeldahl Nitrogen.	45	45	20	<10	45	45 <100
12. Total Phosphate phosphorous.						<5.0

2. **Oligotrophic species** : Those species which are likely to inhabit in low nutrient containing water bodies viz. *B. falcatus*; *Keratella cochlearis*; *Keratella tropica*; *Lepadella (Lepadella) ovalis*; *L. (L) leontina*; *L. (L) nana*; *L. (M) decipiens* and *Asplanchna priodonta*.

3. **Acidophilic species** : Those species which are likely to inhabit in acidic water bodies viz.: *B. quadridentatus*; *Euchlanis dilatata*.

4. **Alkaline mesotrophic species** : Those species which are likely to inhabit in alkaline and moderately nutrient containing water bodies viz *Brachionus angularis*; *B. bidentata*;

B. caudatus personatus; *B. rubens*; *B. calyciflorus*; *B. falcatus*; *B. forficula*; *Keratella tropica*; *Lecane (L) curviconis curviconis*; *Lecane (Monostyla) bulla*; *L.(M) lunaris*; *Polyarthra vulgaris*; *Pompholyx sulcata*; *Filinia longiseta*.

5. **Worm stenothermal species** : Those species which are likely to live in narrow range of worm water viz. *B.bidentata*; *B. forficula*; *B. falcatus*; *Keratella tropica*; *Beauchampiella eudactylota*; *L. (M) stenroosi*.

6. **Eurythermal species** : Those species which are like to live in wide range of temperature

variation viz. *Brachionus angularis*; *B. calyciflorus*; *B. rubens*; *Lepadella (Lepadella) ovalis*; *L.(L) hastate*; *Polyarthra vulgaris*.

Pejler (1983) mentioned that along a trophic scale, the number of planktonic rotifer species successfully increased upto mesotrophic condition after which the numbers declined till hypereutrophic end.

On the basis of scales as developed by Wilhm and Dorris (1968), nine different study sites located on three freshwater rivers, through six seasons of two consecutive years showed Shannon index of diversity of Rotifera

community between 1 and 3 (Table 7). Based on such information, the water of such water bodies can be regarded as moderately polluted.

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LITERATURE CITED

- APHA, 1995. American Water Workes Association and Water environmental Federation. Stadard Methods for the examination of water and wastewater. 19th Edition. Washington DC. 2000.
- ARORA, H. C. 1961. Rotifera as indicator of pollution. *Bull. CPHERI Nagpur*, 3 and 4 : 24-36
- ARORA, H. C. 1966. Rotifera as indicator of trophic nature of environment. *Hydrobiologia*, 27 : 146-159.
- BATTISH, S.K. 1992. *Fresh water zooplankton of India*. Oxford and IBH publishing Co., New Delhi.
- BARTRAM, J. and HELMER, R. 1996. Water Quality Monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes. Ed : J. Bartram and R. Ballance. Pub : UNEP. London. pp. 383.
- BERZINS, B. and PEJLER, B. 1987. Rotifera occurrence in relation to pH. *Hydrobiologia*, 147 : 107-116. -
- BERZINES, B. and PEJLER, B. 1989a. Rotifera occurrence in relation to temperature . *Hydrobiologia*, 175 : 223-231
- BERZINS, B. and PEJLER, B. 1989b. Rotifera occurrence in relation to trophic degree. *Hydrobiologia*, 182 : 171-180
- BERZINS, B. and PEJLER, B. 1989c. Rotifera occurrence in relation to oxygen content. *Hydrobiologia*, 183 : 165-172.
- BERZINS, B. AND PEJLER, B. 1989d. Rotifera occurrence in relation to water colour. *Hydrobiologia*, 184 : 23-28.
- DATTA, N.C. 2001. Biomonitoring of aquatic environment-concept, scope and limitations. In. *Water Quality Assessment, Biomonitoring and Zooplankton diversity* (Ed. B. K. Sharma),. Department of Zoology, NEHU, Shillong : 36-44
- DEPAUW, N, GHETTI, P.F., MANZINI, P. and SPAGGIARI, R. 1992. Biological assessment methods for running waters. In *River water quality ecological assessment and control* (Eds. P.J. Newman., M.A. Piavaux and R.A. Sweeting). Commission of the European Communities, Bruxelles : 217-249
- DHANAPATHI, M.V.S.S.S. 2000. *Taxonomic notes on the rotefers from India* (from 1889-2000). Pub. Indian Association of Aquatic Biologists, Hyderabad-500095, A.P., India, : 1-178.

- DONNER, J. 1978. Material zur saprobiologischen Beurteilung mehrerer Gewässer des Donau-Systems bei Wallsee und in der Lobau, Österreich, mit besonderer Berücksichtigung der litoralen Rotatorien. *Arch. Hydrobiol. Suppl.*, **52** : 117-228.
- EDDY, S. 1934. A study of freshwater plankton communities. *Illinois biol. Monogr.*, **12**(4), 1293. 7.1, 7.2.
- EDMONDSON, W.T. 1959. Rotifera. In : Fresh Water Biology. Ed. : W.T. Edmondson. John Wiley and Sons, Inc. New York, London : 420-494.
- ELLIS, N.M. WESTFALK, B.A. and ELLIS, M.D. 1946. Determination of water quality for fish and wild life service. U.S. Interior Res. Rept. 9, 122 P.
- FULLER, D.H., STEMBER, R.S. AND GANNON, J.E. 1977. Limnetic rotifers as indicators of trophic change. *J. Elisha Mitchell Sci. Soc.*, **93** : 104-113.
- GANNON, J.E. and STEMBERGER, R.S. 1978. Zooplankton (especially crustaceans and rotifers) as indicator of water quality. *Trans. Amer. Micros. Soc.*, **97** : 16-35.
- GAUFIN, R.F. and GAUFIN, A.R. 1966. Ecological aspects of organic pollution in streams. World Health Organisation. WHO./EBL.
- GHETTI, P.F. and RAVERA, O. 1994. European perspective on biological monitoring. In : *Biological monitoring of aquatic systems*. Ed : S.L. Loed and A. Spacie. Lewis Publishers, New York. 31-46.
- HAKKARI, L. 1972. Zooplankton species as indicator of environment. *Aqua ftm.*, **72** : 46-54.
- HOFMANN, W. 1977. The influence of abiotic factors on population dynamics in planktonic rotifers. *Arch. Hydrobiol. Beih., Ergebn. Limnol.*, **8** : 77-83.
- KARABIN, A. 1983. Ecological characteristics of lakes in North-eastern Poland versus their trophic gradient. VII. Variation in the quantitative and qualitative structure of the pelagic zooplankton (Rotatoria and Crustacea) in 242 lakes. *Ekol. Pol.*, **31** : 383-409.
- KOLKWITZ, R. 1935. *Pflanzenphysiologie*. 3. Aufl. G. Fisher, Jena, 310pp.
- KOLKWITZ, R. and MARSOON, M. 1902. Grundsätzliches über die Beurteilung des Wassers nach seiner Flora und Fauna. *Mitt. Der Kaiserl. Preuss. Für Wass. Und Abwass.* (Berlin -Dahlem), 1-33.
- KOLKWITZ, R. and MARSOON, M. 1908. Ökologie der pflanzlichen Saprobien. *Ber. dt. bot. Ges.* **26** : 505-519.
- KOLKWITZ, R. and MARSOON, M. 1909. Ökologie der tierischen Saprobien. Beiträge zur Lehre von der biologischen Gewässer-beurteilung. *Int. Revue ges. Hydrobiol. Hydrogr.*, **2** : 126-152.
- MAEMETS, A. 1983. Rotifera as indicators of lake types in Estonia. *Hydrobiologia*, **104** : 357-361.
- MENHINICK, E.F. 1964. A comparison of some species-individuals diversity indices applied to samples of field insects. *Ecology*, **45** : 859-861.
- MICHAEL, R.G. 1968. Studies on the zooplankton of a tropical fish pond. *Hydrobiologia*, **32** : 47-68.
- NAYER, C.K.G., 1970. Studies on the rotifer population of two ponds at Pilani, Rajasthan. *J. Zool. Soc., India*, **22** : 168-185.
- NEEDHAM, J.G. and NEEDHAM, P.R. 1962. A guide to the Study of fresh water biology. Published by- Holden-Day, Inc. San Francisco : 1-108.
- PEJLER, B. 1957. Taxonomical and ecological studies on planktonic Rotifera from Central Sweden. *K. Vetensk. Akad. Handl., ser.*, **4**, **6** : 1-52.

- PEJLER, B. 1981. On the use of zooplankton as environmental indicators. In : *Some approaches to saprobiological problems* (Ed. M. Sudzuki) : 9-12.
- PEJLER, B. 1983. Zooplankton indicators of trophic and their food. *Hydrobiologia*, **101** : 111-114.
- PEJLER, B. AND BERZINS, B. 1989. On choice of substrate and habitat in brachionid rotifers. *Hydrobiologia*, **186/187** : 137-144.
- PEJLER, B. and BERZINS, B. 1993. On choice of substrate and habitat in bdelloid rotifers. *Hydrobiologia*, **255/256** : 333-338.
- PIELOU, E.C. 1966. The measurement of diversity in different types of biological collections. *J. Theor. Biol.*, **13** : 131-144.
- POURRIOT, R. 1965. Notes taxinomiques sur quelques Rotiferes planctoniques. *Hydrobiol.*, **26** : 579-604.
- RADWAN, S. 1976. Planktonic rotifers as indicators of lake trophic. *Ann, Univ. Mariae Curie – Skłodowska, sectio C*, **31** : 227-235.
- RAO, R. K. AND MOHAN, C.P, 1977. Rotifera as indicator of pollution. *Curr. Sci.*, **46** : 190.
- REID, G.K. 1961. Ecology of inland waters and estuaries. Reinhold Publication Corp. New York : 109-127 pp.
- REINHARD, E.G. 1931. The plankton ecology of the upper Mississippi Mininneapolis to Winona. *Ecol. Monorg.*, **1(7)**, 395-464.
- SAKSENA D.N. 1987. Rotifers as indicators of water quality Acta Hydrochem. *Hydrobiol.*, **15** : 481-485.
- SAKSENA, D.N. and KULKARNI, N. 1986. On the rotifer fauna of two sewage channels of Gwalior (India). *Limnologica (Berlin)*. **17** : 139-148
- SAMPATH, V. SRINIVASAN, A., and ANANTHANARAYANAN, R., 1979. Rotifers as biological indicators of water quality in Cauvery river. *Proc. Symp. Env. Biol.*, 449-452.
- SHANNON, C.E. and W. WEAVER. 1949. *The Mathematical Theory of Communications*. Illionois University Press. Urbana.
- SHARMA, B.K. 1986. Assessment of pollution indicators in Indian Rotifera J. Meghalaya. *Sci. Soc.*, **9** : 47-49.
- SHARMA, B.K. 1992. Freshwater Rotifers (Rotifera : Eurotatoria) In : *Fauna of West Bengal. State Fauna Series*, **3(13)** : 1-121. *Zool. Surv. India*, Calcutta.
- SHARMA, B. K. 1996. Biodiversity of freshwater Rotifera in India–A status report. *Proc. Zool. Soc. Calcutta*, **49** : 73-85.
- SHARMA, B.K. 2001. Biomonitoring and role of Rotifera. In : *Water quality Assessment, Biomonitoring and Zooplankton Diversity* (Ed. B.K. Sharma, Department of Zoology, NEHU, Shillong) 83-95.
- SHARMA, B.K. and DUDANI, V.K. 1992. Rotifers from some tropical ponds in Bihar : Species Composition, similarities and trophic indicators. *J. Indian Inst. Sci.*, **72** : 121-130.
- SHARMA, B.K. and NAIK, L.P. 1996. Result in planktonic Rotifers in the Narmada river (Madhya Pradesh, Central India). In : *Perspective in Tropical Limnology* (Eds. F. Schimer and K.T. Boland). SPB Academic Publishing bv. Amsterdam, The Natherlands : 189-198.

- SHARMA, B.K. and SHARMA, S. 1999. Freshwater Rotifera (Rotifera : Eurotatoria). In : *Fauna of Meghalaya, State Fauna Series*, 4(9) : 11-161. Zool. Surv. India, Calcutta.
- SHARMA, B.K. and SHARMA, S. 2001. Freshwater Rotifera (Rotifera : Eurotatoria). In : *Fauna of Tripura. State Fauna Series*, 7(4); Zool. Surv. India, Calcutta.
- SIMPSON, E.H. (1949. Measurement of diversity. *Nature*, 163 : 688.
- SLADECEK, V. 1956. Rotatoria-Virniky. In : Biological methods of investigation and evaluation of waters (Ed. Hanuska *et al.*). (In Slovakian) : 358-367, Bratislava.
- SLADECEK, V. 1983. Rotifers as indicators of water quality. *Hydrobiologia*, 100 : 169-201.
- TRIVEDI, R.K. AND GOEL P.K. 1984. Chemical and Biological methods for water pollution studies Environmental Publications Post Box-60, Karad-415 110. (India) : 1-215, I-XXXII.
- VASISHT, H.S and SHARMA, B.K. 1976. Seasonal abundance of Rotifer population in a fresh water pond in Ambala City (Haryana). India. *J. Zool. Soc. India*, 28 : 35-44.
- WESTLAKE, D.F. 1975. Macrophytes. In : *Studies in ecology. 2, River Ecology*. Ed. by B.A. Whitton. Blackwell Scientific Publication, Oxford, London, Edinburgh, Melbourne. : 106-128.
- WETZEL, R.G. 1959. Technische Hydrobiologie. Trink-, Brauch-, Abwasser biologie, Akadem. Verlagsges. Geest u. Portig, Leipzig, : 407.
- WHITTON, B.A. and SAY, P.J. 1975. Heavy metals. In : *Studies in ecology. 2, River Ecology*. Ed. by B.A. Whitton. Blackwell Scientific Publication, Oxford, London, Edinburgh, Melbourne : 286-311
- WILHM, J. L. 1975. Biological indicators of pollution. In : *Studies in ecology. 2, River Ecology*. Ed. by B.A. Whitton. Blackwell Scientific Publication, Oxford, London, Edinburgh, Melbourne : 375-402
- WILHM, J.L. and DORRIS, T.C. 1968. Biological parameters for water quality criteria. *Bioscience*, 18 : 477-481.
- ZWART, D. DE. AND TRIVEDI, R.C. 1994. Manual of integrated water quality evaluation. CPCB, Delhi : 318.

ELECTROSENSITIVITY AND RESPONSE OF MUD CRAB, *SCYLLA SERRATA* IN HOMOGENEOUS AND HETEROGENEOUS ELECTRIC FIELD

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ABSTRACT

In order to determine the electrosensitivity and response of mud crab, *Scylla serrata*, experiments have been conducted in homogeneous under-water electric field created by direct current (D.C.) and pulsed direct current. *Scylla serrata* exhibited three recognisable reactions with increasing field intensity, expressed in the present study, as current density (10^{-6} amp/mm²), irrespective of current form, that is, D. C. or pulsed D. C. They are, fright reflex, trying to escape out of field, involuntary restless movement as long as the current continues to flow and muscular rigidity followed by tetanus, at times throwing off their limbs. The threshold values of current density varied inversely with the size of the animals.

In the heterogeneous field of low intensity, the fright reflex and avoidance of the field by the crabs was noticed in low pulse rate of 1/sec. Forced and restless movement followed by immobilization and tetanus was better occurred in pulse frequencies of 2/sec. and 4/sec.

Keywords : Electrosensitivity, *Scylla serrata*, aquatic animal.

INTRODUCTION

Electrofishing has been accepted as useful method and tool of fisheries management in countries like Germany, U.S.A. and U.S.S.R. for many years. Basically, the function of an electrofishing system is to produce sufficient electrical stimulus in aquatic animal near the electrodes to permit easy capture or simple avoidance of an unpleasant electrical stimulus.

In the pulsating and alternating current (A.C.) system on the other hand, fright reflex, followed by immobilisation of fish (electronarcosis or electrotetanus) occurred with the rising current densities. Variation in techniques and performance of electrofishing equipments have been reported (Rollefson, 1958; Burnet, 1959; Patten and Gillaspie, 1966) for various water conditions and fish species. Whereas, the attracting anodic effect is being utilised in easy capture of aquatic animals, the

frightening and blocking effect is used as barriers for preventing the migration of Chinese crabs (*Eriocheir sinensis*) and fencing off water areas successfully (Meyer-Waarden, 1957).

The present study aims to assess the impact of the electrical variables, influencing the water conditions and crustacean species (mud crab), the response of animals to various electrical stimulations, experimental evaluation of electrode array for frightening and blocking effect on *Scylla serrata* in under-water field of direct current (D.C.) and pulsed direct current of low frequencies.

MATERIALS AND METHOD

Experiment with homogeneous under-water electric current

A homogeneous under-water field was created in an insulated glass tank (90×10×10 cm) with two electrodes, made of copper plate

(10 × 9) cm. fixed vertically along the tank extremities. The electrodes were connected to the output terminals of a D.C. rectifier, which in turn, was connected to A.C. mains through a variable resistance. A voltmeter connected in parallel to the terminals of the electrodes indicated potential difference between the two electrodes during the experiment. The field intensity was measured by a microammeter connected in series with the tank electrodes (Figs. 1,2).

While working with pulsed D. C., the output terminal of the impulse transmitter was connected to the electrodes of the experimental tank. The impulse transmitter, mainly designed for low frequencies, had a maximum range of 7 pulses per second. The potential difference between the electrodes was increased by one volt step and the field intensity was monitored by the microammeter. Non-chlorinated tap water formed the media of the electric field, the electrical resistivity of which was measured by an ohms meter and recorded as ohms/cm².

Seventy *Scylla serrata* of 44-122 mm carapace length and 12-250 g weight, after being acclimatized to laboratory conditions for three days, were measured for carapace length and weight; released in the experimental tank,

where they were allowed to settle. The behaviour and physiological conditions during rest were recorded before subjecting the animals to electric shock. The field intensity was then raised from zero potential till the organisms could perceive the surrounding external field and react to it. The magnitude of current densities and potential gradients in bringing out the visible reactions were recorded. A single organism was taken for each experiment, and the treated animals were never re-used before a rest period of atleast forty eight hours. The temperature (29°C), electrical resistance of the water (7000 ohms/cm²), and the light in it, remained constant for each set of experiment.

Experiment with heterogeneous under-water electric current

Heterogeneous under-water electric field was created in the insulated glass tank with three types of electrode-array and the configuration of electric field. The electrodes consist of aluminium rod of 5 mm. thickness.

Electrode-array, in the first set of experiments, was made of four aluminium rod of 31 mm. long and placed vertically from surface to the bottom. Of the total two sets, two electrodes of each set were placed 27 cm. apart from each other and one set was used for

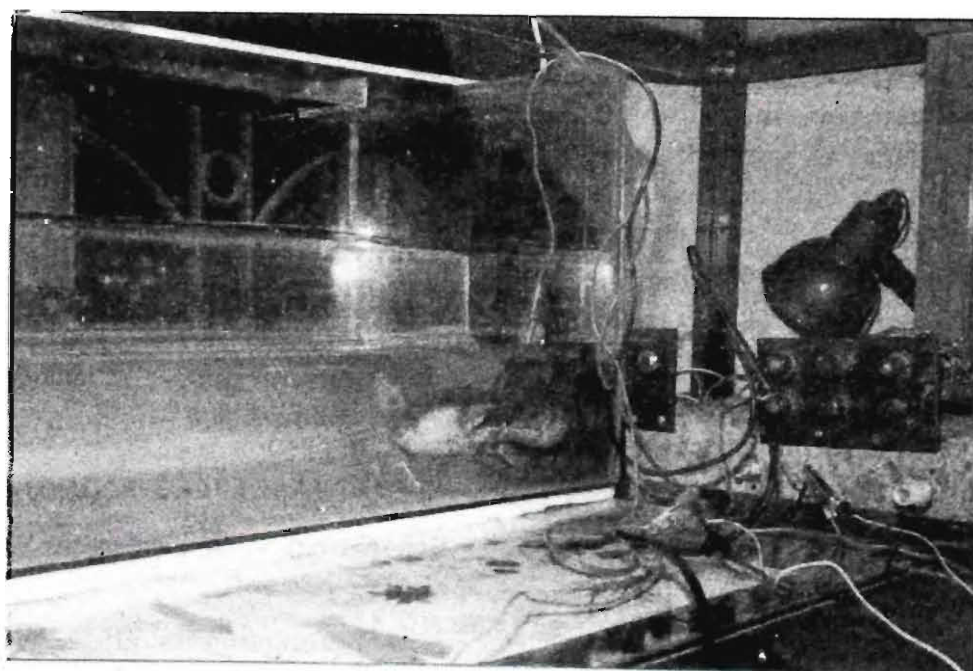


Fig. 1. Anodic taxis leading to muscular rigidity of mud crab in homogeneous pulsed D. C. field

low and the other set for high field strength. The electrodes of higher and lower field strength was kept at a distance of 44 cm. from each other. The electrodes, meant for lower field strength, were connected to the output terminals of a low voltage (7.5 volts) pulsed D.C.; while the higher potential (14.5 volts) were applied to the other electrodes to create higher field strength, simultaneously (Fig. 2).

In the second set of experiments, the electrode -array consists of two sets of aluminium rods of 30 cm. long, and each set

was placed horizontally 45 cm. away from each other. The electrodes of each set were separated from each other by 3 cm. and was connected with the output terminals of pulsed D.C. of lower and higher strength, Applied peak potential difference of lower and higher current conducting electrodes were 7.5 and 14.5 volts respectively (Fig. 3).

Two lattice gates, made of 4 aluminium rods of 30 cm. length each, separated from each other by 5 cm., and kept at a distance of 66 cm. were used as positive and negative electrodes in the

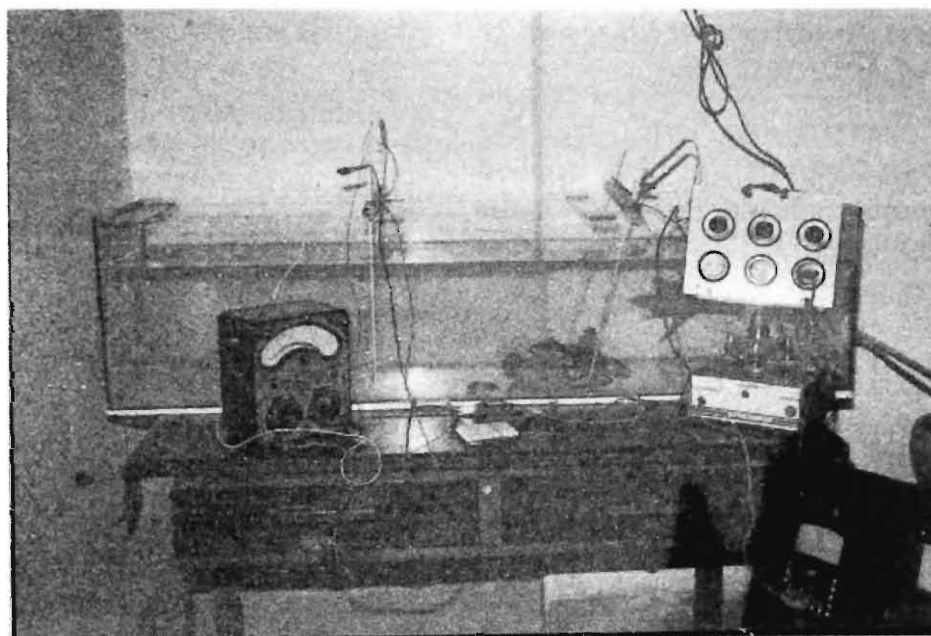


Fig. 2. Blocking effect of mud crab in vertical two electrode-array system in heterogeneous field

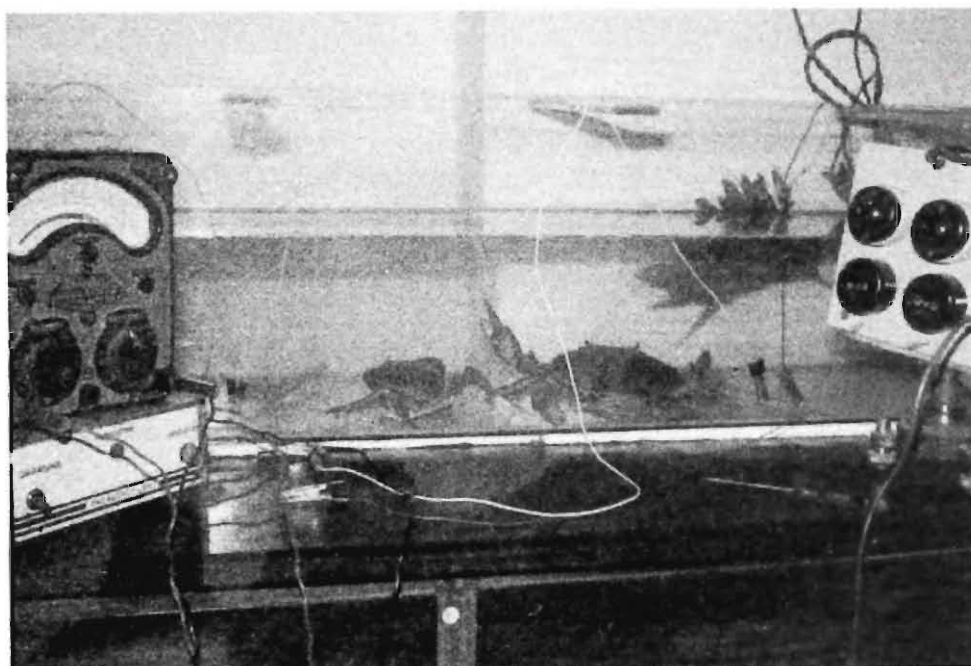


Fig. 3. Fright reflex of mud crab between horizontal electrode-array in heterogeneous field

third set of experiments. Seperate experiments were conducted for low voltage (7-9 volts) and high voltage (16-18 volts) pulsed D.C. independently without any superimposition of lower and higher electric field (Fig. 4).

At the pre-set pulsed field of peak applied voltages of 7.5 volts and 14.5 volts between two sets of electrodes, *Scylla serrata*, acclimatized as described in earlier experiments, were released, one at a time, and their responses were observed and recorded. Two pulse rates of one and two per second were used in the first and second set of experiments, while for the third set of experiments, in addition of 1/sec and 2/sec, pulse rate of 4/sec was tried.

The field intensity ($\mu\text{a}/\text{cm}^2$) and the potential gradient (mv/cm^2) at peak applied voltage were monitored and recorded in the manner stated earlier in relation to the response of individual organisms.

RESULTS

Behavioural response in a homogeneous field, classification of reactions and reaction thresholds

Mud crab (*Scylla serrata*) in normal conditions have been found to crawl at the bottom of estuarine waters slowly by scanning

their surroundings with the help of their antennae. They respond to other external stimuli with a fright reflex of sidewise movement from the area of disturbance with stretched claws, depending on the intensity of the stimuli. Sudden illuminating momentarily stupified them, but afterwards moved away from the illuminated areas.

On exposing them to under-water homogeneous D.C. and pulsed D.C. field, *Scylla serrata* of 44-122 mm. carapace length and weighing 12 to 250 grams, exhibited fright reflex, attempting to escape out of the field (stage-I), involuntary restless movement to either of the electrodes with expanded appendages (stage-II) and muscular rigidity, incapable of any movement, often dislodging of appendages (stage-III) with the increasing current intensities (0.004-8.3338) in 100 percent cases (Table-1). The above reactions were intense in case of pulsed D.C. with observation of anodic taxis in higher pulse frequencies (4-5/sec).

Relationship between size and threshold intensities for different reactions

The threshold current densities for different reactions of *Scylla serrata* varied with their size, and particularly on their carapace length.



Fig. 4. Immobilization of mud crab leading to muscular rigidity between lattice gate electrodes in heterogeneous field.

Table - 1. Response of *Scylla serrata* in homogeneous D.C. and pulsed D.C. field.

Classification of reactions.	Nature of response with the increasing field intensity	Current density in δ required for the reaction	% responded
Stage - I	D.C. (10 animals) Fright reflex, attempt to escape out of the field.	0.111-0.012	100
Stage-II	Forced movement to electrodes with expanded appendages	1.222-1.444	100
Stage-III	Incapable of movement, muscular rigidity, often throwing off their limbs.	6.222-6.888	100
	Pulsed D.C. - 2/sec (15 animals)		
Stage-I	Fright reflex, attempt to escape out of the field.	0.012-0.16	100
Stage-II	No movement, jerks and elevated body with expanded appendages, often throwing off their limbs.	1.333-1.888	100
Stage-III	Incapable of movement, tetanus, often dislodging of appendages.	6.666-8.888	100
	Pulsed D.C.-3/sec (10 animals)		
Stage-I	Fright reflex, attempt to escape out of the field.	0.02-0.05	100
Stage-II	Violent movement with expanded appendages to anode.	0.888-1.055	100
Stage-III	Incapable of movement, muscular rigidity, dislodging of appendages.	2.444-2.666	100
	Pulsed D.C.-4/sec (15 animals)		
Stage-I	Fright reflex, attempt to escape out of the field.	0.004-0.016	100
Stage-II	Involuntary movement to anode with expanded appendages.	0.666-1.111	100
Stage-III	Tetanus, no movement, drops to the bottom.	2.222-2.666	100
	Pulsed D.C.-5/sec (20 animals)		
Stage-I	Fright reflex, attempt to escape out of the field.	0.01-0.13	100
Stage-II	Involuntary movement to positive electrode with vibrating body and expanded appendages.	0.444-3.219	100
Stage-III	Tetanus near positive electrode, no movement, drops to the bottom	3.888-8.333	100

The threshold current densities required for *Scylla serrata* of 99 mm carapace length and 140 g weight to exhibit reactions at three stages were 0.18 δ , 1.834 δ and 9.554 δ respectively in the D.C. field. These threshold values decreased to 0.011 δ , 1.222 δ and 6.888 δ respectively with the increase in size of the animal (carapace length 133 mm. and 240 g weight) (Table 2).

In pulsed D.C. of 2/sec, the current intensities for three reactions were 0.18 δ , 2.464 δ and 9.848 δ respectively for animals of 44 mm carapace length and 12 g weight. The threshold

values decreased progressively with the increase in size of the animal and was lowest of 0.012 δ , 1.888 δ and 6.666 δ respectively, required for the crab of carapace length of 112 mm and 200 g weight.

The reaction thresholds in pulsed D.C. of 3/sec were 0.05 δ , 1.055 δ and 2.666 δ respectively for animals of 105 mm carapace length and 150 g weight. But crabs of 122 mm carapace length and 240 g weight exhibited similar sequence of reactions in threshold values of 0.02 δ , 0.888 δ and 2.444 δ respectively.

Similar trend of inverse relation of threshold intensities to the size of the animals have also been noticed in pulse D.C. of 4/sec. and 5/sec. In the former case, the threshold values were 0.0168, 0.7228 and 2.6668 respectively for animals of 80 mm carapace length and 90 g weight, as against 0.0048, 0.1668 and 2.2228 for crabs of 108 mm carapace length and 200 g weight.

Mud crab of 44 mm carapace length and 12 g weight were influenced at current intensities of 0.138, 3.2198 and 8.3338 respectively in pulsed D.C. of 5/sec whereas, for bringing out similar reactions, current densities of 0.018, 0.4448 and 3.8888 were required for the animals of 120 mm. carapace length and 340 grams weight (Table-2).

Response in heterogeneous field

Heterogeneous D.C. fields were created under water with different electrode-array, which formed two and four aluminium metal rods fixed vertically in water at some distance (27 cm and 66 cm) from each other and extending from the water surface to the bottom.

Electrode-array of two aluminium rods at 3 cm spacing, laid horizontally at the bottom, was also tested for blocking effect on the crabs.

Low voltage (7.5-18 volts) pulsed D.C. of frequencies of 1 pulse/sec, 2 pulses/sec and 4 pulses/sec. were used in the experiments.

In all the applied pulse frequencies, fright reflex, attempting to escape from electric field, restless movement, immobilization followed by tetanus have been observed at varying degree (Table 3). Though 100 percent fright reflex have been observed in two electrode-array systems, namely, (1) placed vertically from surface to bottom and (2) laid horizontally at the bottom, yet 40 percent of the animals managed to escape out of the field after 3 to 4 attempts. But in 4-electrode-array, none of the organism could escape out of the field, though fright reflex was noticed in 14 to 60 percent cases depending on the field intensity and pulse rates. Anodic galvanotaxis was highest (86-100%) in vertical two electrode-array at a pulse frequency of 2/

sec. Cathodic galvanotaxis was highest (40%) in horizontal 2-electrode array at a pulse rate of 2/sec., followed by (14-30%) in vertical 4-electrode-array at a pulse rate of 2/sec.

Immobilization followed by tetanus and throwing off their limbs, in 70 to 100 percent animals in all the electrode-array systems, at the pulse rate of 2/sec. and 4/sec. (Table 3).

Thus it can be concluded that the fright reflex with attempts to escape from the field can be best achieved at pulse frequency of 1/sec. At a pulse rate of 2/sec and 4/sec, galvanotaxis followed by immobilization and tetanus can be initiated better.

DISCUSSION

Investigations have been carried out for the visible signs of crab (*Scylla serrata*) behaviour subjected to under-water D.C. and pulsed D.C. field. The definite sequence of reactions, such as, fright reflex attempting to escape out of the field, involuntary restless movement with expanded appendages, often throwing off their limbs followed by muscular rigidity, incapable of movement and tetanus was observed in all the animals tested with the increase of field strength in homogeneous field.

The electrode configuration, used in the present study, consisted of two parallel flat copper plates, placed vertically in the water 90 cm apart. The advantage of such arrangement is that, the electric field strength and current densities in the water are uniform throughout the test region, and, therefore, the reaction of the organism will be the same regardless of its location. This fact made the correlation of responses with the field strength much simpler than it would have been if the field had not been uniform. The changes in the field strength were made by altering the voltages applied to the electrodes.

Fish can perceive minute electrical current in water (Cattley, 1955). According to Holzer (1932), the conductivity of fish body being greater than the surrounding media (fresh water), all the current lines are directed towards the fish body and the organism is thus

Table 2. Relationship between size and threshold intensities for different reactions of *Scylla serrata*

Size of animals		Threshold current densities for different reactions														
Carapace length in mm	Weight in g	D.C.			Pulsed D.C. 2/sec			Pulsed D.C. 3/sec			Pulsed D.C. 4/Sec			Pulsed D.C. 5/sec		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
122	250							0.02	0.888	2.444						
120	340													0.01	0.444	3.888
117	330													0.01	0.5	4.444
113	240	0.011	1.222	6.888												
112	200				0.012	1.888	6.666									
108	200										0.004	0.166	2.222			
105	150							0.05	1.055	2.666						
104	200				0.1	1.634	7.111									
99	140	0.18	1.834	9.554	0.16	1.333	8.888									
94	130										0.014	1.111	2.444			
80	90										0.016	0.722	2.666	0.125	2.222	6.111
44	12				0.18	2.464	9.848							0.13	3.219	8.333

I – Perception of field and fright reflex.

II – Involuntary movement, often dislodging appendages.

III – Immobilization, tetanus and throwing off their limbs.

Table-3. Response of *Scylla serrata* in heterogeneous field of low intensity

Characteristics of electrode array, field intensity and pulse rates	Fright reflex	Escape from Field.	Percentage of responses of <i>Scylla serrata</i>			
			Forced restless movement		Immobilization and dislodging of appendages	Tetanus
			+ve	- ve		
A. 2 sets of aluminum rods at 27 cm. spacing placed vertically 44 cm apart.						
10 mv/cm & 3 μ a/cm ² , 1 pulse/sec	100	40			14	
20 mv/cm & 2 μ a/cm ² , 1 pulse/sec	100	-				
20 mv/cm & 10 μ a/cm ² , 2 pulse/sec	-		86			
30 mv/cm & 7 μ a/cm ² , 2 pulse/sec			100		14	86
B. 4 sets of aluminium rods at 5 cm spacing placed vertically 66 cm apart.						
30 mv/cm & 2 μ a/cm ² , 1 pulse/sec	60			-	40	
40 mv/cm & 2 μ a/cm ² , 1 pulse/sec	40	-	-	-	60	
20 mv/cm & 1 μ a/cm ² , 2 pulse/sec	60		42	14	46	-
28 mv/cm & 2 μ a/cm ² , 2 pulse/sec	30	-		30	70	-
5 mv/cm & 0.5 μ a/cm ² , 4 pulse/sec	30	-	-		70	
10 mv/cm & 1 μ a/cm ² , 4 pulse/sec	14	-	14		-	100
C. 2 sets of aluminium rods at 3 cm. apart placed horizontally 45 cm. from each other.						
90 mv/cm & 27 μ a/cm ² , 1 pulse/sec	100	40	-	-	-	-
180 mv/cm & 18 μ a/cm ² , 1 pulse/sec	40		40	-	20	-
180 mv/cm & 90 μ a/cm ² , 2 pulse/sec	-	-	-	-	100	-
270 mv/cm & 63 μ a/cm ² , 2 pulse/sec	-		-	40	-	60

satisfactorily influenced by electricity. Based on the above principle, visible signs of animal response towards external electric fields followed a definite sequence of reactions with the rise of field intensity.

Data were collected characterising the reactions of the subject species to different electrical current forms (direct and pulsed current) as a function of the applied electrical field strength. Primary emphasis was given on the determination of minimum field strength required to initiate fright reflex, auto-adjustment towards electric field (electrotaxis and immobilization and tetanus) for animals, when a specific current form was used.

The reactions of fish to under-water electric field occur only when the density of current reach a specific value, and those values are constant for fish of the same species and size. Cattley (1955) defined the current density as the intensity of current for any cross-sectional area between the electrodes and can be expressed as amperes per square centimeter (as that is, 10^{-6} amp./mm² in the present experiments).

100% of *Scylla serrata* responded for fright reflex with an attempt to escape out of the field; auto-adjustment with stretched appendages, often throwing off their limbs and immobilization, muscular rigidity and tetanus with the increasing field intensity of homogeneous field.

Earlier work indicated that pulsating D.C. were most effective for electrofishing through the inducement of temporary immobilization of fish (Houston, 1949).

In the present study, however, *Scylla serrata* exhibited directional movement towards electrode, when the pulse frequency was 3/sec. or more. Vibration of the body at each pulse

were noticed at a pulse rate of 5/sec. Reduction of threshold values of current density for the on-set of reactions were only noticed in pulsed D.C. of 3 and 4 pulse per second.

The requirement of reaction thresholds were found to be inversely proportional to the size of the crabs tested. Several reasons can be put forward, but the most evident one is the large specimens have longer nervous structures. Short nerves in an electric field are excited at a higher value of current than long nerves (Laugier, 1921).

It has been stated (Newman, 1959) that the electric fish screen caused a fish response in the nature of a simple avoidance of an unpleasant stimulus, rather than a forced reaction to the directional properties of the field.

In order to observe the avoidance behaviour of *Scylla serrata*, three types double row electrode-array (two placed vertically and one horizontally) was tested with pre-set low and high field intensity and varying pulse rates (1, 2 and 4/sec)

In the present test, 100 percent mud crab exhibited fright reflex even at low field strength of 10 mv/cm² and at low pulse rate of 1/sec. In any heterogeneous field, of course, the animal may avoid high voltages by rapidly swimming away from the electrode-array, which could only be possible at low pulse rate (1/sec. in the present experiment).

At higher pulse rates (2/sec and 4/sec) 70 to 100 percent of mud crabs could no longer escape from the electric field and loss of orientation ability followed by muscular rigidity and throwing off their limbs in some cases occur irrespective of field strength. The immobility of the crab, dropping at the bottom with contractile limbs were recognized as the chief signs of the reaction.

LITERATURE CITED

- BURNET, A.M.R. 1959. Electric fishing with pulsatory direct current, New Zealand Sci., 2 : No. 1, 21-23.
- CATTLEY, J.G. 1955. Your guide to electrical fishing, 4 (3-5), 125, 3, 166 John Trundell Ltd., London : 3-12.

- HOLZER, W. 1932. An absolute stimulus tension in fishing, *Pflugers Archiv. f. d. ges. Physiol. Bd.*, **229** : 153-172.
- HOUSTON, R. B. 1949. German commercial electrical fishing device, U.S. Dept. of Int., Fish and Wildl. Serv., *Fishery Leaflet* No. **348** : 1-4.
- LAUGIER, H. 1921. Electrotonus et excitation-Recherches sur l'excitation d' cuverture. *Thes. Fac. Sec. Dr. Univ.*, : **187** : 124-135.
- MEYER-WAARDEN, P.F. 1957. Electrical fishing, FAO Fisheries Study No. **7** : 5-27.
- NEWMAN, H.W. 1959. Effect of field polarity in guiding salmon fingerlings by electricity, U.S. Fish Wildl. Serv. Spec. Scient. Rep. Fish, **319** : 1-15.
- PATTEN, B.G. and GILLASPIE, Ch. C. 1966. The bureau of commercial fisheries type IV- Electrofishing shocker-its characteristics and operation, *Sepc. Scient. Rep., Fish. U.S. Fish Wildl. Serv.*, **529** : 1-15.
- ROLLEFSON, M.D. 1958. The development and evaluation of interrupted direct current electrofishing equipment, Coop. Res. Project No. I, Colorado, State Univ. Wyoming Game and Fish : 1-18.

BIODIVERSITY CONSERVATION THROUGH PEOPLE'S PARTICIPATION : AN INITIATIVE

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ABSTRACT

As a signatory country to the Convention on Biological Diversity, India has met several obligations concerned with conservation of biodiversity of this country. The most important is the introduction of a legal document aimed towards conservation and sustenance of biodiversity – The Biological Diversity Act, 2002. For implementation of the provisions of the Act, a three tier system has been formed–National Biodiversity Authority (NBA), State Biodiversity Board (SBB) and Biodiversity Management Committee (BMC). Among many others, the most prioritized function of BMC, as per the Act and subsequently the Biological Diversity Rule, 2004 is to document the bioresources and associated knowledge and practices of the people of an area in the form of People's Biodiversity Registers-PBR. This is a new decentralized approach of documentation where the participation of local people has been ensured. This identified approach can contribute to communicating biodiversity messages in a way that engages people's hearts and minds which in turn creates a sense of oneness of the human mind with the surrounding biodiversity and motivates conservation efforts. This dynamic register is not a mere listing of species found in a particular area but addresses a multitude of related components which are relevant to the local inhabitants in resource and landscape management involving the local people. The information is collected under the broad heads of Landscape, Lifescape, Peoplescape, Timescape and Mindscape. The most important aspect of PBR is to engage local people for collecting the information and documenting them in the local language using local terminologies. It is also necessary to validate the information thus collected by experts in related fields and only then would this register serve as a knowledge base for conservation. The West Bengal Biodiversity Board, constituted in September, 2004, has initiated this process in different districts of this state at the Gram Panchayat, village and Municipality levels. The paper is an attempt to review the background of the approach and an overview of the methodology being adopted for the PBR exercise in the state of West Bengal.

INTRODUCTION

Biodiversity is a term in vogue in the present times but the concept is far from being simple and what follows is that the communication challenges for biodiversity issues exist on multiple levels: the complexity of the problem and solutions regarding biodiversity loss; the urgency of the issue; and the competition with other urgent social issues in the media and society (Farrior, 2005). The public is deluged with information, yet there exists a lacuna in understanding of basic ecological principles. As such, a failure to conceptualize biodiversity connections with everyday lives is evident

along with a sense of hopelessness about the issue. Moreover, consistent and continuous messaging and awareness creation regarding biodiversity is also not treated as a priority area. People tend to get confused about what biodiversity is and why they should care about it. Local aspects of biodiversity tend to get neglected in the media, further perpetuating people's lack of connection to the issue. Although the problem of biodiversity loss is complex, but framing biodiversity as simply a species loss issue should not be encouraged, instead biodiversity should be placed in a broader sustainability context, which includes lifestyle change and over-consumption issues.

The approach or strategy to fulfill such goals is obviously involving people and encouraging them to participate in such activities which promote the goals of a sustainable future.

The term biodiversity derived its present status of importance as well as popularity since the Convention on Biological Diversity (CBD) at the United Nations Conference on Environment and Development held at Rio-de-Janeiro in 1992. As a signatory to the CBD, India has met three positive obligations—(i) *Submission of a status report* – A report entitled “Status of Biodiversity in India” was prepared in 1997 and submitted in 1998; (ii) *Submission of “National Biodiversity Strategy and Action Plan (NBSAP)”* in October, 2002 and (iii) *Enacting laws to protect biodiversity of the country* – The Biological Diversity Act, 2002, followed by the formation of the Biological Diversity Rules, 2004. The Biological Diversity Act of 2002 provides necessary statutory and administrative mechanisms to realize the objectives of the CBD. The main intent of the legislation is to protect India’s rich biodiversity and associated knowledge against their use by foreign individuals and organizations without sharing the benefits arising out of such use, and to check bio-piracy. A three-tiered system of regulation is envisaged under the Biological Diversity Act, which consists of the National Biodiversity Authority (NBA) at the head, followed by State Biodiversity Boards (SBB) and local-level Biodiversity Management Committees (BMC).

The first and foremost step aiming at attaining the objective of the Act is to document the biological resources. Such a mammoth task can never see the light of success without the active participation of the common people. At the global level as well, CBD has urged respect towards knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing

of the benefits arising from the utilization of such knowledge, innovations and practices’ [CBD, Article 8(j)] This identified approach, also adopted by India, can contribute to communicating biodiversity messages in a way that address socio-altruistic concerns and make biodiversity relevant to everyday life. This would encourage public involvement in creating PBR – the Register of the people, by the people and for the people. The task is nothing less than inspiring individual and social commitment in order to preserve the diversity of life. This task of preparing the People’s Biodiversity Register has gained momentum as it is a mandatory function of the BMCs (The Biological Diversity Act, 2002; Biological Diversity Rules, 2004).

ACTIONS AND IMPLICATIONS

The basic contents of the PBR attribute a unique character to the registers. This dynamic register incorporates information on status of ecological habitats, population of biodiversity elements – both wild and domesticated/harvested, harvest, trade, transport, processing of bio-resources, demand for and consumption of bio-resources, existing technologies and practices, and also people’s ideas about the management of bio-resources (Gadgil, 2006). The entire exercise of documentation is to be handled at local level based on local information and can be separated into the following sub heads:

- 1) **The Landscape** : The mapping and description of landscape of an area is the first step of preparation of PBR. It covers the habitation as well as, source of the local population’s requirements in terms of food, fuel wood, fodder, leaf manure, medicinal plants etc. Food includes both cultivated and wild, from land and waterbody. Local people have their own understanding of the landscape and they may have specific names for a particular field or waterbody; therefore this mapping is in terms of understanding and naming of the landscape by local people. This description and mapping is an important tool in realizing the

patterns of use and management of different landscape elements by local people as well as outsiders who are also acting upon the local resources. This will, in turn, help the local communities to draw their own strategies for conservation and sustainable use of biological resources and landscape management.

ii) **The Lifescape** : This is an inventory of flora and fauna of the area both wild as well as cultivated/domesticated. This part includes the present occurrence of biological elements along with the history as recounted by the elderly people. Agriculture (varieties, practice, and production) and medicinal plants are two major components in this part. Though informal, it will provide a baseline data on some important aspects which are mostly overlooked, *viz.*, changes in population of weeds and pest species, changes in agricultural practices, availability and exploitation of medicinal plants of that locality. Therefore this account has also its potential value in understanding the present scenario of bioresources of an area.

iii) **The Peoplescape** : It is the documentation of human population in terms of caste, creed, societies, livelihood, etc. This also includes the composition of human population, both resident and nomadic, as regular and occasional user groups, which may be defined from the perspective of their relationship with biological resources, *viz.*, farmers, fishermen, milkmen, artisans depending directly upon natural resources, folk-medicine practitioners etc. This part of PBR has a component of inventory of local traditional knowledge holders. The knowledge is in terms of ecological wisdom and traditional practices which is flowing mostly as oral database. So this part of PBR will reflect the economy of an area depending upon the bio-resources and knowledge and practices thereon, subsequently helping to formulate strategies on wise-use of bio-resources for economic upliftment of the local populace.

iv) **The Timescape** : This part of PBR incorporates the changes in land use pattern, occurrence of bio-resources, patterns of

exploitation of bio-resources, dependence of people on bio-resources etc. in course of time. These are very evident to the local aged people who have natural ecological wisdom. They have their own evaluation on these changes which also are the components of this part. This history is obviously very interesting and important in understanding the effects of the changes which, in turn, would be effective to adopt future management strategies.

v) **The Mindscape** : This final part of PBR is the ultimate reflection of the People's minds about biodiversity and its management in an area. It documents the attitude towards the state sponsored conservation programmes, if any, of that area. Moreover, it also documents the conservation measures existing among the local people in the name of sacred ponds or groves or areas, sacred species, etc. and other religious beliefs, practices associated with the bio-resources. Different stakeholders or user groups have different views in accessing biological resources for their livelihood. The conflicts of different stakeholders are also the components of PBR. The priority areas of conservation, the ways and means of sustainable use of local bioresources, the pros and cons of changing land use pattern, planning towards economic growth etc. have to be integral sections of this part of PBR. So, this would guide the policy makers towards adopting any strategy of development of a particular area.

The West Bengal Biodiversity Board, formed in September, 2004, has started the PBR exercise through BMCs. Several BMCs have been constituted at the Block Level and Municipalities of different districts and the PBR activities have been initiated in Gram Panchayats of those Blocks and the Municipalities. This PBR will be a dynamic register which is to be updated at regular intervals and will be in custody of the concerned BMC. The most important aspect of PBR is to engage local people in such a mighty endeavor. As is evident, this Register will be a record of comprehensive information on availability of bioresources, folk/local knowledge and

traditional practices associated with these resources. Needless to say the information collected by the local people needs to be validated by the concerned expertise and then only it will be a complete register which will serve as a component of the societal knowledge base for conservation.

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LITERATURE CITED

The Biological Diversity Act. 2002. No. 18 of 2003. Section 41 of Chapter X.

Biological Diversity Rules. 2004. G.S.R. 261 (E). Rule 22 (6).

Convention on Biological Diversity (1992). <http://www.cbd.int/doc/legal/cbd-un-en.pdf>

People's Biodiversity Register (Volume-1 Biodiversity) A Simplified Methodology (2008). <http://www.nbaindia.org/docs/comments-the-public.pdf>.

FARRIOR, M. 2005. Breakthrough Strategies for Engaging the Public: Emerging Trends in Communication and Social Sciences. Biodiversity Project. Madison WI.

GADGIL, M and SESHAGHIRI RAO, P. R. 1998 *Nurturing Biodiversity : An Indian Agenda*. Centre for Environment Education, Ahmedabad.

GADGIL, M. 2006. *Methodology Manual for People's Biodiversity Register*. National Biodiversity Authority, Chennai.

INFLUENCE OF ABIOTIC FACTORS ON POPULATION BUILD UP OF WHITEFLY, *DIALEUROPORA DECEMPUNCTA* (QUAINTANCE & BAKER) AND THEIR RELATION WITH CROP LOSS ON MULBERRY, *MORUS ALBA* L

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ABSTRACT

Population dynamics in insects are the result of interaction between physical condition, population movement and both density dependent and independent factors. Influence of abiotic factors viz., average maximum and minimum temperature, average maximum and minimum relative humidity (R.H) and rainfall on seasonal occurrence of whitefly *Dialeuropora decempuncta* on mulberry plantation and their relation to crop loss for two consecutive years during 2002 and 2003 was assessed in Murshidabad and Birbhum districts of West Bengal. The results indicate that the whitefly adult and nymphal population starts building up from June onwards thereafter reaches peak in August and September. The increase of adult population of whitefly is positively and significantly correlated with the R. H. and rainfall in the two districts. In Murshidabad district the peak population of adults i.e., 18.00 & 45.63/leaf and nymphal population i.e., 11.98 & 13.64/leaf reaches in August and September with a percent crop loss of 6.35 and 16.64 respectively. In Birbhum district the peak population of adults i.e., 28.47, 29.42 & 15.04/leaf and nymphal population i.e., 15.37, 35.72 & 5.44/leaf reaches with a percent crop loss of 10.07, 25.83 and 7.30 in August, September and November respectively. During 2002 high percentage of crop loss with boost up population was observed but that trend was not observed in the year 2003. A prediction model was fitted with all the lag abiotic factors and with the help of statistical Stepdown Regression analysis, it was predicted that there is a relation between whitefly populations and the R. H. and rainfall. It was revealed that average minimum relative humidity and rainfall is positively and most significantly responsible to boost up the adult population which affect the crop loss in mulberry.

Keywords : Whitefly, Seasonal incidence, Abiotic factors, Crop loss, Stepdown Regression and Multiple Correlation

INTRODUCTION

Among the various species of insects reported on mulberry (*Morus alba* L), the whitefly *Dialeuropora decempuncta* (Quaintance & Baker) (Homoptera : Aleyrodidae) is one of the most economically damaging pests in certain areas of Malda, Murshidabad and Birbhum districts of West Bengal (Bandyopadhyay *et al.*, 1999). The pest is

polyphagous and is active throughout the year in different host plants depending upon regional ecological conditions (Bandyopadhyay and Shantakumar, 2003). The damage occurs in various ways; reducing mulberry crop yield by sucking plant sap and long delicate nymphal filamentous wax covering the leaves thus reducing the photosynthetic area results in yield reduction. It can cause serious indirect damage to the crop due to honeydew excretion

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on leaf what encourage growth of sooty mould fungus and in turn affect the yield both in quantitative and qualitative terms.

The intensity of this whitefly population has been found increasing alarming in mulberryfields of Jorhat, Assam causing a considerable loss to mulberry crop by reducing leaf yield (Rajkhowa and Chakravorty, 2004). Bandyopadhyay *et al.* (2005) reported the increase in pupulation of various stages of aleyrodid at Malda district of West Bengal is significantly correlated with increase in previous seven days of average maximum relative humidity (R. H.) at Malda district of West Bengal.

In last decade among different whiteflies in the agricultural fields, some scientists reported the relation of whitefly population with the fluctuation of abiotic factors. David *et al.* (1973) reported, the increase in population of various stages of castor aleyrodid *Trialeurodes rara* Singh being significantly correlated with increase in maximum temperature. Verma *et al.* (1990) reported on the influence of temperature on development of whitefly *Bemisia tabaci* on tomato. Rao & Chari (1992) showed the population dynamics of whitefly *Bemisia tabaci* in cotton and tobacco in relation to weather factors. Selvakumaran *et al.* (1999) reported that the abiotic components had only 24% and 43% influence on the population build up of cardamom whitefly *karakarajiella cardamomi* on cardamom. Duration of different life stages of whitefly, *Bemisia tabaci* was found negatively correlated with temperature and relative humidity (Chaudhuri *et al.*, 2001). Srivastava (1993) opined that climatologically conditions like temperature, humidity directly affect the population of both pest and host plants and was responsible to disperse the pests to particular localities or spread far and wide.

In view of the serious outbreak of *Dialeuropora decempuncta* in three traditional districts related with sericultural activities in West Bengal and also the importance of whitefly as a serious pest, an effort was made to study the population dynamics of whitefly on mulberry crops at farmers level in relation to

weather factors and also to study the crop loss in relation to the population size in Murshidabad and Birbhum district of West Bengal, so that the information can effectively being utilized in formulating the pest management programme.

MATERIALS AND METHODS

The experiments were conducted for two years from 2002 to 2003 in the mulberry fields from 25 villages under 6 blocks involved in mulberry sericulture of Murshidabad district and under 4 blocks involved in mulberry sericulture of Birbhum district. Population of whitefly was recorded in randomly selected 7 mulberry plots per village. The adult population from top two leaves, early nymphs from middle two and late nymphs from bottom two leaves of 10 randomly selected plants per plot was assessed as because adult whiteflies exhibited more on the top leaves. Early and late nymphal population was more on the middle and bottom leaves respectively.

For assessing leaf loss percentage leaves affected by leaf curl and sooty mould disease were counted as those were unfit for silkworm rearing along with healthy leaves per plant. Similarly 10 plants were selected randomly from each plot. Average leaf loss percentage was assessed by counting the infected leaves versus total number of leaves per plant.

The abiotic factors viz., maximum and minimum temperature and relative humidity (R. H.) and also rainfall were recorded daily and mean values of each of the population recorded were taken into consideration for statistical analysis involving the abiotic factors as independent variables and population as dependent variables for simple correlation and multiple regression analysis. Correlation and Multiple Regression Analysis (Draper and Smith, 1981) were made to find the relationship significantly or not and also positive or negative between the whitefly populations build up with the weather factors. In multiple regression all the independent factors may not be equally responsible for explaining variation in the dependent factors. So the objective comes out

to identify the most important independent factors through step down regressin process.

RESULTS

Fluctuation of whitefly population during the crop growing season for two years from July 2002 to December 2003 revealed that the whitefly population in the mulberry crop was initiated on the onset of monsoon in West Bengal. Heavy whitefly population was observed for a short period subsequently to rainy periods and their numbers were comparatively low during the rest of the year which is in line with the findings of Seif (1981) on Cassava in Kenya. The whitefly population gradually increased in all sericultrual areas of Murshidabad and Birbhum districts from July onwards till November. Moderate population was maintained upto last weak of July in both the districts. In Murshidabad district the peak population of adults i.e., 18.00, 45.63 and 4.21/ leaf and nymphal population i.e., 11.98, 13.64

and 2.04/leaf reaches in August, September and November in 2002 with a percent crop loss of 6.35 and 16.64 respectively only in August and September month (Fig. 1). As the population in the month of November is very few in number, so the percent crop loss was not observed in the field in the year 2002. In the next year the population was very negligible. More or less same trend was observed in Birbhum district. In Birbhum district the peak population of adults i.e., 28.47, 29.42 & 15.04/leaf and nymphal population i.e., 15.37, 35.72 & 5.44/ leaf reaches with a percent crop loss of 10.07, 25.83 and 7.30 in August, September and November respectively (Fig. 2) in the year 2002. Like that of Murshidabad district in the year 2003 same trend was observed. Rajkhowa and Chakravorty (2004) reported that in Jorhat, Assam whitefly, *Dialeuropora decempuncta* remained active from August and reached its peak in October on mulberry plantation, confirms the present investigation.

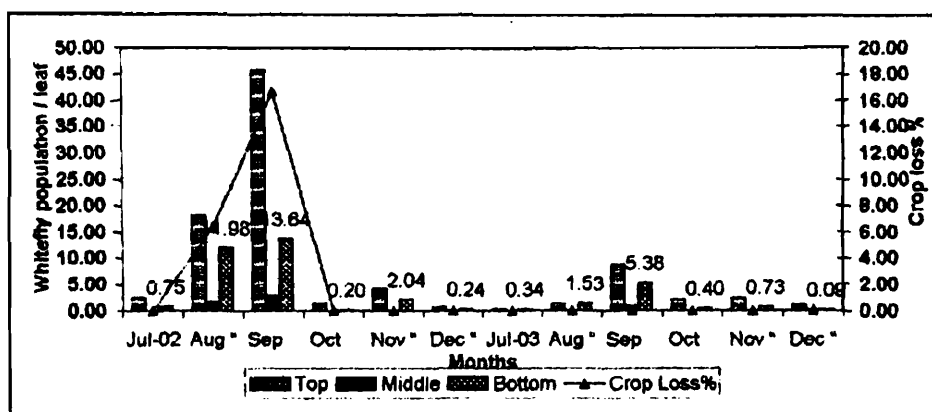


Fig. 1. Whitefly population in relation to crop loss in Murshidabad district

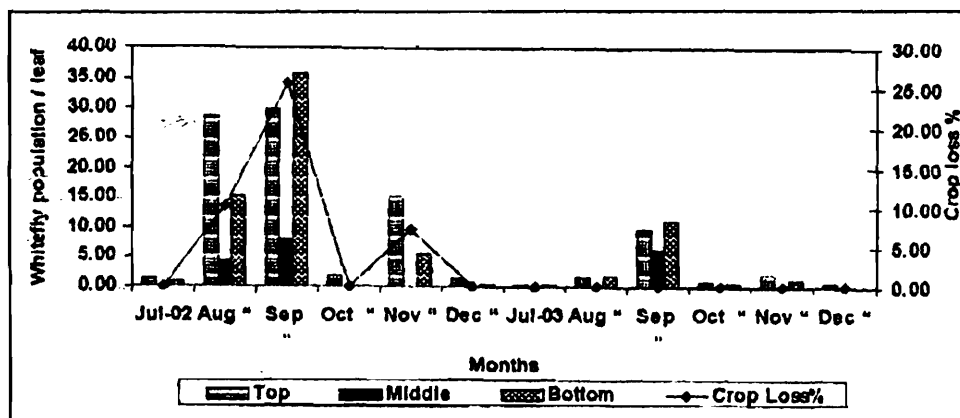


Fig. 2. Whitefly population in relation to crop loss in Birbhum district

It was revealed that there is a positive correlation in increase population with increase in crop loss (Fig. 1 & 2). The same type of relation between whitefly *B. tabaci* with crop loss was reported by Mound (1965) on cotton in Sudan. The relationship between *B. tabaci* with 20-95% yield loss in tomato was also noticed by Verma *et al* (1989). It was observed that minimum R. H. is correlated with the population build up of whitefly (Table 1 & 2), which is related with the finding of David (1963) in the aleyrodid, *Siphoninus phillyreae finitimus* Goux on Pomegranate. Whereas the maximum temperature and R. H. exhibited a significant negative association with population build up

of adult whitefly and nymphs (Fig. 3 & 4), which is in conformity with the findings of Selvakumaran *et al* (1999) in the whitefly *kanakarajiella cardomomi* on cardamom. The results under present investigation were not in conformity with Rajkhowa and Chakravorty (2004) where whitefly population on mulberry was nonsignificant negative correlation with rainfall and positive correlation with maximum temperature and R. H. in Jorhat, Assam. This might be due to wide variation in temperature and relative humidity in two completely different agro ecological situations. The same type of statistical result was shown by Rao and Chari (1992) on whitefly *B. tabaci* on tobacco.

Table 1. Results of Correlation between the population levels of *Dialeuropora decempuncta* and abiotic factors of Murshidabad district.

Variables	Top pop	Mid pop	Bot pop	Leaf loss%	MaxTem	MinTem	Max RH	Min RH	Rainfall
Top pop	1.000								
Mid pop	0.944**	1.000							
Bot pop	0.897**	0.869**	1.000						
Leaf loss	0.905**	0.922**	0.856**	1.00					
Max Temp	0.242	0.188	0.272	0.213	1.00				
Min Temp	0.310	0.255	0.327*	0.253	0.886**	1.00			
Max RH	0.093	0.059	0.023	-0.039	-0.367	-0.098	1.00		
Min RH	0.454**	0.373**	0.397**	0.219*	0.271	0.526**	0.326*	1.00	
Rainfall	0.336*	0.315*	0.326*	0.269	0.504**	0.827**	0.293*	0.715**	1.00

*Significant at 0.05 and ** Significant at 0.01

Table 2. Results of Correlation between the population levels of *Dialeuropora decempuncta* and abiotic factors of Birbhum district.

Variables	Top pop	Mid pop	Bot pop	Leaf loss%	MaxTem	MinTem	Max RH	Min RH	Rainfall
Top pop	1.000								
Mid pop	0.536**	1.00							
Bot pop	0.719**	0.888**	1.00						
Leaf loss	0.802**	0.560**	0.845**	1.000					
Max Temp	0.143	0.236	0.199	0.068	1.000				
Min Temp	0.279	0.333*	0.311*	0.189	0.909**	1.000			
Max RH	0.315*	0.352*	0.326*	0.239	0.211	0.519**	1.000		
Min RH	0.330*	0.422**	0.378**	0.262	0.475**	0.726**	0.797**	1.000	
Rainfall	0.702**	0.317*	0.379**	0.437**	0.427**	0.551**	0.456**	0.501**	1.00

*Significant at 0.05 and ** Significant at 0.01

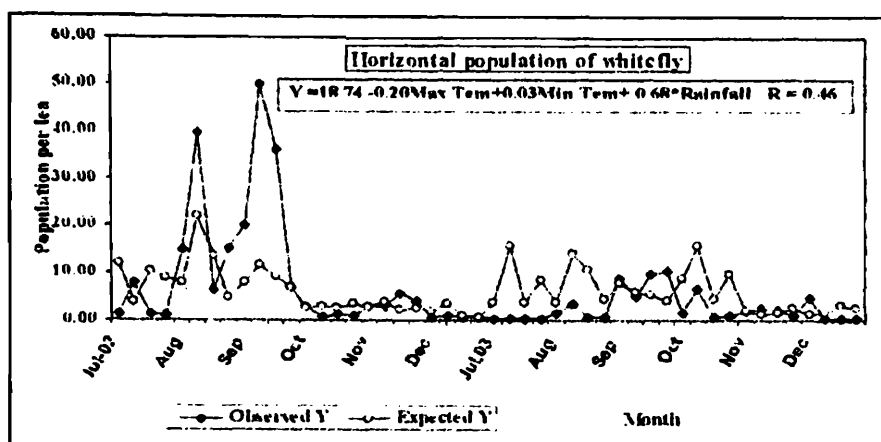


Fig. 3. Prediction of Whitefly population based on abiotic factors at Murshidabad district

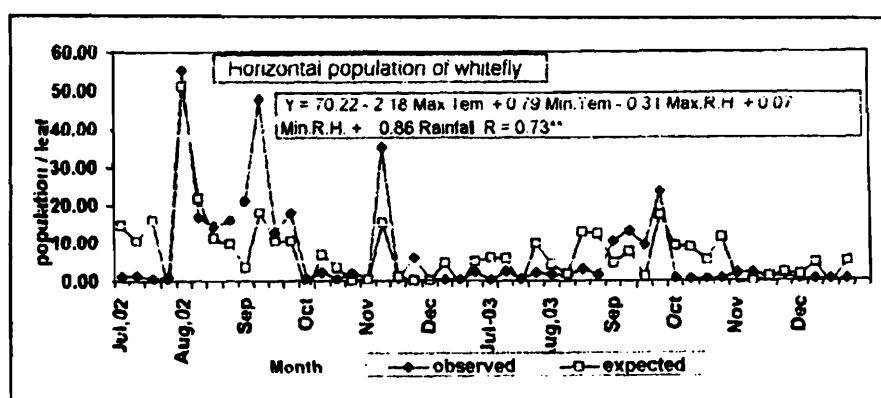


Fig. 4. Prediction of Whitefly population based on abiotic factors at Murshidabad district

DISCUSSION

In Murshidabad and Birbhum districts the whitefly population in the year 2002 was high but in the year 2003 it was negligible. It may be due to high temperature and scanty rainfall exhibited in the year 2003. The observation of present study on the intensity of whitefly population was more or less similar with that of Rajkhowa and Chakravorty (2004) as far as ascending and descending phase of occurrence of whitefly population was concerned, except the peak period, which was observed during October in Jorhat, Assam. This might be due to variation in regional climatic conditions. As the abiotic factors were different from season to season and year to year, for that reason probably whitefly incidence was different. During silkworm rearing at farmers level it was observed the shortage of qualitative mulberry leaves during August-September commercial crop season at Murshidabad and Birbhum districts. This was caused due to heavy infestation of whitefly during that period which

caused heavy economic damage with leaf loss by direct feeding and indirectly by interfering photosynthesis by sooty mould fungus, which settles on honeydew excreted by the nymphs. As maximum whitefly population was observed in the rainy season and as a significant positive correlation was found between rainfall and the whitefly population, so it may be suggested that the rainfall resulted in the abundance production of succulent young leaves on which the whitefly adults feed.

In both the district it was noticed that the maximum temperature is negatively correlated. So it may be detrimental for build up of whitefly population. That means a steady temperature, R. H. and rainfall are preferably for the build up of whitefly population. Lal (1981) observed that stable temperature and rainfall favored the population build up of *B. tabaci* on Cassava.

As whitefly population had more significant positive correlation with minimum R. H. and rainfall, so the present study indicated that

minimum R. H. and rainfall in the month of August and September might have favored the multiplication of whitefly population and it shows that under tropical conditions humidity in general plays a more important role in conditioning the infestation of aleyrodids than any other weather factors. This finding was in contrary to that of Rajkhowa and Chakravorty (2004). Statistically it was predicted by Step down regression analysis that there is a relation between whitefly population with the relative humidity and rainfall, which is mostly responsible to boost up the population at top canopy level.

From a pest management point of view, control strategies to prevent such population explosions to be a more effective approach than to control the pest when it reached the ETL value.

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LITERATURE CITED

- BANDYOPADHYAY, U. K., RAINA, S. K. CHAKRABORTY, N., SANTHA KUMAR, M. V. SEN, S. K. and SARATCHANDRA, B. 1999. New record of a Homopteran pest on Mulberry (*Morus alba*). *Sericologia.*, **39** : 319-321.
- BANDYOPADHYAY, U. K. and SANTHA KUMAR, M.V. 2003. Record of host plants of whitefly, *Dialeuropora decempuncta* Quaintance and Baker in West Bengal. *Insect & Environment.*, **8** : 177-178.
- BANDYOPADHYAY, U. K., SANTHA KUMAR, M. V., SAHU, P. K. and SARATCHANDRA, B. 2005. Influence of weather factors on the incidence of mulberry aleyrodids *Dialeuropora decempuncta* (Quaintance and Baker) and their relation to yield loss. *Int. J. Indust. Entomol.*, **11** : 129-133.
- CHAUDHURI, N., DEB, D. C. and SENAPATI, S. K. 2001. Biology and fluctuation of whitefly (*Bemisia tabaci* Genn) population on tomato as influenced by abiotic factors under Terai region of West Bengal. *Ind. J. Agric. Res.*, **35** : 155-160.
- David, B. V. 1963. Effect of weather factors on the host predators relationship in the aleyrodid, *Siphoninus phillyreae* finitimus on Pomegranate. *Madras. Agric. J.*, **50** : 3-21.
- DAVID, B. V. RADHA, N. V AND SESHU, K. A. 1973. Influence of weather factors on the population of the castor Aleyrodid *Trialeurodes rara* Singh. *Madras. Agric. J.*, **60** : 496-499.
- DRAPER, N. and SMITH, H. 1981. Applied Regression Analysis. 2nd Edi. John Wiley and Sons : New York.
- LAL, S. S. 1981. Ecological studies of whitefly *B. tabaci* (Genn) population on cassava *Manihot esculenta* Grantz. *Pestology.*, **5** : 11-17.
- MOUND, L. A. 1965. Ecological studies of whitefly *B. tabaci* (Genn) population on cassava *Manihot esculenta* Granz. *Pestology.*, **5** : 11-17.
- MOUND, L. A. 1965. Effect of leaf hair on cotton whitefly population in the Sudan. *Gezira. Emp. Sudan Cotton Gr. Rev.*, **42** : 33-34.
- RAO, G. R. AND CHARI. M. S. 1992. Population dynamics of whitely *Bemisia tabaci* Gen. in cotton and tobacco in relation to weather factors. *Tob. Res.*, **18** : 73-78.

- RAJKHOWA, G and CHAKRAVORTY, R 2004. Studies on the intensity and seasonal population variation of whitefly *Dialeuropora decempuncta* Quaintance and Baker on mulberry *Morus* sp in relation to abiotic factors. *Indian. J. Seri.*, **43** : 204-206.
- SEIF, A. A. 1981. Seasonal fluctuation of adult population of the whitefly, *Bemisia tabaci* on cassava, *Insect. Sci. Application.*, **1** : 363-364.
- SELVAKUMARAN, S; DAVID, B. V. and KUMARESAN, D. 1999. Influence of abiotic factors on population build up of cardamon whitefly *Kanakarajiella cardamomi* (David and Subramanian) on Cardamom (*Elettaria cardamomum* Maton). *J. Sp. Aro. Crop.*, **8** : 67-71.
- SRIVASTAVA, K. P. 1993. A text Book of Applied Entomology Vol-1. Kalyani Publishers. India. pp. 3-126.
- VERMA, A. K., BASU, D., NATH, P.S., DAS, S., GHATAK, S. S. and MUKHOPADHYAY, S. 1989. Relationship between the population of whitefly *Bemisia tabaci* Genn (Homoptera : Aleyrodidae) and the incidence of tomato leaf curl virus disease. *Indian J. Mycol. Res.*, **27** : 49-52.
- VERMA, A. K., GHATAK, S. S. and MUKHOPADHYAY, S. 1990. Effect of temperature on development of whitefly (*Bemisia tabaci*) (Homoptera : Aleyrodidae) in West Bengal, *Ind. J. Agric. Sci.*, **60** : 332-336.

EVOLUTION OF AVIAN JAW KINESIS AND TROPHIC DIVERSIFICATION ACROSS KT-BOUNDARY : A REVIEW

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ABSTRACT

The basic transformation of the avian skull kinesis is important in the evolutionary patterns of the trophic diversification of the major avian taxa which successfully crossed the Cretaceous-Tertiary boundary (KT-boundary) about 65-75 MY ago and established themselves through the KT-transition period. The pre-bird skull led to two principal designs of the jaw apparatus with increased biting forces: a pre-rhynchokinetic and a pre-prokinetic jaw designs. The other line of pre-bird skull was either akinetic (Dromaeosaurids), mesokinetic or prekinetic (*Archaeopteryx*, Alvarezsaurids, etc.) having undetached palate. Hence three major skull designs were obtained : Dromaeosaurids-Enantiornithid-Archaeopterygo-morphs; Ornithomimid-Hesperornitho/Ratitomorphs; and Troodontid/Neognathomorphs. These three types of generalized skull architecture gave rise to three principal types of trophic ecomorphs : (1) Graspers; (2) Browsers that evolved into catchers, browsers and grazers; and (3) Graspers that gave rise to catchers, probers, peckers and slicers. Within each group one lineage of akinetic jaw persisted. The first group represented either meso or pre-kinetic skull while the second and third groups characterized by detached palatal complex represented pre-rhynchokinetic and pre-prokinetic designs which evolved into primary rhynchokinetic and primary prokinetic jaws respectively.

Thus a triplet of neognath trophic ecomorphs and the palaeognaths crossed the KT-boundary, survived through KT-transition as well as Oligocene transition periods to evolve as modern palaeognaths and neognaths.

The trophic diversification was a survival strategy for crossing the KT-boundary against unusual drop of temperature and subsequent radiation was possible once the birds developed suitable adaptations to combat changing eco-systems.

Keywords : Avian jaw kinesis : trophic diversification

INTRODUCTION

The present analysis by the author is a critical review of two excellent publications on "Evolutionary patterns of trophic diversification" (Zweers, G.A., J.C. Vanden Berge and H. Berkhoudt, 1997) and "Birds at geological boundaries" (Zweers, G.A., and J.C. Vanden Berge, 1997/98).

Both these papers highlight the origin of cranial and jaw kinesis in birds through time and space, organismic evolution in birds (such as bipedality, flight, slenderization of cranial bars, endothermy, feathers, heterocoely of vertebrae etc.) as well as their ability to cross

the KT-boundary, survive through KT-transition period and radiate into modern orders of neognaths.

The cladistic and phylogenetic interpretations, mainly based on palaeontological records are changing fast with the discovery of many new fossils. And to this approach must be added comparatively recent findings and interpretations in Molecular Systematics (Sibley and Ahlquist, 1990) which has largely reshaped the conventional cladistic concept in avian phylogeny (Cracraft, 1986; Sanz *et al.* 1995 and Chiappe, 1995a). In the two publications cited above, Zweers & Vanden Berge (1997/98) and Zweers *et al.* (1997) have

analyzed the phylogeny of birds in the context of trophic diversification across the KT-boundary and their subsequent radiations.

This review attempts to integrate and summarize the concept of the origin and evolution of birds in the light of avian jaw kinesis vis-à-vis trophic diversification across KT-boundary.

EVOLUTION OF AVIAN JAW KINESIS

The evolution of jaw kinesis in birds is not a 'de-novo' innovation in the group but it has been acquired from their reptilian ancestors or even earlier from the crossopterygian fishes (Feduccia, 1996).

The caelurosaur cranium and jaws were akinetic and considering the theropod coelurosaur as a monophyletic basal stock for avian evolution, the triplet of trophic ecomorphs for the neognaths and one ecomorph for the palaeognaths as suggested by Zweers *et al.* (1997) may be correlated with the acquisition and diversification of jaw kinesis in different birds. Certain changes in the skeletal configuration of the cranium in course of avian evolution (such as detachment of the palatal complex, streptostyli of the quadrate, etc.) were key innovations towards kinesis of the jaws.

A few representative skull designs are shown here from the Triassic thecodont *Euparkeria* (*Pseudosuchia*) to the Jurassic aviform *Archaeopteryx* to illustrate the dermatocranial fenestration, quadrate-pterygoid-palatine and jugo-maxillary complexes in the skull (Fig. 1).

In the coelurosaurian architecture of the skull (e.g., *Compsognathus*), absence of kinesis or a tendency toward a pre-kinetic condition may be assumed. The coelurosaurian skull represents a typical archosaurian skull—heavily built, with fused temporal fenestrae, thick and stout cranial bars, numerous large teeth and amphicoelous vertebrae. Kinesis was not possible in such a type of skull. Among the maniraptoran Dromaeosauridae (e.g., *Deinonychus*) or in the Alvarezsauridae (e.g., *Alvarezsaurus*, *Mononykus*), the skull was also akinetic. They have been considered as non-avian coelurosaurian dinosaurs (Zhow, 1995). Chiappe *et al.* (1996) comment that they represent very basal metornithean lineage.

Archaeopteryx may have evolved through a Pre-*Archaeopteryx* stage where metakinetic hinge was replaced by a mesokinetic hinge in the skull and the quadrate became streptostylic. This condition persisted in *Archaeopteryx*, which either possessed a mesokinetic or an amphikinetic skull (i.e., with both meso- and metakinetic hinges), a streptostylic quadrate and with uncoupled kinesis of jaws.

The post-*Archaeopteryx* Enantiornithes represented by *Sinornis*, *Concornis*, *Cathayornis* and *Gobipteryx*, as also an earlier form *Patagopteryx* were all pre-bird forms known as 'Palaeoavis'. They also retain teeth (except *Gobipteryx*) that are smaller in size and number. These birds exhibit meso- or prokinesis but were far from developing a rhynchokinetic or a prokinetic skull as achieved by the Ornithurine.

The other line of pre-bird skull showed decreased cranial bars with longer snout, wide at base. These birds developed long neck, heterocoelous vertebrae and were prepared for kinesis in the skull. From such a skull type were derived two lines of kinesis—one towards pre-rhynchokinesis and the other towards prokinesis which eventually evolved in the Ornithurine into primary rhynchokinetic (as in the Hesperornitho-Ratitormorph group) and primary prokinetic (as in the early Neognathomorph group) jaws respectively. Both these types of kinesis were possible due to detachment of the palatal complex together with slenderization of the cranial bars. With remarkable trophic divergence in the neognaths, secondary rhynchokinesis (charadriiform, columbiform and many other birds) and secondary prokinesis (most passeriform birds) evolved among the neognaths. As the Odontognaths and the Palaeognaths diverged earlier than the neognaths and possessed rhynchokinetic upper jaw, Zhow (1995) suggested that rhynchokinesis may have appeared earlier than prokinesis. This assumption is contrary to the views held by Hofer (1949) and Bühler (1987).

It is evident that along with the radiation of neognath birds across the KT-boundary through time and space, several grades of

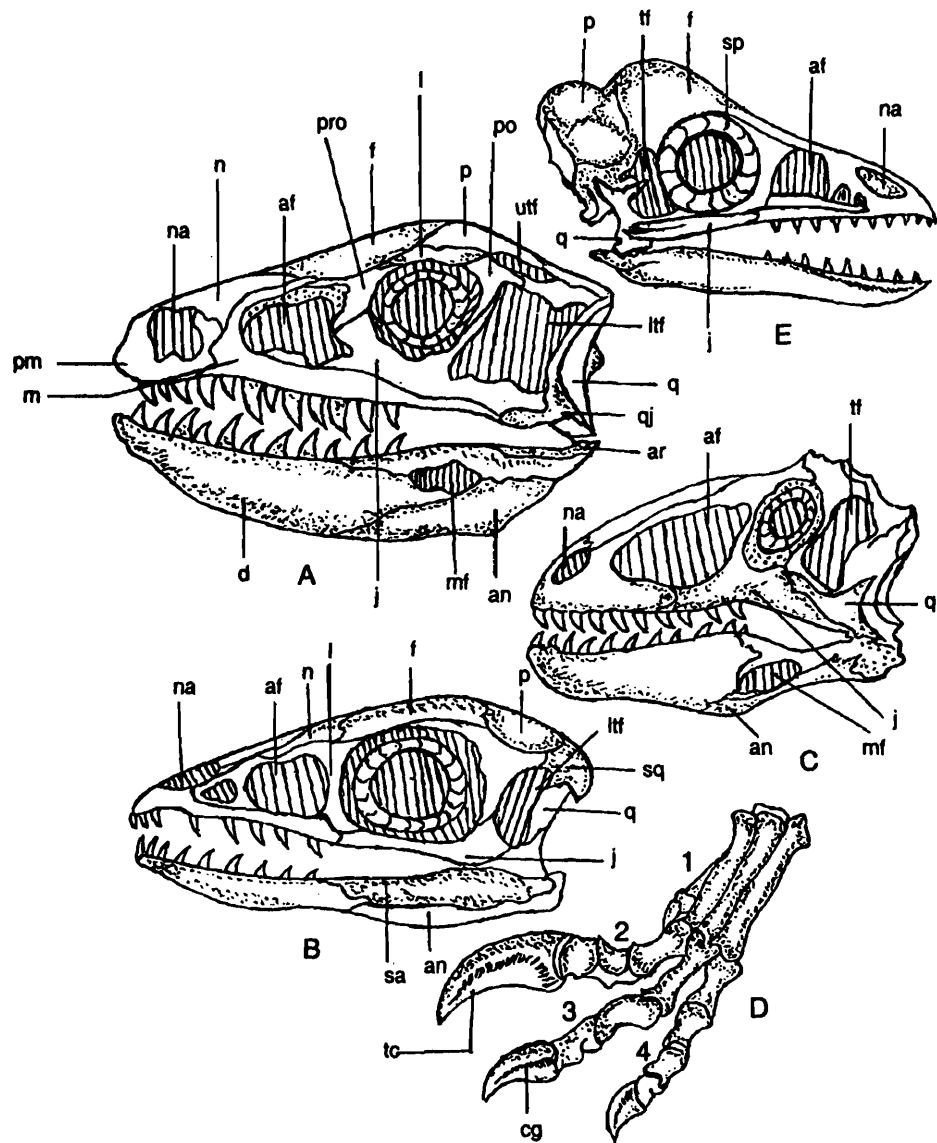


Fig. 1. Lateral view of a few archosaurian skull types showing changes in dematocranial fenestration, jugo-maxillary configuration and dentition. A. *Euparkeria* (basal archosaur; Thecodontia); B. *Compsognathus* (coelurosauria; Theropoda); C. *Deinonychus* (Dromaeosauridae; Coelurosauria); D. Foot of *Deinonychus* showing digits 2 bearing the enormous 'temple claw' which is raised upward and backward while running on digits 3 and 4; E. *Archaeopteryx* (the legendary reptile-bird and recognized as the first avian relic).

[af — Antorbital fenestra; an — Angular; ar — Articular; cafz — Caudal Flexon Zone; cfh — Craniofacial hinge; cfz — Central flexon zone; cg — Claw groove; d — Dentary; db — Dorsal Bar; f — Frontal; fz — Flexon zone; hn — Holorhinal Nostril; j — Jugal; l — Lacrimal; lb — Lateral Bar; ltf — Lower Temporal Fenestra; m — Maxilla; mf — Mandibular foramen; n — Nasal; na — Narial aperture; nis — Nasal-interorbital septum; p — Parietal; pa — Palatine; pm — Premaxilla; po — Postorbital; pro — Preorbital; pt — Pterygoid; prf — Prefrontal; q — Quadrate; qj — Quadratojugal; qmj — Quadrato-mandibular joint; rfz — Rostral Flexon Zone; sa — Supraangular; sp — Sclerotic plates; sq — Squamosal; tc — Terrible Claw (Temple claw); tf — Temporal Fenestra; utf — Upper temporal fenestra; vb — Ventral bar]

rhynchokinesis and prokinesis evolved. This was possible due to several changes of which the detachment of palate from the brain case was the key innovation.

A brief explanation to prokinesis and rhynchokinesis is given below.

1. Prokinesis : A prokinetic skull is that in which the upper jaw as such is not flexible, but it moves up and down as a single unit around a craniofacial hinge (cfh). The hinge may be formed by a craniofacial flexon zone at that site where a gap called 'craniofacial hiatus' occurs between the nasal and interorbital

septum. In some larger birds (e.g., *Anser*, *Pelecanus*), a true synovial joint occurs at the nasofrontal hinge. Further, a flexible zone is present, one in the nasal process of the premaxilla and the other at the premaxillar process of the nasal. In a prokinetic skull, the oval naris lies rostral to the craniofacial hinge and the interorbital septum is not continuous with the nasal septum. This is referred to as 'holorhinal nostril' which is usually the characteristic type of a prokinetic skull (e.g., Passerimorphs).

Prokinesis may be of two types : (1) **Uncoupled**, where the movement of the upper jaw is not coupled with that of the lower jaw so that both the jaws can be moved independently; (ii) **Coupled kinesis**, where the movable quadrate takes a leading role in depressing the lower jaw and raising the upper jaw. In fact, the movements of both the jaws are coupled in such a way that the mandible cannot be depressed without raising the upper jaw, but the upper jaw can be raised without correlated depression of the lower jaw (Bock, 1964; Fig. 2).

2. Rhynchokinesis : Following Bock (1964), the skull may be called rhynchokinetic where the dorsal and ventral bars of the upper jaw have flexible regions within them and the two bars are separated by a flexible lateral bar of the nasal. A rhynchokinetic skull lacks in a craniofacial hiatus or hinge.

A rhynchokinetic skull usually (but not always) possesses a schizorhinal nostril in which the nasal-interorbital septum extends continuously within the nasal cavity (e.g. Tinamou-ratitiforms; trochilid, charadriiforms, columbid, gruid skulls)

Bühler (1981) has elaborated various grades of avian rhynchokinesis and prokinesis with examples and Bock (1964) has summarized the possible sequence in the evolution of skull features and kinesis in jaws with the help of a dendrogram. Bock (1964) states that from the ancestral stock of modern birds possessing prokinetic skull, secondary rhynchokinesis might have been derived later in the gruids and charadriiform birds (Fig. 3).

The evolutionary significance of avian jaw kinesis has enormous bearing on the trophic diversification of birds, because feeding novelties in modern birds would not have been possible without kinetic jaws. Adaptability for diversified food and feeding was possible only after the acquisition of a light-weight toothless skull, detached palate, fully rhamphothecad, kinetic jaws and heterocoelous vertebrae.

Fig. 4 : depicts the skull type, palate and trophic diversification from the coelurosaurs to birds.

TROPHIC DIVERSIFICATION ACROSS KT-BOUNDARY

Zweers and Vanden Berge (1997/98) have referred to a symposium on "Vertebrate design at geological boundaries" (Kardong and Zweers, 1997) where some important questions were addressed about relationships of vertebrate evolution and occurrence of geological boundaries. This meeting also discussed about which avian taxa could successfully cross the KT-boundary and while others could not. What were the preadaptations that equipped the successful ticket-holders to cross the KT-boundary? Zweers and Vanden Berge (1997/1998) have discussed several hypotheses on the timing of radiation of modern birds. Feduccia (1995, 1996) stated that only one representative of one order was already present before the KT-boundary. It appears that this hypothesis too is not sufficient to explain the fate of other representatives of each order. A consensus hypothesis states that all the extant orders were present before the KT-boundary, and so, they faced little problem to cross the boundary. This hypothesis, however, does not mention about the special attributes of those birds which could cross the KT-boundary unaffected and many other aviform coelurosaurs could not pass through and became extinct.

The alternative proposal by Zweers *et al.* (1997) and Zweers and Vanden Berge (1997/98) explains stepwise acquisition of jaw kinetics and other features by birds as suitable preadaptations for crossing the KT-boundary

and for evolving into several feeding groups called trophic ecomorphs. These authors have proposed 4 trophic ecomorphs—one of palaeognaths and three of neognaths. The Pico-Passerimorphs including the song birds have been labeled by these authors as the latest neognath radiation from the Galli-Columbi-Falconimorph lineage (Fig. 5).

It is observed from palaeontological records that there has been mass extinction of many coelurosaurian dinosaurs throughout the cretaceous period. Many of these coelurosaurs which started showing some aviform characteristics were either fully or partially dented graspers with akinetic skull (e.g., Dromaeosauridae) or the Palaeo-avis with

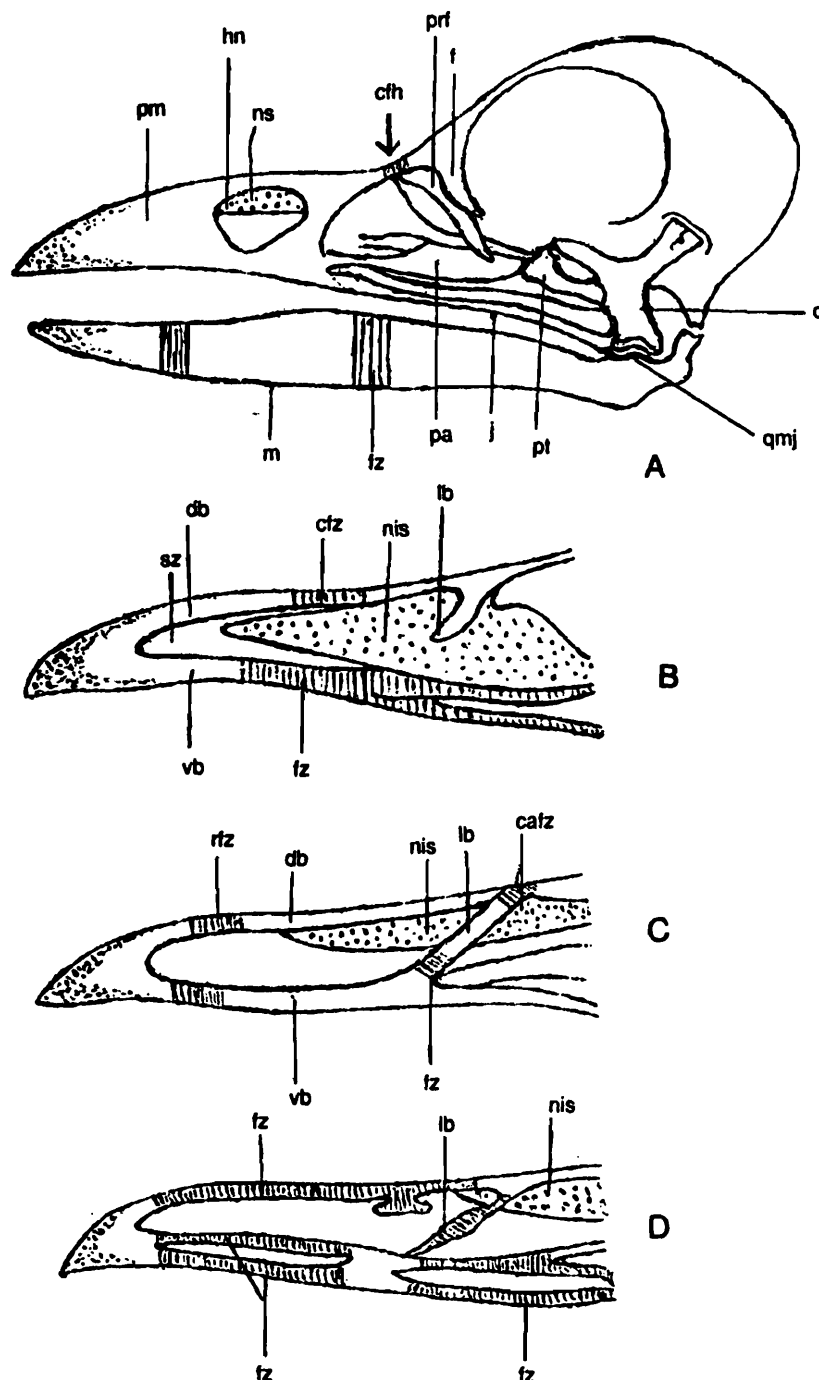


Fig. 2. Lateral view of the skull (A) and upper jaw (B,C,D) showing prokinetic and rhynchokinetic jaws. A. prokinetic skull with holorhinal nostril and craniofacial hinge/craniofacial flexion zone in the upper jaw and a pair of mandibular flexion zones; B. Ratifomorph rhynchokinesis with incomplete lateral bar and central flexion zones; C. charadriiform rhynchokinesis with proximal and caudal flexion zones; D. Trochilid rhynchokinesis with extensive flexion zones in both dorsal and ventral bars (modified from Bühler, 1981). [For abbreviation see Fig. 1]

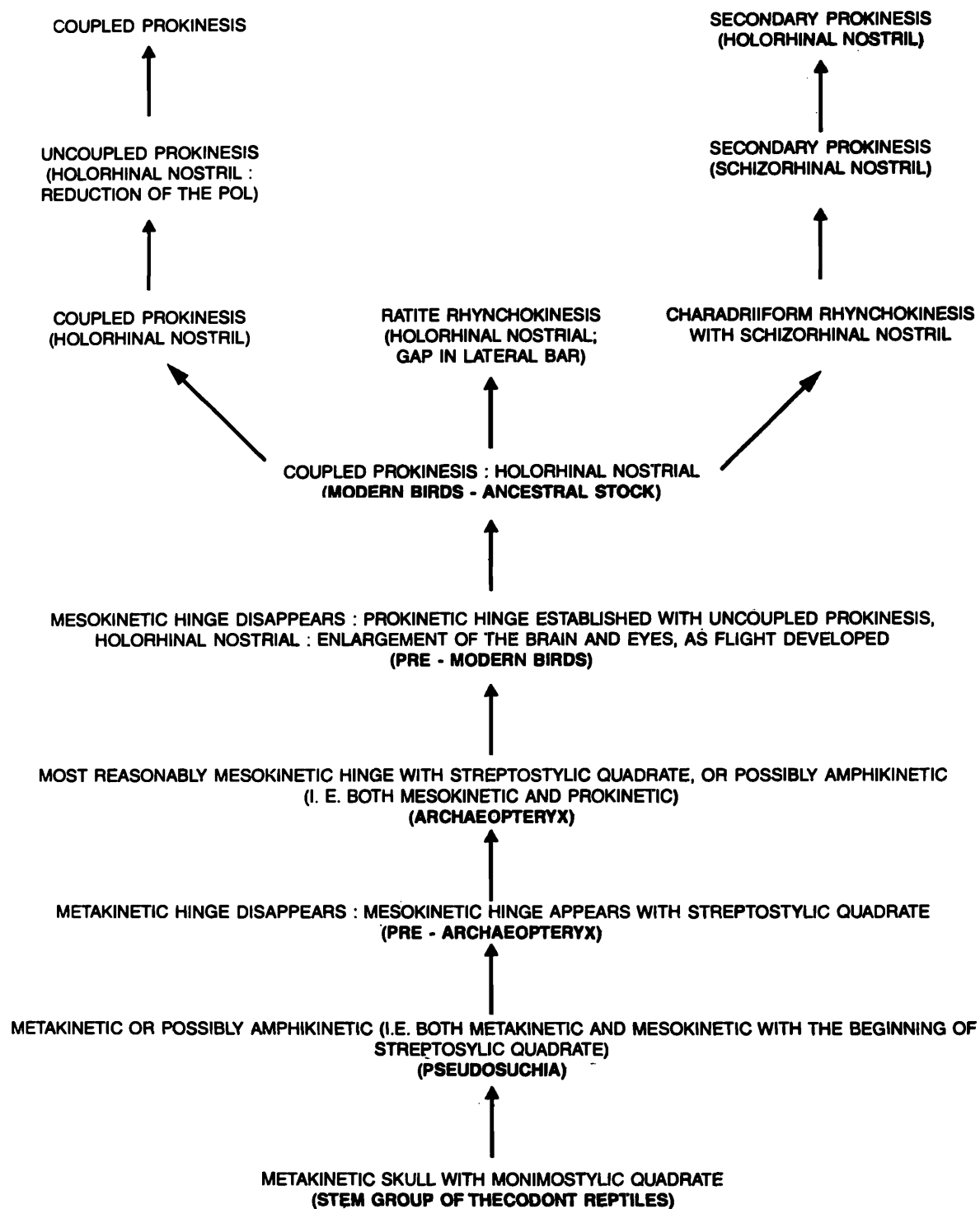


Fig. 3. The possible sequences in the evolution of avian cranial kinesis (a summary of different view points : modified from Bock, 1964)

either mesokinetik or prokinetik skull (e.g., *Archaeopteryx*, *Alvarezsauridae*, *Enantiornithes*, etc). In later forms, there was a gradual reduction in the number and size of teeth but those bird groups such as *Hesperornithiformes*, *Gobiapteryx*, etc also could not escape the hazard of KT-boundary and so became extinct. The Ornithurine diverged into two lines: the

Hesperornitho-ratitormorphs characterized by rhylichokinetik jaws and the neognaths with prokinetik jaws. *Hesperornithiformes* and *Ichthyornithiformes* were piscivores and possibly due to some major ecological changes in the late Cretaceous, affecting trophic system of these birds, they could not cross the KT-boundary and became extinct. The ratitormorphs

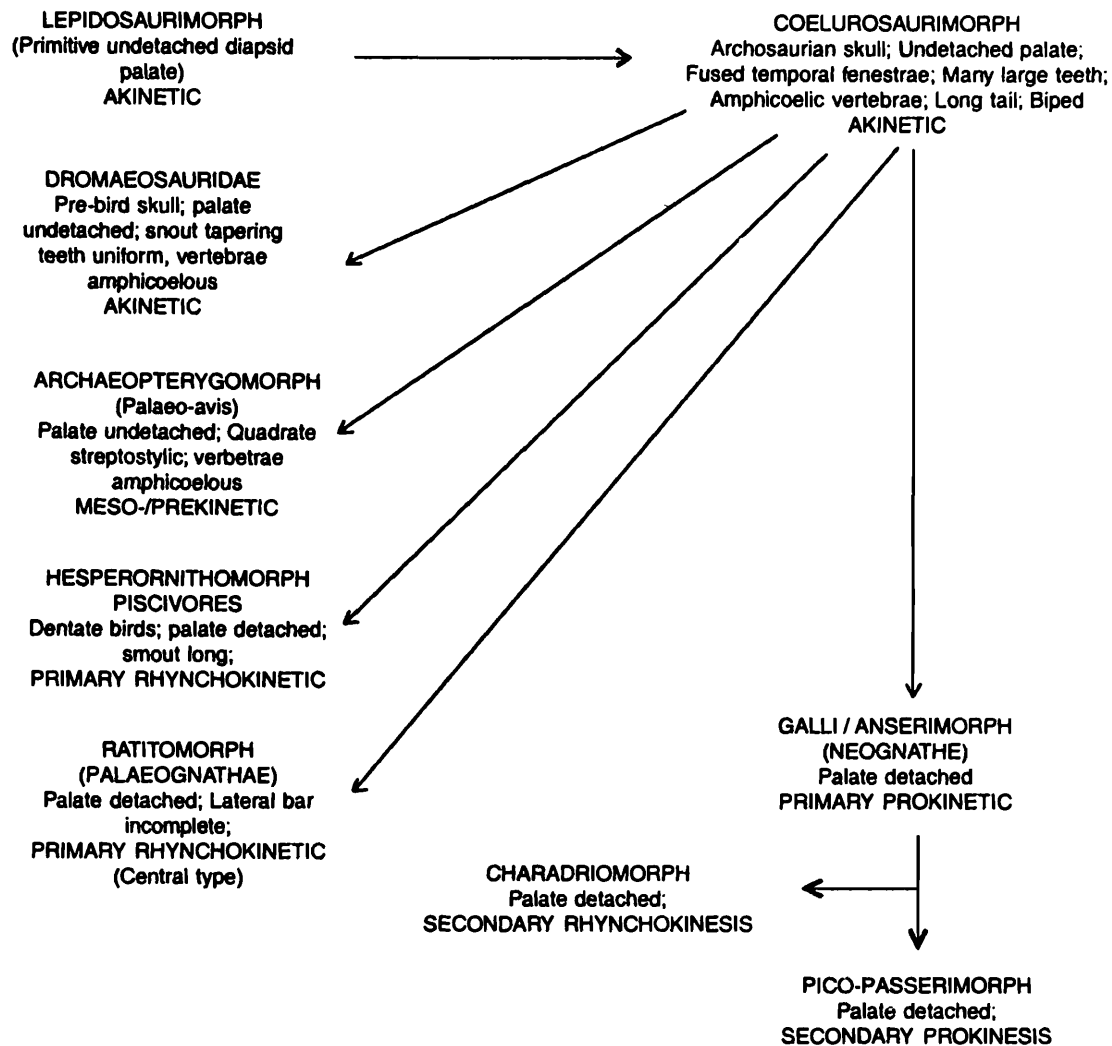


Fig. 4. Evolution of skull type, palate and kinesis from Coelurosaur to birds (Modified from Zweers *et al.*, 1997)

remained unaffected by the KT-boundary. They were mainly browsers and grazers on herbs and grassland that were abundant at that time.

The neognath trophic ecomorphs as observed in the prokinetic and secondarily rhynchokinetic (e.g. Charadriiform birds) Ornithurine radiated into diversified trophic systems of which three lines emerged : (i) the grebe-like catchers that were mainly aquatic; (ii) the plover like probes that were semi aquatic shore-birds and (iii) almost fully terrestrial (may have been secondary re-invasion) rail like peckers and slicers which also included the very large pico-passerimorph assemblage.

KT-BOUNDARY

Along with the acquisition of more and more avian characteristics such as endothermy,

feathers and flight, at least three (or four?) radiations occurred in the evolution of birds : one (or two?) during the cretaceous period which culminated in mass extinction at the KT-boundary or rather at the late cretaceous period, one at the KT-transition period and the last one in the Oligocene transition period. The KT-boundary period was short and operated for less than 100 KY whereas the KT-transition was longer and lasted for about 1 MY. The Oligocene transition period (O-tr) was slightly longer than the KT-B (4-8 KY) and was marked by further cooling down of temperature and dwindling of many vegetational communities that could not sustain too many browsers and grazers; only small sized birds with superior flight capabilities, vision and brain function together with a light weight kinetic skull for fast pecking and swallowing of food particles could successfully cross the KT-boundary and radiate as sustainable modern neognaths.

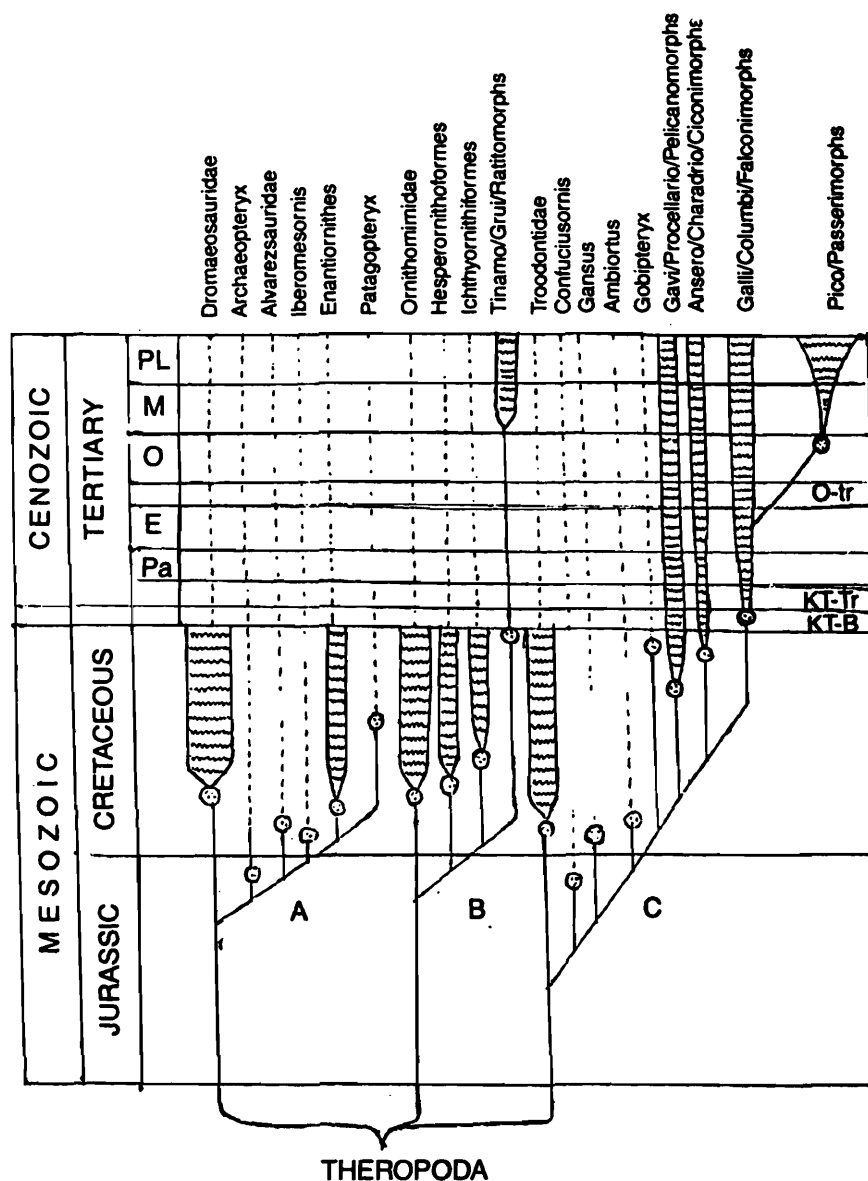


Fig. 5. Major coelurosaurio-Avian taxa, integrated into a triplet of Trophic Designs and corresponding jaw kinesis. A. Toothed Graspers with Meso/Prekinetic skull; B. Toothed piscivores and toothless Browsers and Grazers with primary Rhynchokinesis; C. Toothless Graspers with Prokinetic skull evolved into catchers, probers, peckers and slicers (Based on and modified from Zweers *et al.*, 1997).

A simplified phylogeny of birds from the coelurosaurians onward is given here for ready reference (Fig. 6).

DISCUSSION AND CONCLUSION

Zweers *et al.* (1997) and Zweers and Vanden Berge (1997/98) in their publications cited in the text have proposed a reasonably acceptable model for the trophic diversification of birds across the KT-boundary. From the fossil evidence gathered so far, these authors have divided the evolutionary sequence of these fossils, from the study of skull elements

including kinesis, into three types :
 (i) Dromaeosaurid/Enantiornithid/Archaeopterygo-morphs; (ii) Ornithomimid/Hesperornitho/Ratito-morphs; and (iii) Troodontid /Neognatho-morphs. Corresponding to these three types of coelurosaurian skull derivations (along with the evolution of cranial and jaw kinesis), three generalized trophic lineages have been proposed. These are : (i) dentate graspers with large and numerous teeth which became smaller and reduced in number in later forms; (ii) catchers, browsers and grazers which contain both dentate and edentate groups; and

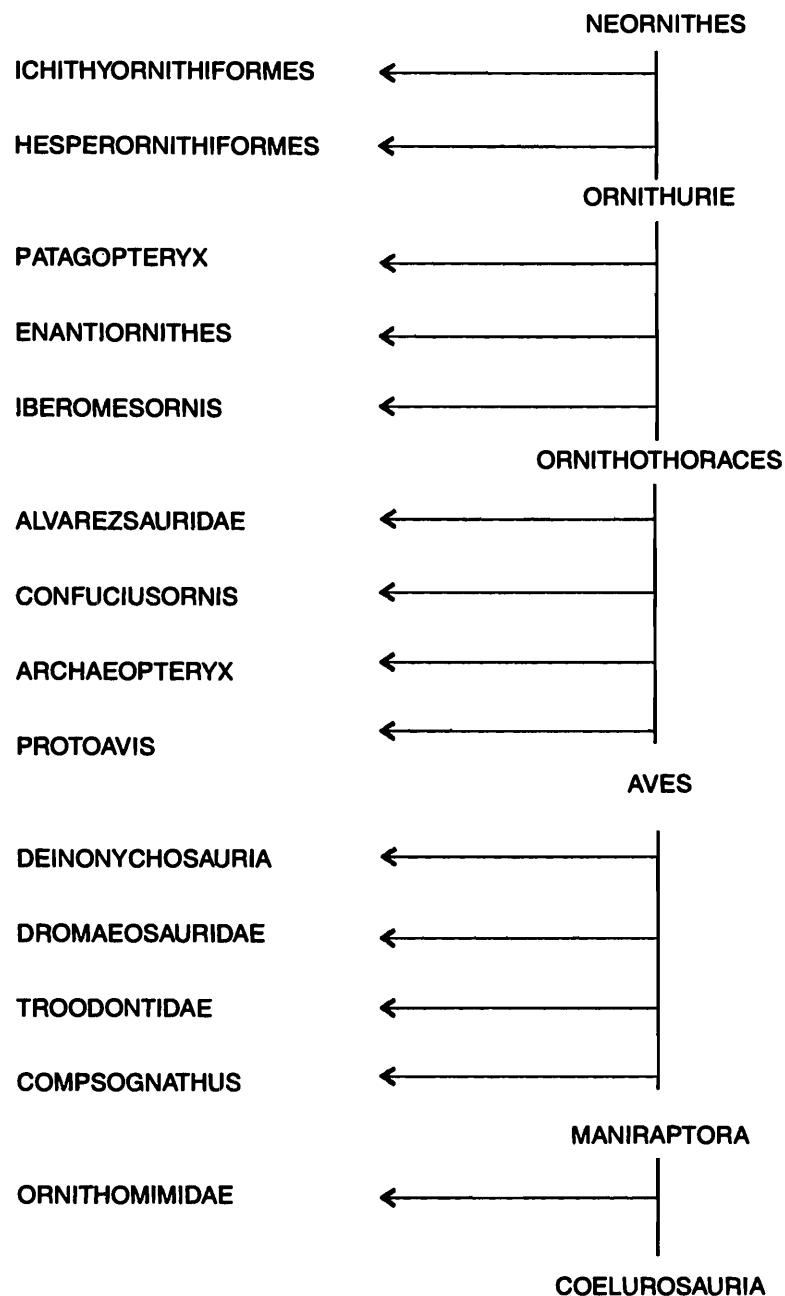


Fig. 6. A simplified cladogram on the phylogeny of birds from the Coelurosauria onward (Zweers *et al.*, 1997). The sketch combines the cladogram of Gauthier (1986), Cracraft (1986), Sanz *et al.*, (1995) and Chiappe (1995). The Neornithes includes the Palaeognathae and Neognathae. Benton's chart (1997) is also almost the same. However, Cooper and Penny (1997) have re-shaped this phylogeny, based on DNA sequences.

(iii) probers, peckers and slicers.

The above hypothesis is quite convincing for the fact that a correlation has been drawn between the evolution of kinesis of the skull and that of trophic diversification. It is quite reasonable to infer that the evolution of a kinetic skull, detachment of palate from the braincase and rhamphothecad covering of the beaks were essential prerequisites for the birds in attaining diversity in feeding. Further modifications in the skeletal elements as well as in flight, bipedality, etc. led to specific preadaptations

which equipped certain groups of birds to cross the KT-boundary for further radiations.

From the above analysis, it may be concluded that :

1. To begin with theropod coelurosauria, avian evolution may be considered monophyletic, as true flight and feathers developed only once. However, discovery of a Triassic bird, *Protoavis* by Chatterjee (1991, 1995) needs to be explained if it really represents a pre-*Archaeopteryx* form.

2. As to the phylogeny of birds, findings in Molecular Systematics based on the mitochondrial and DNA hybridization techniques (Mindell, 1997) are required to be compared and reconciled to phylogenetic cladograms based on palaeontological records.
3. The evolution of trophic diversification in birds across the KT-boundary may be correlated to the evolution of cranial and jaw kinesis, beginning with the coelurosaur-maniraptoran lineage.
4. Avian trophic diversification before and after the Cretaceous-Tertiary boundary (KT-boundary) might have been possible due to : (i) modifications and diversification in jaw kinesis; and (ii) evolution of improved avian features like fully rhamphothecad jaws, heterocoelous vertebrae, modes of flight, feeding and brooding.
5. The early and mid-Cretaceous radiations (may be only one mid-Cretaceous radiation as held by a few authors) were all extinct by the end of late Cretaceous or at the KT-boundary. The fourth (or the third) radiation occurred beyond KT-boundary (at the KT-transition period) and the surviving bird groups could be assembled into one palaeognath and three neognath ecomorphs. The fifth (or the fourth) radiation occurred in the Oligocene-transition period (O-tr).
6. Among diverse modes of feeding and drinking, pecking and browsing together with tip-up-drinking appear to be the ancestral designs for neognaths and palaeognaths.

LITERATURE CITED

- BENTON, M.J. 1997. *Vertebrate Palaeontology*, 2nd ed. Chapman and Hall; London, New York, Tokyo
- BOCK, W.J. 1964. Kinetics of avian skull. *J. Morphol.*, 114 : 1-52
- BÜHLER, P. 1981. Functional Anatomy of the avian jaw apparatus. In : *Form and function in birds*. Vol. 2 (Eds. A.S. King and J. Mclelland. Academic press. London, New York).
- BÜHLER, P. 1987. On the mobility of the upper jaw and the segment of the brain case in the Mesozoic birds, *Doc. Lab. Geol. Lyon*, 99 : 41-48.
- CHATTERJEE, S. 1991. Cranial anatomy and relationships of a new Triassic bird from Texas. *Phil. Trans. R. Soc. London B*. 332 : 277-342
- CHATTERJEE, S. 1995. The Triassic bird *Protoavis*. *Archaeopteryx*, 13 : 15-31.
- COOPER, A. and PENNY, D. 1997. Mass survival of birds across the Cretaceous-Tertiary boundary, Molecular evidence. *Science*, 275 : 1109-1113.
- CRACRAFT, J. 1986. The origin and early diversification of birds. *Palaeobiology*, 12 : 383-399.
- CHIAPPE, L.M. 1995. The first 85 million years of avian evolution. *Nature*, 378 : 349-355.
- CHIAPPE, L.M., N. A. NORELL and J. M. CLARK. 1996. Phylogenetic position of *Mononykus* (Aves : Alvarezsauridae) from the late Cretaceous of the Gobi desert. *M. Queensland Mus.* 39 : 557-582
- FEDUCCIA, A. 1995. Explosive evolution in Tertiary birds and mammals. *Science*, 277 : 637-638
- FEDUCCIA, A. 1996. *The origin and evolution of birds*. Yale University Press, New Haven.
- GAUTHIER, J. 1986. Saurischian monophyly and the origin of birds. In : K.Padian (Ed). *The origin of birds and the evolution of flight*. *Mem. Calif Acad. Sci.*, 8 : 1-55.

- HOFER, H. 1949. Die Gaumenlucken Der *Vogel*. *A. Acta. Zool.*, **30** : 209-248.
- KARDONG, K.V. and G.A. ZWEERS. 1997. Vertebrate evolution at geological boundaries. *Zoology*, **100** : 121-127.
- MINDELL, D.P. 1997. Avian Molecular evolution and Systematics. Academic Press, London.
- SANZ, J.L., L.M. CHIAPPE and A.D. BUSCALIONI. 1995. The osteology of *Concornis lacustris* (Aves : Enantiornithes) from the lower Cretaceous of Spain and re-examination of its phylogenetic relationship. *Am. Mus. Nov.*, **3133** : 1-23.
- SIBLEY, C.G. and AHLQUIST, J.E. 1990. Phylogeny and classification of birds : A study in Molecular Evolution, Yale University Press, Yale.
- ZHOU, Z. 1995. Is *Mononykus* a bird? *Auk*, **112** : 958-963
- ZWEERS, G.A.; J.C. VANDEN BERGE and H.BERKHOUDT. 1997. Evolutionary patterns of avian trophic diversification. *Zoology*, **100** : 25-57.
- ZWEERS, G.A.; J.C. VANDEN BERGE. 1997/98. Birds at geological boundaries. *Zoology*, **100** : 183-202.

SOME ASPECTS OF ECOLOGY OF ORIBATID MITE POPULATIONS AT HIGH HILL AND FOOT HILL REGIONS OF THE HIMALAYAS

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ABSTRACT

Collection of soil samples were carried out at two different altitudinal locations, Sandakphu (3636m) and Sukna (181m) in Darjeeling Himalayas of West Bengal. Densities of oribatid mites as well as their relative abundance were more in Sukna than those in Sandakphu. Coefficient of variation (CV) was also higher in Sukna and differed significantly ($p < 0.05$) from that of Sandakphu. Numerical dominance of oribatid mites however was more in Sandakphu than that of Sukna. One way ANOVA test reveals that the populations of two sites are significantly different from each other ($p < 0.05$). Trend analysis of population indicated that the numerical abundance of oribatid mites gradually declined in Sukna while it increased in Sandakphu as the study period progressed. Highest abundance was observed during spring in Sukna and in early summer in Sandakphu whereas lowest abundances in both sites were recorded during monsoon. Numbers of species of oribatid mites recorded were 18 and 20 in Sandakphu and Sukna respectively. Among them only one species and six genera were common to both places. Relative humidity near soil surface showed weak positive and negative correlation with abundance of oribatid mites in Sukna and Sandakphu respectively. Soil temperature was positively correlated in Sandakphu and in Sukna it was negatively correlated. Phosphate showed negative correlation in Sandakphu and positive in Sukna. A weak positive correlation was observed for pH in Sandakphu and in Sukna the correlation was significantly negative.

Keywords : Oribatid mites, altitudes, edaphic factors.

INTRODUCTION

Oribatid mites, in general, constitute the largest numerically abundant group among the soil microarthropods in temperate forest soil (Wallwork, 1983). Their numerical abundance has laid an immense importance upon them as far as ecology and fertility are concerned (Spencer, 1951). Some species of oribatid mites can be used as potential bioindicator (Banerjee and Sanyal, 1991; Van Straalen *et al.*, 1997). Studies on soil acari in relation to altitudes were made by Lamoncha and Crossley (1998), Kalimanis *et al.* (2002) and a few others. In India, however, this type of work is scanty. Ecological studies on acarine fauna in the Darjeeling

Himalayas were made by a few workers like Choudhuri and Pandey (1981, 1982), Ghosh and Roy (2004) and Moitra *et al.* (2006). No work however specifically emphasized the interrelation between the abundance of oribatid mite population and the changes in edaphic factors due to altitudinal differences. Besides, the information on ecology of this particular group of mite at altitudes higher than 3000m and how this differs from that of foot hill regions is also lacking in India. The present work was carried out to investigate the nature of abundance, relative abundance and dominance of oribatid mite population and how it is related to the different physicochemical parameters for the purpose of studying the

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existing variations at two different altitudes (Sandakphu, 3636m; Sukna, 181m) with a gap of more than 3000m in the Himalayan ecosystem.

Collection sites : Sandakphu (3636m) is located in the Singalila range of the Darjeeling Himalayas. Soil is blackish brown in colour and sandy loam in texture. Vegetation of the plot chiefly consists of *Quercus* sp., *Rhododendron* sp. with patches of *Arundinaria* sp. Sukna (181m), located at the foot hill regions of the Darjeeling Himalayas has brown soil with clay loam texture. *Tectona grandis*, *Shorea robusta*, *Bauhinia* sp., *Saraca indica* were among the common vegetation of the plot.

MATERIALS AND METHODS

Uncultivated plots with natural vegetation were selected at both the collection sites. Soil samples were collected with stainless steel cores (5 cm dia. × 5 cm deep) as employed by Dhillon and Gibson (1962) up to a depth of 5 cm of soil profile and soil fauna were extracted by Tullgren funnel apparatus modified by Macfadyen (1953). Altogether 360 soil samples were collected from January, 2004 to December, 2006. Oribatid mites were separated from the extracted microarthropods. The numbers of oribatid mites were determined per core and the data was transformed to log x to achieve homogeneous variance for one way analysis of variance (ANOVA) and also to work out the regression equations with physicochemical parameters as predictors. Relative Humidity was recorded by a dial hygrometer. Soil temperature was recorded by a soil thermometer and soil moisture was measured by an Infra-Red Moisture balance. Organic

carbon content of the soil was estimated by rapid titration method of Walkley and Black (1934) and pH was measured by an electric pH meter. Nitrate was measured by soil colorimetric method described by Dodswell (1959) and for phosphate, molybdenum blue test was employed (Dodswell, 1959).

RESULTS AND DISCUSSIONS

A total of 64,795 soil microarthropods were obtained and of them 24,100 (37.19%) were oribatid mites. Total species of oribatid mite was 38. Of them 18 species were recorded from Sandakphu and 20 from Sukna. Among them only one species (*Nothrus gracilis*) and six genera (*Hoplophorella*, *Hoplophthiracarus*, *Malaconothrus*, *Masthermannia*, *Dolicheremaeus* and *Tectocephus*) were common to both places.

Density as well as relative abundance of oribatid mites were more in Sukna than those in Sandakphu (Table 1). Coefficient of variation (CV) was also higher in Sukna. The CV of two sites differed significantly ($0.01 < p < 0.05$) from each other. Numerical dominance of oribatid mites however was more in Sandakphu (39.58%) than that of Sukna (35.61%). One way ANOVA test reveals that the populations of two sites are significantly different from each other ($0.01 < P < 0.05$) (Table 2). Trend analysis of population indicated that the numerical abundance of oribatid mites gradually declined in Sukna while it increased in Sandakphu as the study period progressed (Fig. 1). Highest abundance was observed during spring season in Sukna and in early summer in Sandakphu whereas lowest abundances at both sites were recorded during monsoon (Fig. 2 and Table 3).

Table 1. The mean abundance (N/core), mean density (N/m²), relative abundance, dominance and coefficient of variation of oribatid mites at two different altitudes.

		DF	MS	F
TOTAL SS =	2.2107	71	0.03114	
GROUP SS =	0.2192	1	0.2192	7.7047*
ERROR SS =	1.9915	70	0.02845	

Table 2. The result of one way analysis of variance (ANOVA) test for the mean number of oribatid mites per core.

Data were transformed to log x; SS = sum of square; DF = Degree of Freedom; MS= Mean square; F = F statistic; * = 0.01 < p < 0.05.

Physico-chemical parameter	Mean Value ($\pm$ Standard Error)	r value	Level of significance	Regression Equation ($a = bx + c$)
R. H. (%)	77.64 $\pm$ 0.9776	-0.278	ns	$Y = -0.708X + 3.07$
Soil moisture (%)	28.86 $\pm$ 1.0765	-0.708	****	$Y = -0.930X + 3.08$
Soil temperature($^{\circ}$ C)	9.45 $\pm$ 0.6863	0.338	*	$Y = 0.241X + 1.51$
Organic Carbon (%)	4.11 $\pm$ 0.1552	0.377	*	$Y = 0.416X + 1.48$
Nitrate (ppm)	2.28 $\pm$ 0.1085	0.496	****	$Y = 0.453X + 1.58$
Phosphate (ppm)	0.32 $\pm$ 0.2508	-0.378	*	$Y = -0.588X + 4.18$
pH	4.71 $\pm$ 0.0398	0.054	ns	$Y = 0.0013X + 1.73$
R. H. (%)	78.27 $\pm$ 0.6876	0.133	ns	$Y = 0.12X + 1.62$
Soil moisture (%)	13.08 $\pm$ 0.6774	-0.383	*	$Y = -0.601X + 2.51$
Soil temperature($^{\circ}$ C)	23.56 $\pm$ 0.4889	-0.362	*	$Y = -1.48X + 3.88$
Organic Carbon (%)	3.5 $\pm$ 0.0863	0.644	****	$Y = 2.00X - 0.769$
Nitrate (ppm)	2.41 $\pm$ 0.1388	0.386	**	$Y = 0.359X + 1.72$
Phosphate (ppm)	0.37 $\pm$ 0.0262	0.365	*	$Y = 1.12X + 3.84$
pH	5.19 $\pm$ 0.0051	-0.441	***	$Y = -2.99X + 17.3$

Y = Oribatid mites; X = Physicochemical Parameters; * = 5% level of significance, ** = 2% level of significance, *** = 1% level of significance, **** = 0.5% level of significance, ***** = 0.1% level of significance.

Table-3. The mean value of physicochemical parameters, correlation coefficients between the physicochemical parameters and the abundance of oribatid mites.

	Sandakphu (3636m)	Sukna (181m)
Mean value (N/core) $\pm$ S. E.	56.74 $\pm$ 2.6657	77.14 $\pm$ 5.4629
Mean density (N/m ²) $\pm$ S. E.	28888.03 $\pm$ 2781.12	39273.47 $\pm$ 1357.07
Relative abundance (%)	15.74	21.43
Dominance (%)	39.58	35.61
Coefficient of variation	28.19	42.49
F test of CV	2.264	

N = Number of oribatid mites, CV = Coefficient of variation, S. E. = Standard Error, F = F statistics of CV

Average monthly relative humidity (R.H.) was more in Sukna (78.27%) than that of Sandakphu (77.64%), soil moisture, however was higher in Sandakphu (28.86%) than that of Sukna (13.08%) (Fig. 3). Relative humidity near soil surface showed weak positive and significant negative correlations with the abundance of oribatid mites in Sukna and Sandakphu respectively, while soil moisture

showed significant negative correlation in both sites. Strong negative correlation with Relative Humidity might be resulted from higher humidity in monsoon when abundances of oribatid mites were very low. Negative correlation with soil moisture matches with the results of earlier studies (Choudhuri and Pande, 1981, 1982; Ghosh and Roy, 2004). Soil temperature was 9.45 $^{\circ}$ C and 23.56 $^{\circ}$ C in average

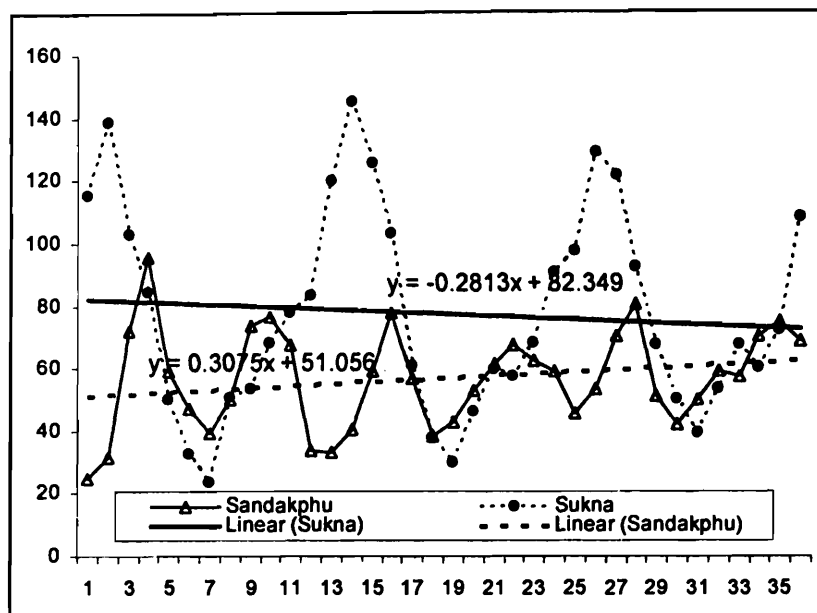


Fig. 1. Shows the abundances of oribatid mites and the trend lines of the same at two collection sites.

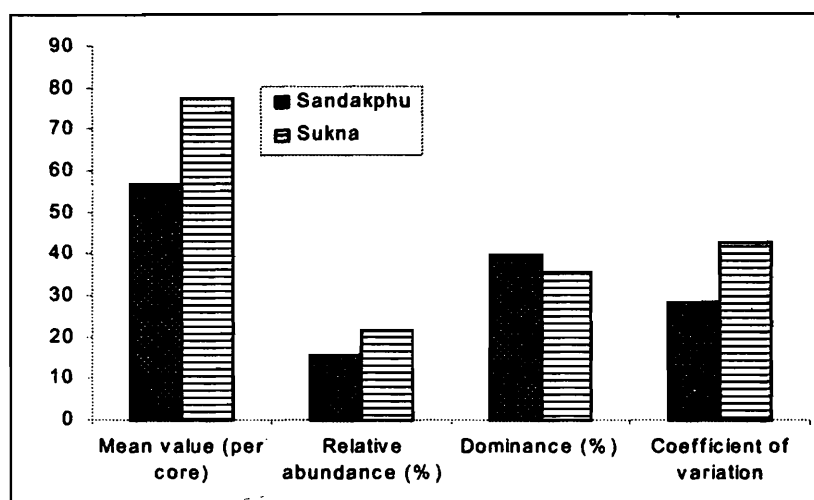


Fig. 2. Shows different characteristics of oribatid mite populations at two collection sites.

in Sandakphu and Sukna respectively. It was positively correlated with abundance in Sandakphu and in Sukna it was negatively correlated. Positive correlation with the temperature was observed by Choudhuri and Pande (1981) in Birch Hill, while the same authors (1981) and Ghosh and Roy (2004) also noticed negative correlation in other sites in the Darjeeling Himalayas. Positive correlation with temperature might be due to lower range of soil temperature in Sandakphu. Nitrate and organic carbon had significant positive correlation with abundance in both sites. This is in conformity with the observations of earlier workers (Choudhuri and Pande, 1981, 1982;

Ghosh and Roy, 2004). Phosphate however showed negative correlation in Sandakphu and positive correlation in Sukna. Negative correlation with phosphate was observed earlier by Choudhuri and Pande (1982). Positive correlation in Sukna resulted probably for the lower phosphate content of soil during the monsoon when oribatid mites were also fewer in numbers. A weak positive correlation was observed between pH and the abundance of oribatid mites in Sandakphu and in Sukna the correlation was significantly negative. Positive correlation between pH and oribatid mite population was recorded by Choudhuri and Pande (1981) in Birch Hill, in other sites in the

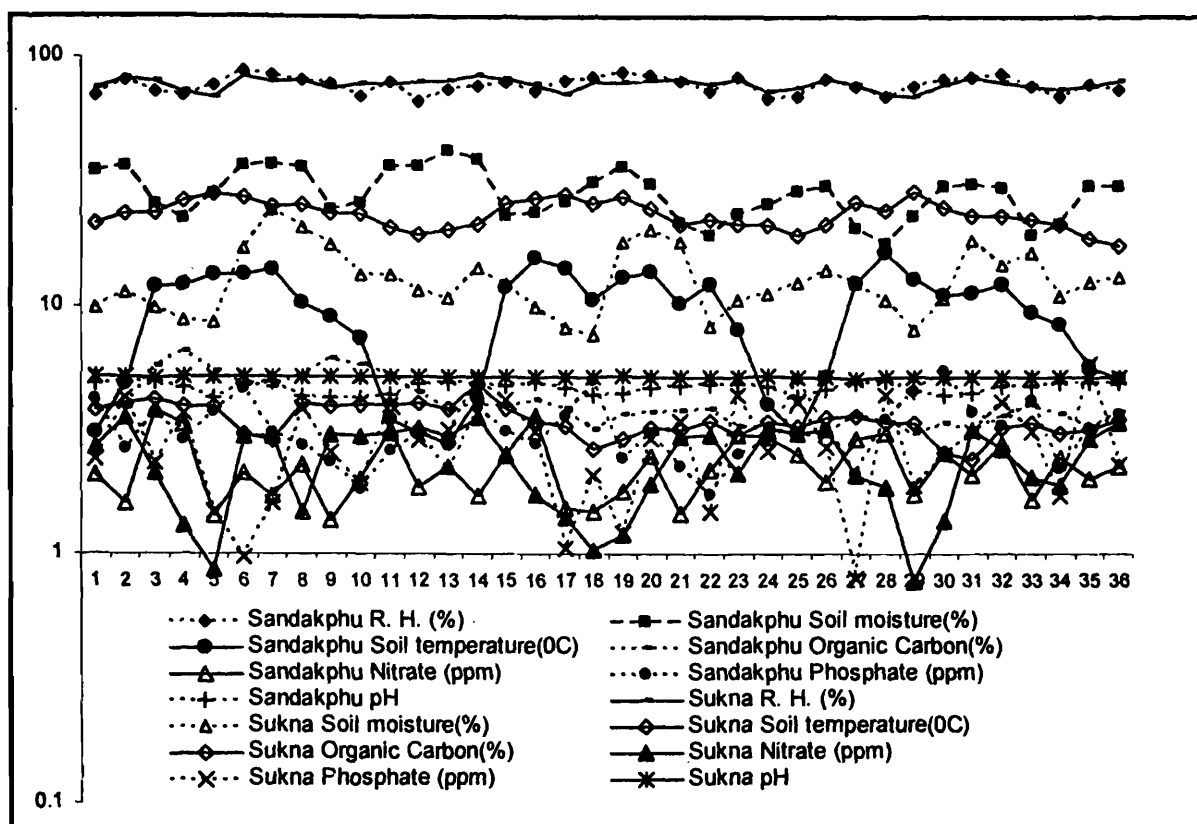


Fig. 3 : Shows the values of different physicochemical parameters at two collection sites.

Himalayas the negative correlation was observed by the same authors (Choudhuri and Pande, 1981, 1982 and Ghosh and Roy, 2004).

Variation in abundance of oribatid mite populations and the way they are related to the different edaphic factors is expected to exist at two sites that are about 3500 m apart in altitudes and therefore having different climatic conditions. Sukna has higher oribatid population probably because of favorable range of soil moisture, temperature and higher pH. Though in Sukna, the abundances of oribatid mites were negatively correlated with all these factors, the averages of these factors probably were close to the optimum level that favors higher abundance of oribatid mites. The relative abundance of oribatid mites however was higher in Sandakphu probably because of lower pH as oribatid mites are more successful inhabitant of acidic soil in comparison to other groups of soil dwelling microarthropods (Hagvar and Abrahamsen, 1980).

Decomposition of litter in soil generally

decreases towards upper altitudes (Schinner, 1982) probably because an increase in temperature would accelerate the microbial decomposition of organic matter (Wang *et al.*, 2000). The release and resultant availability of nutrients might cause a rise in oribatid mite population other than causing a growth in fungal population. Oribatid mites mostly subsist on fungus (Crossley *et al.*, 1999) that grows well in moderate soil moisture as high moisture may cause a decline in fungal growth reducing aeration (Waid, 1960). So high soil moisture as recorded in Sandakphu may also account for the comparative lower abundance of oribatid mites there.

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LITERATURE CITED

- BANERJEE, S. and SANYAL, A. K. 1991. Oribatid mites as bioindicator of soil organic matter. *Advances in Management and conservation of soil fauna*. Proc. 10th Int. Soil Zool. Colloq., Bangalore, India : 877-880.
- CHOUDHURI, D. K. and PANDE, T. 1979. High altitude soil animals and their relationship with soil factors, with special reference to mites. *Rev. Ecol. Biol. Sol.*, **16** : 219-226.
- CHOUDHURI, D. K. and PANDE, T. 1981. Studies on the population and distribution of high altitude soil acarines in relation to different soil factors. *Contributions to Acarology in India*. *Acarological Soc. India, Univ. of Agric. Sci.*, Bangalore, India : 147-154.
- CHOUDHURI, D. K. and PANDE, T. 1982. An ecological study of acarines from soil of Himalayan ecosystem. *Geobios News Report*, **1** : 24-26.
- CROSSLEY, D.A. JR. and DAVID COLEMAN C. 1999. Microarthropods. In : Malcom E. Sumner (ed.-in-chief), *Handbook of Soil Science*. CRC Press, Boca Raton : C-59 – C-65
- DHILLON, B. S. and GIBSON, N. H. E. 1962. A study of acarina and collembola of agricultural soils. *Pedobiologia*, **1** : 24-26.
- DODSWELL, W. H. 1959. *Practical Animal Ecology*. Methuen Educational Ltd., London : 320.
- GHOSH, T. C. and ROY, S. 2004. Distribution and diversity of acarina community in three tea gardens at different altitudes of Darjeeling Himalayas. *Proc. zool. Soc.*, Calcutta, **57** : 87-93.
- HAGVAR, S and ABRAHAMSEN, G. 1980. Colonisation by Enchytraeidae, Collembola and Acari in sterile soil samples with adjusted pH level. *Oikos*, **34** : 245-258.
- KALLIMANIS A. S., ARGYROPOULOU M. D. and SGARDELIS S. P. 2002. Two scale patterns of spatial distribution of oribatid mites (Acari, Cryptostigmata) in a Greek mountain. *Pedobiologia*, **46**(6) : 513-525
- LAMONCHA K. L. and D. A. CROSSLEY, JR. 1998. Oribatid mite diversity along an elevation gradient in a southeastern Appalachian forest. *Pedobiologia*, **42**(1980) : 43-55.
- MACFADYEN, A. 1953. Notes on methods for the extraction of small soil arthropods. *J. Anim. Ecol.*, **22** : 65- 77.
- MOITRA, M. N., A. K. SANYAL, and CHAKRABARTI, S. 2006. Impact of Four Edaphic Factors on the Abundance of Soil Acari in Relation to Altitudes in the Darjeeling Himalayas, West Bengal, India. *Environment and Ecology*, **24**(2) : 366-372.
- SCHINNER, F. 1982. Soil microbial activities and litter decomposition related to altitude; *Plant and Soil*, **65**(1) : 87-94
- SPENCER, J. A. 1951. Special Subject Report, Department of Forestry Library, University of Oxford : 77.
- VAN STRAALLEN, M. NICO and A. VERHOEF HERMAN 1997. The development of bioindicator system of soil acidity based on arthropod pH preferences. *J. Appl. Ecol.*, **34** : 217-232.
- WAID, J. S. 1960. The growth of fungi in soil. In : *Proc. Symp. Ecol. Soil Fungi. Liverpool* (1953), Liverpool University Press, 55-75.
- WALKLEY, A. and I. A. BLACK. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of chromic acid titration method. *Soil Sci.*, **37** : 29-38.
- WALLWORK, J. A. 1983. Oribatids in forest ecosystems. *Ann. Rev. Entomol.*, **28** : 109-130.
- WANG, Y., RONALD, A. and XU-FENG NIU. 2000. Seasonal and altitudinal variation in decomposition of soil organic matter inferred from radiocarbon measurements of soil CO₂ flux. *Global Biogeochemical Cycle*, **14**(1) : 199-212.

FOOD PREFERENCE OF FOUR AGRICULTURAL PESTS (ORTHOPTERA : ACRIDIDAE)

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ABSTRACT

Food preference of four agricultural pests viz., *Hieroglyphus banian* (Fabricius), *Acrida exaltata* (Walker), *Spathosternum prasiniferum prasiniferum* (Walker) and *Oxya fuscovittata* (Marschall) (Orthoptera : Acrididae) has been studied taking twelve food plants from two families namely Poaceae and Cyperaceae. The choice-test or acceptability preference shows that all of these pests are selective within the framework of their polyphagous nature. Among diverse food sources each pest performs a 'test-bite' to each plant initially but on ensuring palatability or tastelessness, the insect accepts or rejects the host plant. The 'actual feeding' of the pest commences by switching over their most acceptable host plant in all investigational trials, but in absence of most palatable (acceptable) host, the pest further switches over to the next-level acceptable plant. In this way a general trend of evolution from monophagy to polyphagy took places in all the studied pests.

Keywords : Orthoptera, food preference, choice-test.

INTRODUCTION

Insects and plants have perfect symbiotic and adaptive relationship in acquiring food from nature. Although plants have some resistant mechanisms but insect also developed some mechanisms to overcome plant resistance. Some chemicals of plant may thus reduce its palatability or in some way reduce the pressure of insects to feed that plant. All insects initially have single food instinct but when there is overcrowding on a particular plant, the shortage of food and space influence insect dispersal to a new palatable plant. Thus insects shifted from monophagous (specific feeder to a particular plant species) to polyphagous (feeder to a variety of plant species) type.

Host-plant selection of a polyphagous acridid is a complex phenomenon involving host-habitat finding, host-finding, host-

recognition, host-acceptance and host-suitability. Insects receive the sensory information from the host plant leading to pursuit the source, but finding of a plant within a habitat involves visual stimuli. Movement leading to the arrival or stay of insects on a particular plant influenced by plant's physical (colour, texture, softness) and chemical (organic, water content) composition characteristics. Once the insect makes 'chemical contacts' with a possible food source, it is stimulated to perform a 'test-bite' or 'test-probe' for having an intimate contact between the plant contents and the insect's chemical sense. On ensuring that the host plant is suitable, it is accepted and actual feeding commences. Not only that, suitability of a host plant depend on to whether the colonizing insects are utilizing the plant for feeding and oviposition and whether the larvae or nymphs are capable to completing their

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normal growth and development on the same plant or not. Acridids generally prefer to take succulent leaves and plants, because water present in the host plant drastically influences their growth.

Many theories have been published in attempt to understand the mechanism of enormous voracity and food selection of locusts and grasshoppers (Ucekert *et al.*, 1972; Mulkern *et al.*, 1964) and for this many experiments have been done in relation to food preference in different species of acridids (Muthukrishnan *et al.*, 1976; Mukerji *et al.*, 1976; Uvarov, 1977; Hinks and Olfert, 1992, Das *et al.*, 2002). Species living mainly on ground are more likely to feed on low plants and plant debris, while climbing species choose the vertical blades of plants. At night, acridids fed mostly on tall plants where they roosted, but in the morning, and early afternoon, when they descended nearer the ground, the main foods were short grasses (Chapman, 1959). The daily rhythm of feeding in relation to other activities is connected with daily changes of environmental conditions or starvation (Bomar and Lockwood, 1991). However the average feeding diversity increased significantly in later instars, but the sexes did not differ in feeding pattern (Howard, 1995).

Beside crop plants, acridids have significant differential feeding patterns (Woodhead and Chapman, 1986) and growth responses (Hewitt, 1969; Sanchez and Onsagar, 1998) on grass species. In grasses, there are number of factors that influence grasshoppers at different stages of development (Hinks and Olfert, 1992). However, leaf trichomes, pubescence and silica deposits have negative effects on feeding (McNaughton *et al.*, 1985). Leaf texture also regulates feeding; young nymphs tend to feed on upper epidermis and the mesophyll tissue of younger leaves leaving the tougher lower epidermis and the leaf veins, while older nymphs are more general feeders but avoid tougher tissues and sclerotized leaves. In general, seedling grasses are distasteful to grasshoppers compared to mature plants of the same species (Bernays and Chapman, 1973). Though food

preference is to some extent hereditarily determined and genetically inherited (Hansen and Ucekert, 1970), but all herbivores have definite food selection and plant frequency in a certain habitat exerts some degree of influence upon their food habit (Ucekert *et al.*, 1972). Grasshoppers prefer most palatable food plants than others though present in surroundings (Pickford, 1962) and though they are ready to take any possible food in necessity (Thomas, 1966).

In the present dissertation the studied Acridids are very notorious to agricultural crops and economy, hence their studies of food preference are very important to note their feeding habit, host-plant range, host-plant switching, population structure and identification of reproductive bed. Since host selection in acridids are conditioned by general behavior of the insect, therefore, utilization of different host plants helps us to understand the feeding range of insects that reflects the degree to which they have adapted to their host (Fanny *et al.*, 1999).

MATERIALS AND METHODS

The following four species of Acridids (Orthoptera) were chosen for the experimental study namely, 1. *Hieroglyphus banian* (Fabricius) 2. *Acrida exaltata* (Walker) 3. *Spathosternum prasiniferum prasiniferum* (Walker) and *Oxya fuscovittata* (Marschall).

Among the selected species, *Hieroglyphus banian* (Fabricius) (pest of paddy, sugarcane and maize) is univoltine and abundantly found throughout September-December in the study area but during rest of the year they were absolutely missing from the study area. *Acrida exaltata* (Walker) (pest of jute, paddy and cotton) is bivoltine and richly found during June-July, though during rest of the year they were found moderately. The remaining two species viz., *Spathosternum prasiniferum prasiniferum* (Walker) and *Oxya fuscovittata* (Marschall) (both are pest of paddy, wheat and sugarcane) are multivoltine, completes at least four generations per year and hence found more or less abundantly throughout the year.

Adult grasshoppers were collected by sweeping net from the field in and around Santiniketan, W.B., India and were caged and acclimatized for studies. Studies on food preference for all the four species of acridids were conducted in the laboratory using twelve food plants viz. *Cynodon dactylon* Pers., *Oryza sativa* Lin., *Brachiaria reptans* Lin., *Brachiaria ramosa* Lin., *Chrysopogon aciculatus* Trin., *Triticum aestivum* Lin., *Saccharum officinarum* Lin., *Sorghum halepense* Willd., *Zea mays* Lin. and *Hordeum vulgare* of family Poaceae and *Cyperus kyllingia* Endl. and *Cyperus difformis* Lin. of family Cyperaceae.

The basis of selection of these plants were their 1. easy availability in the study area 2. pest occurrences 3. pest roosting 4. availability throughout the year 5. economic stand point and 6. all the plants can be grown separately in garden laboratory. For all the acridid species *Cyperus kyllingia* was taken as standard (control plant) and its mean acceptability percentage was considered as 100 and, to which other food plants were compared. In field survey it was noticed that all the four species, either nymphs or adults, devour *Cyperus kyllingia* with more or less higher efficacy and hence this plant was taken as control. The foliage supplied to the insects was taken from these plants which were four to eight weeks old. All experiments were conducted at room temperature (25-35°C, 60-80% relative humidity and 500 ± 100 lux illumination).

For each set of experiments the rearing cage (3'x2'x2') was supplied with four species of plants at a time, two samples of the control plants and two samples each for other three. Sample plants were placed randomly in the cage. Only the green shoots of the plants were taken for the experiments. Plants were placed in a water filled 50 ml conical flask and their heights were taken equal. A total of fifty adult grasshoppers of a species, which have been deprived of food for twenty hours, were used for each set of experiment. After a few exploratory bites the grasshoppers started to feed on selected plants within each choice test. Counts of grasshopper feeding on plants were

taken after three consecutive five minutes intervals. After that the position of the plant samples were changed, and three counts were taken again. Thus, in each choice test 12 counts were taken for an experiment. The order of preference for each plant was calculated by assuming the number of adults feeding on the standard plant (control) to be 100 and calculating the corresponding number of adults feeding on the other plants (Halder et al., 1995; Das et al., 2002). A total of 3 sets of experiment were conducted for each food plant and all experiments were performed thrice in a year with a break of four months.

RESULTS AND DISCUSSION

Laboratory experiments revealed that all the four species consumed a wide variety of food plants from the tested two families Poaceae and Cyperaceae, rather than a particular plant exclusively. Among the three most preferred food plants of *Hieroglyphus banian* the mean acceptability percentage of *Cynodon dactylon*, *Oryza sativa* and *Cyperus kyllingia* were 149%, 117% and 100% respectively. *Brachiaria reptans* (89%), *Cyperus difformis* (84%) and *Brachiaria ramosa* (82%) showed somewhat similar acceptability percentage to *H. banian*. The mean acceptability percentages of the remaining six food plants are also tabulated in Table-1. Being very strong masticatory apparatus like mandible and maxilla, *H. banian* consumes most of the tested plants within a shorter period of time. Their paddy pest status, as reported by various authors (Roffey, 1964; Uvarov, 1966), goes with the feeding performances and preferences.

The same twelve food plants when considered for the food preference experiment of *A. exaltata*, it was found that *Oryza sativa*, *Brachiaria ramosa* and *Triticum aestivum* were the three most preferred food plants to this insect and their mean acceptability percentages were 135% (*O. sativa*), 122% (*B. ramosa*) and 116% (*T. aestivum*). Plants like *Cyperus difformis* (110%), *Saccharum officinarum* (108%) and *Cyperus kyllingia* (100%) were nearly equally acceptable to *A. exaltata*. The mean acceptability

percentages of other food plants are also tabulated in Table-2. *A. exaltata* also possesses strong chewing and biting mouthparts and hence they devour almost all the tested plants with high efficiency. Though this species holds the pest status of cotton (Nayar *et al.*, 1976),

rice and jute (Bhowmik and Haldar, 1984), but the present experimental finding reveals that it preferred a wide range of food plants as observed by Haldar *et al.* (1995) also.

For *Spathosternum pr. prasiniferum* the order of food preference in terms of their mean

Table 1. Relative preference of *Hieroglyphus banian* to various food plants*

Name of plant	Family	Acceptability percentage			
		Exp. 1	Exp. 2	Exp. 3	Mean
1. <i>Cyperus kyllingia</i> Endl.	Cyperaceae	100	100	100	100
2. <i>Cynodon dactylon</i> Pers.	Poaceae	163	149	136	149
3. <i>Oryza sativa</i> Lin.	"	109	118	125	117
4. <i>Brachiaria reptans</i> Lin.	"	74	95	98	89
5. <i>Cyperus difformis</i> Lin.	Cyperaceae	77	80	95	84
6. <i>Brachiaria ramosa</i> Lin.	Poaceae	105	79	62	82
7. <i>Chrysopogan aciculatus</i> Trin.	"	58	60	77	65
8. <i>Triticum aestivum</i> Lin	"	62	59	47	56
9. <i>Saccharum officinarum</i> Lin.	"	43	58	28	43
10. <i>Sorghum helepense</i> Willd.	"	23	38	35	32
11. <i>Zea mays</i> Lin.	"	18	19	26	21
12. <i>Hordeum vulgare</i> Lin.	"	21	24	18	21

* Number of insects feeding on *C. kyllingia* was taken as 100. See text for detail.

Table 2. Relative preference of *Acrida exaltata* to various food plants*

Name of plant	Family	Acceptability percentage			
		Exp. 1	Exp. 2	Exp. 3	Mean
1. <i>Cyperus kyllingia</i> Endl.	Cyperaceae	100	100	100	100
2. <i>Oryza sativa</i> Lin.	Poaceae	142	105	158	135
3. <i>Brachiaria ramosa</i> Lin.	"	92	139	135	122
4. <i>Triticum aestivum</i> Lin	"	96	120	132	116
5. <i>Cyperus difformis</i> Lin.	Cyperaceae	90	119	121	110
6. <i>Saccharum officinarum</i> Lin.	Poaceae	122	95	107	108
7. <i>Chrysopogan aciculatus</i> Trin.	"	105	94	86	95
8. <i>Cynodon dactylon</i> Pers.	"	84	91	95	90
9. <i>Sorghum helepense</i> Willd.	"	63	98	64	75
10. <i>Zea mays</i> Lin.	"	75	52	77	68
11. <i>Brachiaria reptans</i> Lin.	"	75	62	52	63
12. <i>Hordeum vulgare</i> Lin.	"	39	24	42	35

* Number of insects feeding on *C. kyllingia* was taken as 100. See text for detail.

acceptability percentages were 132% (*C. dactylon*), 115% (*B. reptans*) and 100% (*C. kyllingia*) respectively. Here *B. ramosa* (95%) and *C. difformis* (92%) were nearly equally acceptable to *S. pr. prasiniferum*. The mean acceptability percentages of rest seven food plants of this species along with five highly preferred plants are tabulated in Table-3. Though *S. pr. prasiniferum* is relatively smaller in size and a pest of wheat, rice and sugarcane (Iqbal and Aziz, 1974), but the present finding reveals that it preferred a very wide range of food plants. It might be due to its multivoltine nature and year through occurrence. Hence, during scarcity of its highly preferred food plants it migrates to its nearby hosts.

In the fourth species (*O. fuscovittata*) the order of three preferred food plants were *Brachiaria reptans*, *Oryza sativa* and *Cynodon dactylon* and their mean acceptability percentages were 134% (*B. reptans*) 124% (*O. sativa*) and 114% (*C. dactylon*) respectively. *Triticum aestivum* (106%), *Chrysopogan aciculatus* (105%), *Saccharum officinarum* (104%) and *Cyperus kyllingia* (100%) were nearly equally acceptable to *O. fuscovittata*. The mean acceptability percentages of the rest five food

plants are also tabulated in Table-4. Experimental result shows that *O. fuscovittata* mostly preferred the food plants belonging to family Poaceae than Cyperaceae to which it was tested. They are also very good feeder and consume almost all the tested plants with high efficacy. Though it was recorded as a pest of sugarcane, paddy and jute (Mishchenko, 1952; Hollis, 1971), but their wide range of food preference might be due to their multivoltine nature and year through occurrence.

Thus, the study of food preference of all the four species viz., *H. banian*, *A. exaltata*, *S. pr. prasiniferum* and *O. fuscovittata* give the knowledge that all of them are very good feeder of the plants belonging to families Poaceae and Cyperaceae. Katiyar (1956) on *Parahieroglyphus bilineatus* and Fanny et al. (1999) on *Oxya nitidula* also found similar observations that these acridids mostly preferred the plants of monocot type. On studies of *Eyprepocnemis alacris alacris* Serv., Muralirangan and Ananthakrishnan (1977) stated that though this species is polyphagous but turn to monophagous when the most preferred food plant is available, i.e., selective within the framework of its polyphagy. It prefers variety of food plants especially

Table 3. Relative preference of *Spathosternum pr. prasiniferum* to various food plants*

Name of plant	Family	Acceptability percentage			
		Exp. 1	Exp. 2	Exp. 3	Mean
1. <i>Cyperus kyllingia</i> Endl.	Cyperaceae	100	100	100	100
2. <i>Cynodon dactylon</i> Pers.	Poaceae	162	119	115	132
3. <i>Brachiaria reptans</i> Lin.	"	147	117	81	115
4. <i>Brachiaria ramosa</i> Lin.	Poaceae	86	109	91	95
5. <i>Cyperus difformis</i> Lin.	Cyperaceae	76	95	105	92
6. <i>Chrysopogan aciculatus</i> Trin.	"	98	92	65	85
7. <i>Oryza sativa</i> Lin.	"	61	40	52	51
8. <i>Triticum aestivum</i> Lin.	"	52	45	38	45
9. <i>Saccharum officinarum</i> Lin.	"	35	53	41	43
10. <i>Sorghum helepense</i> Willd.q	"	29	42	28	33
11. <i>Zea mays</i> Lin.	"	29	42	28	33
12. <i>Hordeum vulgare</i> Lin.	"	30	36	30	32

* Number of insects feeding on *C. kyllingia* was taken as 100. See text for detail.

Table 4 : Relative preference of *Oxya fuscovittata* to various food plants*

Name of plant	Family	Acceptability percentage			
		Exp. 1	Exp. 2	Exp. 3	Mean
1. <i>Cyperus kyllingia</i> Endl.	Cyperaceae	100	100	100	100
2. <i>Brachiaria reptans</i> Lin.	Poaceae	145	121	136	134
3. <i>Oryza sativa</i> Lin.	"	175	112	85	124
4. <i>Cynodon dactylon</i> Pers.	"	115	106	120	114
5. <i>Triticum aestivum</i> Lin.	"	101	112	105	106
6. <i>Chrysopogan aciculatus</i> Trin.	"	106	97	111	105
7. <i>Saccharum officinarum</i> Lin.,,	"	99	110	103	104
8. <i>Cyperus difformis</i> Lin.	Cyperaceae	80	76	83	79
9. <i>Brachiaria ramosa</i> Lin.	Poaceae	99	40	43	61
10. <i>Zea mays</i> Lin.	"	56	63	53	57
11. <i>Hordeum vulgare</i> Lin.	"	30	57	32	40
12. <i>Sorghum helepense</i> Willd.	"	44	38	32	38

* Number of insects feeding on *C. kyllingia* was taken as 100. See text for detail.

grasses and also exerts a choice between feeding and not feeding on a given plant. The authors also remarked that though *Eyprepocnemis alacris alacris* tends to feed to a number of plants when provided in the laboratory, it does not do so till it becomes satisfied with a food of high preference value. In the present study the four species of acridids also did not restrict their feeding habits to a few food plants, but consumed most of the tested food plants with greater efficacy. This result might be due to the selection of food plants from only two highly preferred families to these insects. Plants belonging to families other than Poaceae and

Cyperaceae certainly will give different results and it can be assumed that the food plant acceptability of these insects might fall down feeding on plants other than the plants belonging to families Poaceae and Cyperaceae.

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LITERATURE CITED

- BERNAYS, E. A. and CHAPMAN, R. F. 1973. The role of food plants in survival and development of *Chortoicetes terminifera* (Walk.) under drought conditions. *Aus. J. Zool.*, 21 : 575-592.
- BHOWMIK, H. K. and HALDAR, P. 1984. Remarks of twelve species of newly recorded grasshoppers (Orthoptera : Acrididae) from West Bengal. *Bull. zool. Surv. India*, 6(1-3) : 45-55.
- BOMAR, C. R. and LOCKWOOD, J. A. 1991. Developmental and dietary effects on consumption of wheat bran by laboratory reared *Melanoplus sanguinipes* F. (Orthoptera : Acrididae). *J. Kansas Entomol. Soc.*, 64(3) : 295-299.
- CHAPMAN, R. F. 1959. Field observations on the behavior of hoppers of the Red Locust (*Nomadacris septemfasciata* Serv.). *Anti-Locust Bull.*, 33 : 51.

- DAS, A., DAS, S. and HALDAR, P. 2002. Effect of food plants on the growth rate and survivability of *Hieroglyphus banian* (Fabricius) (Orthoptera : Acridoidea), a major paddy pest in India. *Appl. Entomol. Zool.*, **37**(1) : 207-212.
- FANNY, P., RAVIKUMAR, T., MURALIRANGAN, M. C. and SANJAYAN, N. P. 1999. Influence of host plants on the duration of post embryonic development and food utilization of *Oxya nitidula* (Walker) (Orthoptera : Acridoidea). *J. Orthoptera Res.*, **8** : 119-124.
- HALDAR, P., BHANDARI, K. P. and NATH, S. 1995. Observations on the food preference of an Indian grasshopper *Acrida exaltata* (Walker) (Orthoptera : Acridoidea). *J. Orthoptera Res.*, **4** : 57-59.
- HANSEN, R. M. and UECKERT, D. N. 1970. Dietary similarity of some primary consumers. *Ecology*, **51** : 640-648.
- HEWITT, G. B. 1969. Twenty-six varieties of forage crops evaluated for resistance to feeding by *Melanoplus sanguinipes*. *Annals of the Entomology Society of America*, **61** : 739-744.
- HINKS, C. F. and OLFERT, O. 1992. Cultivar resistance to grasshoppers in temperate cereal crops and grasses. *J. Orthoptera Research*, **1** : 1-8.
- HOLLIS, D. 1971. A preliminary revision of the genus *Oxya* Audinet-Serville (Orthoptera : Acridoidea). *Bull. Br. Mus. Nat. Hist. Ent. London*, **26**(7) : 269-343.
- HOWARD, J. J. 1995. Variation in dietary patterns among and within polyphagous grasshopper species (Orthoptera : Acrididae). *J. of Insect Behav.*, **8**(5) : 563-577.
- IQBAL, M. and AZIZ, S. A. 1974. Life history of *S. pr. prasiniferum* (Walker) (Orthoptera : Acridoidea). *Ind. J. Zool.*, **2**(1) : 37-43.
- KATTYAR, K. N. 1956. The life history and ecology of the short horned grasshopper, *Parahieroglyphus bilineatus* Bol. (Orthoptera: Acrididae). *Agra Univ. J. Res. (Sci.)*, **5**(1) : 179-192.
- McNAUGHTON, S. J., TARRANTS, J. L., McNAUGHTON, M. M. and DAVIS, R. H. 1985. Silica as a defense against herbivory and a growth promoter in African grasses. *Ecology*, **66** : 528-535.
- MISHCHENKO, L. L. 1952. Insects-Orthoptera IV No. 2. Acrididae (Catantopinae) (In Russian). *Fauna SSSR*, **54** : 610.
- MUKERJII, M. K., PICKFORD, R. and RANDELL, R. L. 1976. A quantitative evaluation of grasshopper (Orthoptera: Acrididae) damage and its effect on spring wheat. *The Canadian Entomologist*, **108** : 255-270.
- MULKERN, G. B., TOCZEK, D. R. and BRUSVEN, M. A. 1964. Biology and ecology of North Dakota grasshoppers II. Food habits and preferences of grasshoppers associated with the sand hills prairie. *North Dakota Agr. Exp. Sta. Res. Rep.*, **11** : 59.
- MURALIRANGAN, M. C. and ANANTHAKRISHNAN, T. N. 1977. Biological studies on *Eyprepocnemis alacris alacris* (Serv.) (Orthoptera: Acrididae)-growth in terms of weight, length and eye stripe number. *Entomon.*, **2**(2) : 193-200.
- MUTHUKRISHNAN, J., DELVI, M. R. and PANDIAN, T. J. 1976. Assimilation efficiency of *Poecilocus pictus* and *Mantis religiosa*. *Comparative Physiological Ecology*, **1** : 69-73.
- NAYAR, K. K., ANANTHAKRISHNAN, T. N. and DAVID, B. V. 1976. In : *General and applied entomology*. Tata McGraw-Hill publishing Company Limited, New Delhi, India.
- PICKFORD, R. 1962. Development, Survival and Reproduction of *Melanoplus bilituratus* (Walk.) (Orthoptera : Acrididae) reared on various food plants. *Canadian Entomologist*, **94** : 859-869.

- ROFFEY, J. 1964. Notes on some locusts and grasshoppers of economic importance in South East Asia. *Ann. Tech. Bull. Kasetsart Ent. Phytopath. Soc.*, **4** : 74-83.
- SANCHEZ, N. E. and ONSAGER, J. A. 1998. Life history parameters of *Melanoplus sanguinipes* (F.) in two-crested wheat grass pastures. *Can. Entomol.*, **120** : 39-44.
- THOMAS, J. G. 1966. The sense organs of the mouthparts of the desert locust, *Schistocerca gregaria* Frosk. *J. Zool.*, **148** : 420-448.
- UECKERT, D. N., HANSEN, R. M. and Terwilliger Jr., C. 1972. Influence of plant frequency and certain morphological variations on diets of Rangeland grasshoppers. *J. Range Management.*, **25** : 61-65.
- UVAROV, B. 1966. In : *Grasshoppers and locusts—a handbook of general acridology*, Cambridge University Press. **1** : 481.
- UVAROV, B. 1977. In : *Grasshoppers and locust—a handbook of general acridology*. (Center for Overseas Pest Research) Cambridge University Press. **2** : 613.
- WOODHEAD, S. and CHAPMAN, R. F. 1986. Insect behavior and the chemistry of plant surface waxes. In : *Insect and plant surfaces* (Juniper and Southwood, Ed.). Edward Arnold : London : 123-136.

**TOXICOLOGY, RISK ASSESSMENT
AND
ENVIRONMENTAL MANAGEMENT**

POLYCULTURE OF SEX REVERSED TILAPIA WITH INDIGENOUS MAJOR CARPS : A SOCIO-ECONOMIC BOON

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Abstract

Very little is known about the impact of hormone treated, sex reversed tilapia on the growth potentiality of Indian major carps (IMCs) during polyculture in ponds. Polyculture can produce an expected result if the fish with different feeding habits are stocked in proper ratios and combinations. But, the problems associated with autostocking propensity of the mixed sex tilapia culture may reduce the growth rate of tilapia itself and can also hamper the growth potentiality of the IMCs. In our study, equal numbers of control and hormone treated tilapia were cultured in two separate earthen ponds along with *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* at a ratio of 6:2:1:1 respectively. At the end of the five month culture period, the highest and least growths among the IMCs were shown by *Catla catla* and *Cirrhinus mrigala* respectively. Interestingly, when cultured with hormone treated, sex reversed tilapia, weight and length of all the fish types became significantly higher (P -value < 0.05) compared to those that were reared with control tilapia. Such increased growth might be attributed to the fact that the hormone treated all male tilapia could not disrupt the stocking equilibrium by producing overlapping juvenile population. Moreover, mean economic gain from polyculture with treated tilapia was much greater compared to that with control tilapia. In the modern scenario, there is an increased pressure on aquaculture to improve efficiency and reduce environmental impacts. Polyculture of IMCs with hormone treated, monosex tilapia population will almost certainly play an important role in this process.

Keywords : Tilapia, Sex reversal, Polyculture

INTRODUCTION

The underlying goal of polyculture involves increasing productivity by more efficiently utilizing the ecological resources within an aquatic environment. This culture system can produce an expected result if the fish with different feeding habits are stocked in proper ratios and combinations (Azad *et al.*, 2004). Stocking two or more complementary species can increase the maximum standing crop of a pond by allowing a wider range of available foods and pond volume to be utilized. Although, the country is blessed with vast species diversity, cultured species are limited

in number with the three Indian major carps (IMCs : *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*) as the dominant ones (Alikhuni, 1957). But, nowadays, tilapias are introduced in fresh water ponds for polyculture with other compatible fish species (Azad *et al.*, 2004).

The efficiency of reproduction in tilapia has paradoxical consequences. This aptitude allows easy and rapid propagation of the fish in various environmental conditions, but can as well be a source of problem. Within a limited environment, uncontrolled multiplication of the fish not only reduces the faunal diversity of the system but also produces dwarf fish

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population of poor market value (Hepher and Pruginin, 1981; Coleman, 2001). Hence, development of cost-effective monosex culture methods of all-male tilapia population remains a critical objective for tilapia culture industry. Our earlier study has indicated that dietary supplementation of exogenous male steroid hormone to the tilapia spawns in an age, dose and duration specific manner can produce almost all-male tilapia population (Chakraborty *et al.*, 2007).

In spite of an already rich and diverse fish genetic resource of India, more than 300 exotic species have been introduced into the country so far (Jhingran, 1989). However, such indiscriminate introduction of the exotic fish into the open waters has generated a lot of debate in recent years. The ecologists and aquaculturists are concerned with the adverse effect of this exotic group on the indigenous fish population. In a number of reservoirs in India, introduction of tilapia has resulted in poor growth rate or even elimination of the indigenous species and the transplanted Gangetic carps (Sreenivasan, 1967). Moreover, its performance in open water ponds of India has been discouraging over the years because of its early maturity, continuous breeding, overpopulation and dwarfing. But, tilapia of right size has a good consumer preference (Jhingran, 1991) and it forms a readily available source of animal protein in the diets of rural and urban dwellers belonging to the lower socioeconomic strata. Hence, new techniques for maintenance of high growth rate of tilapia along with adequate IMC production are needed. Considering this aspect, our present study aims to evaluate the growth performance of hormone treated monosex tilapia population in combination with the IMCs and its effect on the growth rate of other indigenous fish along with the economic impact of such aquaculture system.

MATERIALS AND METHODS

Initially, two groups ($n = 120$) of 3 days old mixed sex juveniles of tilapia *Oreochromis sp.* were collected from the Fish Hatchery at

Naihati, West Bengal, oxygen packed, transported to the laboratory and reared in glass aquaria for one month. During this period, one of the groups was fed with 17α MT treated diet with a dose of 10 mg/kg at a rate of 20% body weight/day while the other group was given hormone untreated control diet at the same rate. Hormone treated diets were prepared by the alcohol evaporation technique (Shelton *et al.*, 1978). Fresh foods was prepared weekly and stored in a cool, dry place.

After one month, the fish were introduced into two separate earthen ponds (3m $\times$ 3m $\times$ 1m) along with equal numbers of *Labeo rohita* ($n = 40$; mean weight 10.48 ± 0.1 g; mean length 9.43 ± 0.07 cm), *Catla catla* ($n = 20$; mean weight 11.94 ± 0.06 g; mean length 8.91 ± 0.03 cm) and *Cirrhinus mrigala* ($n = 20$; mean weight 10.2 ± 0.08 g; mean length 8.51 ± 0.06 cm) at a ratio of 6:2:1:1 respectively. The fish were cultured for the following five months and during that time the fish were fed twice daily with the hormone untreated control food at a constant rate of 10% body weight/day for the first two months and 5% body weight/day for the rest three months. Different physico-chemical factors like temperature, DO_2 , free CO_2 , pH, total alkalinity and turbidity were regularly monitored (Table-1) using the standard procedures of American Public Health Association (APHA, 1998). To record the growth of the fishes, 10% of all fish species from each pond were sampled monthly to measure the length and weight of each species. All the fishes were harvested at the end of culture period and individual weight, length and other growth parameters like daily weight gain (DWG), food conversion ratio (FCR) and specific growth rate (SGR) were calculated at that time according to the standard formulations (Pechsiri and Yakupitiyage, 2005). Details regarding operational and production cost were estimated and the data were procured, tabulated and analyzed using simple average method. The costs mainly include the recurring ones like seed, feed, hormone, maintenance of the culture system, harvesting etc while the return is solely based on the price obtained from the cultured fish that varies according to the grade and quality of fish.

Finally, data were analyzed statistically to observe the performance of fishes under both situations. All the data are expressed in terms of mean $\pm$ standard error. Duncan's test (at 5%) (Duncan, 1955) was followed to compare the means for significant variations and the statistically homogenous means were denoted by similar alphabets.

RESULTS

After one month of culture in the laboratory before introduction in the pond, the hormone treated tilapia grew significantly more than the control. The growth pattern of all the fish from two ponds clearly indicated that combined fish growth in terms of weight and length in the pond with treated tilapia was significantly higher (P-value < 0.05) than the growth in the pond with control tilapia (Fig. 1). Among the

different fish types cultured, *Cirrhinus mrigala* had the least mean weight (117.86 ± 4.04 g) for combined value of control and treated pond while the best growth was obtained for tilapia (163.02 ± 20.03 g) (Table-2). *Catla catla* had weight (140.3 ± 5.77 g) belonging to both the lower and higher homogenous subsets and that of *Labeo rohita* (122.61 ± 4.17 g) belonged only to the lower one (Table-2). But for lengthwise growth pattern, tilapia grew least and belonged to the same homogenous subset of *Cirrhinus mrigala*, the highest length was achieved by *Catla catla* and *Labeo rohita* had an intermediate length being present in both the homogenous subsets (Table-2). DWG for all the fishes were equivalent as they belonged to the same statistical category (Table-2). Tilapia exhibited significantly lower FCR but higher SGR than other three fishes that were placed in the same

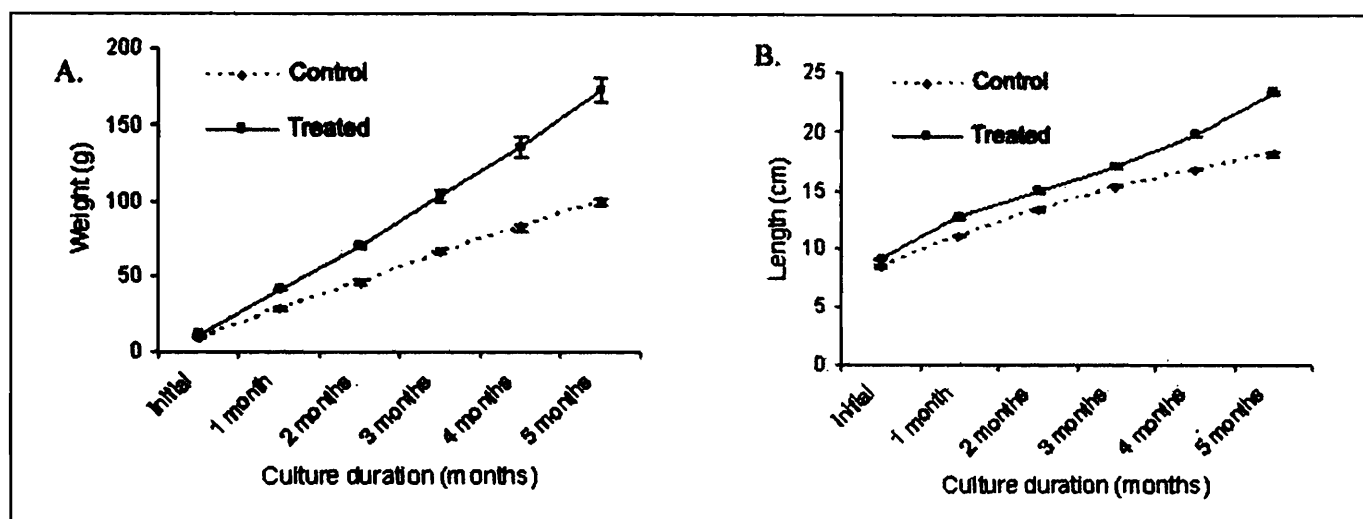


Fig. 1. Comparative growth patterns (A. Weight; B. Length) of all the fish combined for culture with control and hormone treated tilapia.

Table-1. Physical parameters of water during polyculture system.

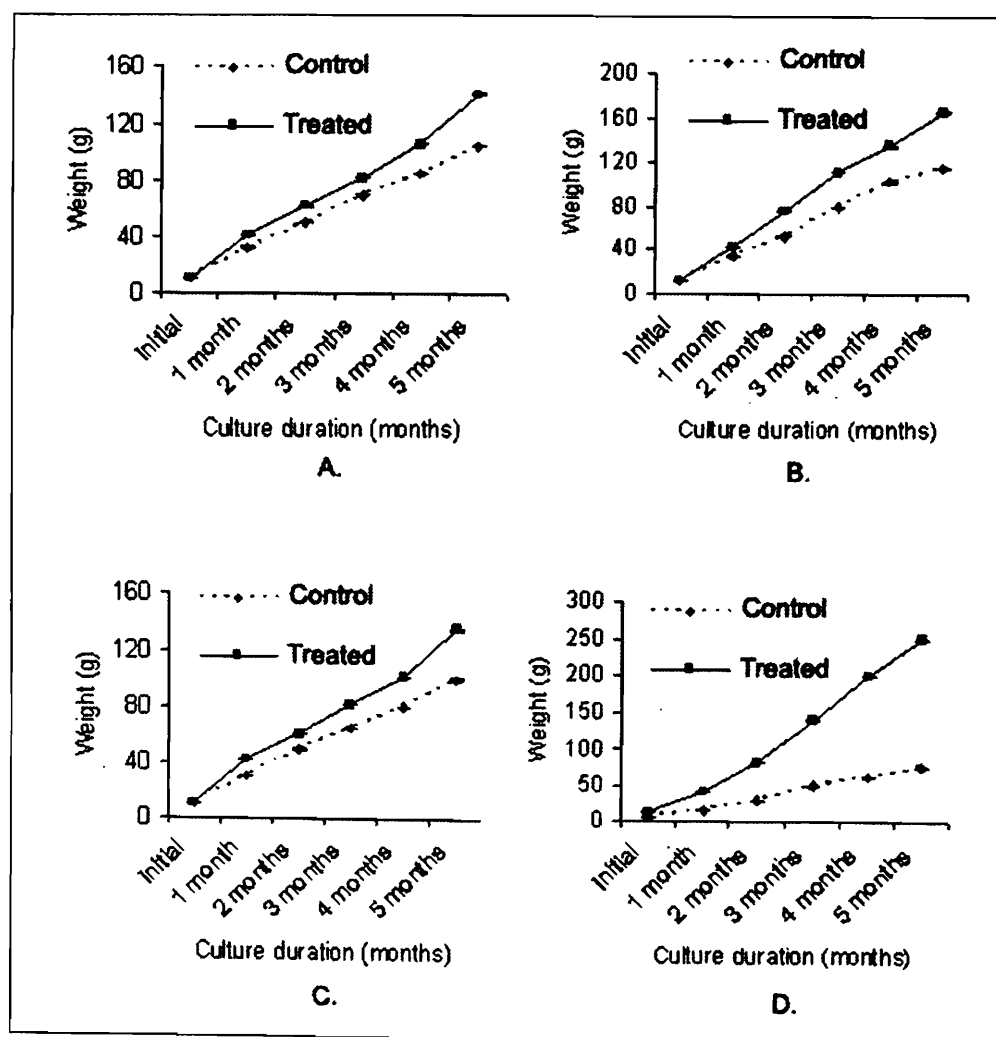
Month	Physical parameters of water					
	Temperature	DO ₂	Free CO ₂	pH	Turbidity	Alkalinity
April	34.1 $\pm$ 0.08	7.2 $\pm$ 0.07	5.5 $\pm$ 0.03	7.57 $\pm$ 0.03	29.33 $\pm$ 0.33	120.5 $\pm$ 0.07
May	35.2 $\pm$ 0.14	6.97 $\pm$ 0.07	6.07 $\pm$ 0.03	7.6 $\pm$ 0.0	28.67 $\pm$ 0.17	115.0 $\pm$ 0.05
June	32.87 $\pm$ 0.33	7.0 $\pm$ 0.05	6.8 $\pm$ 0.03	7.7 $\pm$ 0.03	27.17 $\pm$ 0.17	121.23 $\pm$ 0.07
July	31.0 $\pm$ 0.47	7.4 $\pm$ 0.05	7.5 $\pm$ 0.05	7.5 $\pm$ 0.06	27.33 $\pm$ 0.17	127.1 $\pm$ 0.07
August	30.03 $\pm$ 0.3	7.5 $\pm$ 0.03	7.97 $\pm$ 0.07	7.2 $\pm$ 0.06	25.33 $\pm$ 0.33	135.2 $\pm$ 0.1
September	31.2 $\pm$ 0.4	7.07 $\pm$ 0.03	6.67 $\pm$ 0.03	7.7 $\pm$ 0.0	31.33 $\pm$ 0.33	136.07 $\pm$ 0.03
October	30.4 $\pm$ 0.4	7.47 $\pm$ 0.03	5.9 $\pm$ 0.09	7.73 $\pm$ 0.09	35.0 $\pm$ 0.58	124.13 $\pm$ 0.05

Table-2. Different growth parameters for fishes in polyculture system for combined value of control and treated pond (similar alphabet denotes homogenous means)

Fish	Growth parameters				
	Weight (g)	Length (cm)	DWG	FCR	SGR
<i>Labeo rohita</i>	122.61 ^b ± 4.17	20.55 ^{ab} ± 0.58	0.75 ^a ± 0.06	4.33 ^a ± 0.13	1.63 ^b ± 0.02
<i>Catla Catla</i>	140.3 ^{ab} ± 5.77	22.26 ^a ± 0.5	0.87 ^a ± 0.08	4.52 ^a ± 0.12	1.63 ^b ± 0.03
<i>Cirrhinus mrigala</i>	117.86 ^b ± 4.04	20.35 ^b ± 0.55	0.7 ^a ± 0.08	4.39 ^a ± 0.09	1.62 ^b ± 0.02
<i>Oreochromis sp.</i>	163.02 ^a ± 20.03	19.93 ^b ± 0.83	1.04 ^a ± 0.25	3.62 ^b ± 0.13	1.7 ^a ± 0.06

homogenous group (Table-2). On the other hand, the growth pattern changed considerably when the fish from control and treated pond were analyzed independent of each other. When cultured with hormone treated, sex reversed tilapia, weight and length of all the fish types became significantly higher (P-value < 0.05) compared to those that were reared with control tilapia (Figs. 2,3). Interestingly, control

tilapia had the least weight and length, treated tilapia had the highest weight value and *Catla catla* from the treated pond showed the maximum length (Figures-2, 3). Control tilapia showed the lowest DWG value while treated tilapia had the highest; *Cirrhinus mrigala* from the control pond belonged to the same homogenous category as that of control tilapia but *Cirrhinus mrigala* from the treated pond had

**Fig. 2.** Comparative weight of different fish (A : *Labeo rohita*; B : *Catla catla*; C : *Cirrhinus mrigala*; D: *Oreochromis sp.*) under polyculture system with control and hormone treated tilapia.

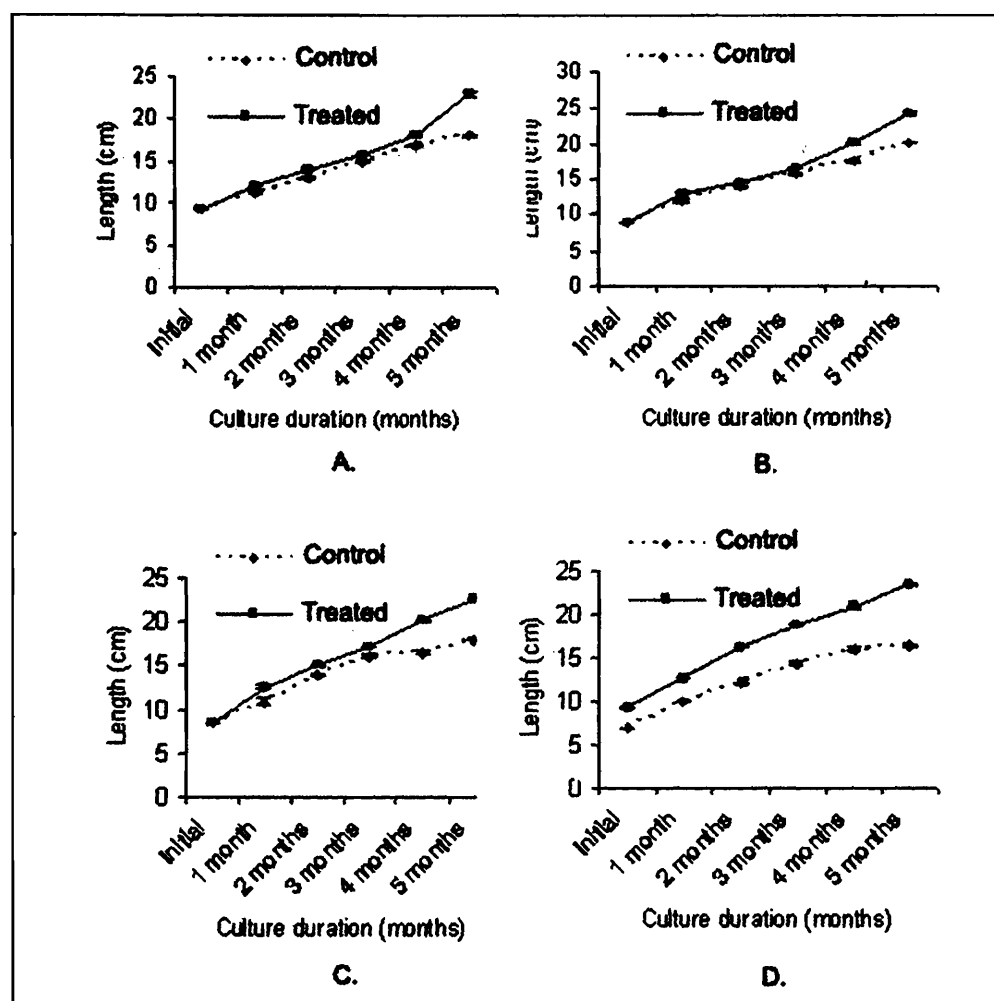


Fig. 3. Comparative length of different fish (A : *Labeo rohita*; B : *Catla catla*; C : *Cirrhinus mrigala*; D: *Oreochromis* sp.) under polyculture system with control and hormone treated tilapia.

statistically equivalent DWG to *Labeo rohita* from treated pond (Fig. 4). FCR value for treated tilapia was found to be the lowest (3.3 ± 0.01) followed by control tilapia (3.92 ± 0.003); all other fish from the control pond had significantly higher FCR values compared to those from the treated pond; the highest (4.8 ± 0.01) being shown by control *Catla catla* (Fig. 4). Conversely, *Catla catla* from the control pond had lowest SGR and treated *Catla catla* showed the highest SGR value (Fig. 4). Mean production cost for polyculture of tilapia with IMCs was comparatively low for both control and treated ponds (Fig. 5). Mean gain from polyculture with control tilapia was much less compared to that with treated tilapia (Fig. 5). While polyculture with control tilapia yielded positive gain only at the end of 5th culture month, culture of IMCs with hormone treated monosex tilapia yielded a positive gain from the 3rd

month of culture and at the end of the culture period it provided much better economic gain (Table-3).

DISCUSSION

In recent years, polyculture has begun to regain attention as a possible means to increase efficiency in aquaculture production systems, and to reduce environmental impacts caused by excess nutrients. It is often of greatest benefit in extensive or moderately intensive fish production. But, the problems associated with polyculture involve handling and sorting species at harvest, overlap of food or habitat preferences in species, or even downright antagonism, and most importantly acceptance by producers and consumers. In many cases, the otherwise ideal candidate for a polyculture system may have low consumer acceptance thereby making such production less profitable.

Table 3. Economical account of polyculture system.

Category	Culture duration	Economics		
		Input (Rs.)	Output (Rs.)	Gain (Rs.)
Control	1st month	303.914	51.474	-252.44
	2nd month	342.621	148.589	-194.032
	3rd month	377.16	294.482	-82.678
	4th month	430.07	417.216	-12.854
	5th month	495.19	612.128	116.938
Treated	1st month	361.266	171.135	-190.131
	2nd month	434.851	422.08	-12.771
	3rd month	501.84	822.012	320.172
	4th month	609.256	1333.401	724.145
	5th month	757.745	2042.603	1284.858

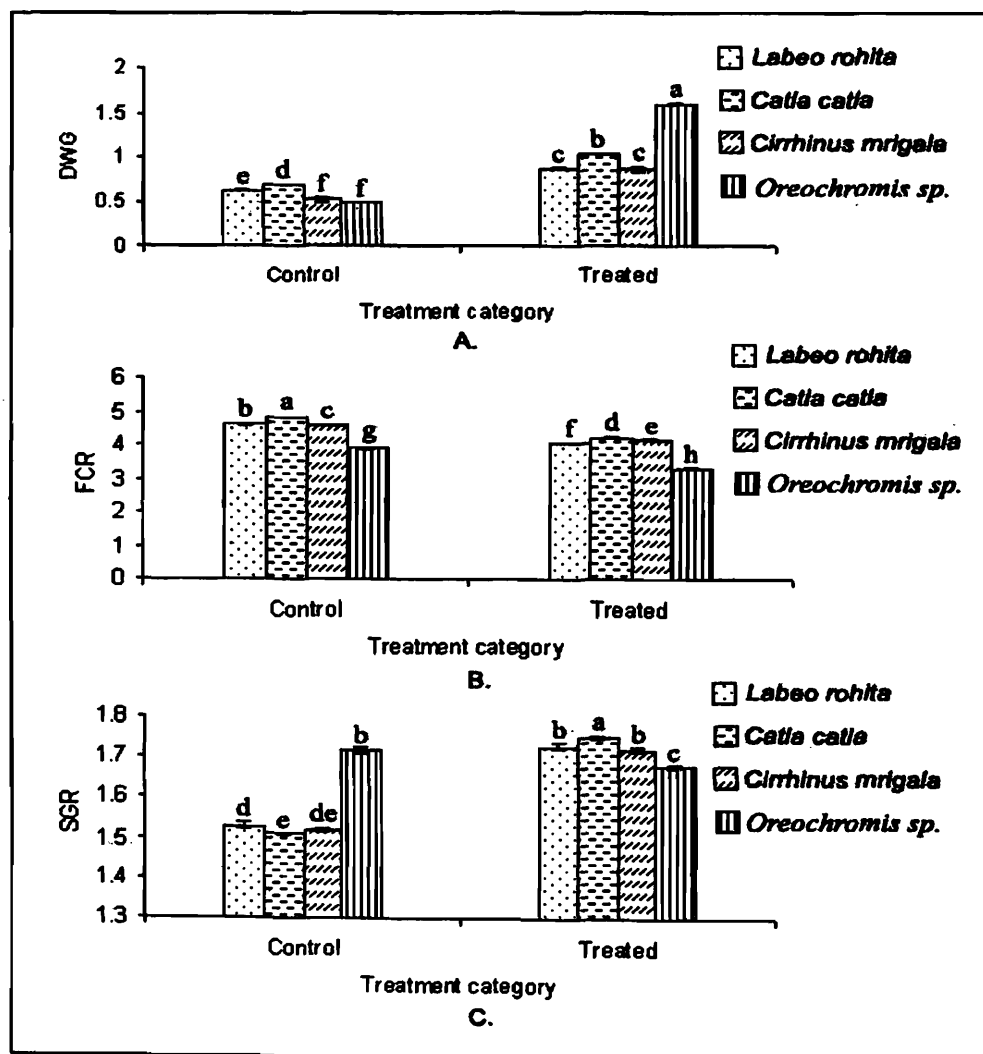


Fig. 4. Comparative growth pattern of different fish for polyculture with control and hormone treated tilapia (A : DWG; B : FCR; C : SGR). Similar alphabet denotes homogenous means.

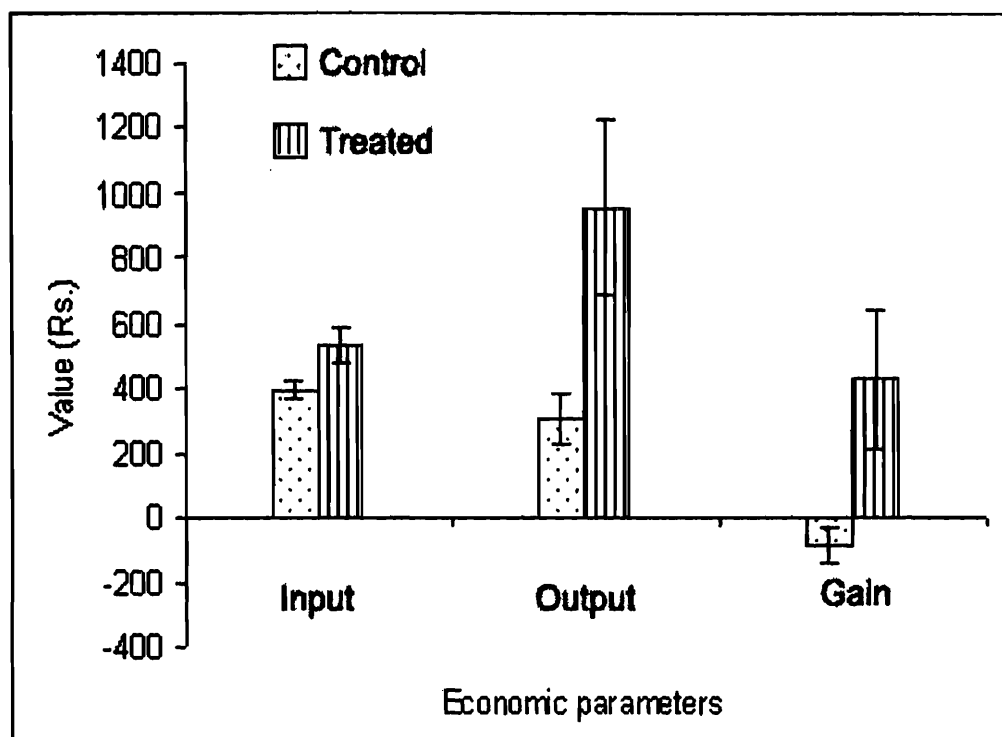


Fig. 5. Economic parameters (mean input, output and gain) for polyculture system with control and hormone treated tilapia.

Fish farmers are often not willing or prepared to adopt polyculture. In West Bengal majority of producers did not fully understand the principle or potential of polyculture, and the technology was applied only to a limited extent (Ghosh *et al.*, 1993).

Culture of hormone treated all male tilapia population with IMCs not only ensured better production of tilapia alone, but also yielded significant increase in growth potential of the IMCs. The general trend of IMC growth pattern was maintained for both control and treated polyculture systems as highest and least growth were shown by *Catla catla* and *Cirrhinus mrigala* respectively. But, culture with treated tilapia had a positive impact on the growth performance of all these fish as they grew significantly more compared to culture with control tilapia. Such increased production level might be attributed to the fact that the hormone treated all male tilapia could not disrupt the stocking equilibrium by producing overlapping juvenile population. The competitive success of IMCs for proper growth achievement mainly depends on the ability to utilize the supplementary feed that is provided considering only the stocked population. Any

substantial increase in fish number will definitely lead to increased competition and subsequent reduction in food availability. The monosex population of tilapia cannot breed to increase in number. Thus the natural and supplementary food present in the system could be utilized totally as well as more effectively by only the stocked fish population leading to a better growth. FCR values decreased as usual with increase in growth for all the fish.

In traditional forms of polyculture, waste products of primary species and the natural productivity they foster provide the basis for production of supplemental species. Species combinations for polyculture are sometimes developed with the intent of improving water quality. Alikhuni (1957) described polyculture of the IMCs while Yashouv (1958) described about the augmented production by the addition of supplemental tilapia to carp ponds. This culture method is often of greatest benefit in extensive or moderately intensive fish production. But, in the modern scenario, there is an increased pressure on aquaculture to improve efficiency and reduce environmental impacts. Polyculture of IMCs with hormone

treated, monosex tilapia population, with its natural emphasis on increased utilization of water and nutrients, will almost certainly play an important role in this process. Therefore, in developing nations like India, where a good number of natural open water systems is available for utilization, our study can lead to a low cost sustainable aquaculture method for the production of a major animal protein source.

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LITERATURES CITED

- ALIKHUNI, K. H. 1957. Fish culture in India. *Farm Bull.* No. 20. *Ind. Coun. Agr. Res.*, New Delhi.
- APHA, 1998. Standard Methods for the Examination of Water and Wastewater. 20th edn. APHA (American Public Health Association), Washington, USA.
- AZAD, M. A. K., RAHMAN, M. R., RAHMAN, Z., KADER, M. A., HAQUE, M. M. and ALAM, M. J. 2004. Polyculture of carp, tilapia and pangas using low cost inputs. *Pak. J. Biol. Sci.*, 7(11) : 1918-1926.
- CHAKRABORTY, S. B., SARBAJNA, A., MAZUMDAR, D. and BANERJEE, S. 2007. Effects of differential dose and duration of 17 α -methyltestosterone treatment on sex reversal of Nile tilapia, *Oreochromis niloticus* at different age groups under Indian perspective. *AJMBES*, 9(3) : 705-710.
- COLEMAN, R. 2001. Cichlids and Science : Bad Cichlids? *Cichlid News Mag.*, 10(2) : 32-34.
- DUNCAN, D. B. 1955. Multiple range and multiple F tests. *Biometrics*, 11 : 1-42.
- GHOSH, S., HAQUE, A. and BISWAS, A. 1993. Farmers' knowledge and extent of application of composite fish culture technology. *Environ. Eco.*, 11(4) : 926-929.
- HEPHER, and PRUGININ. 1981. Commercial Fish Farming. John Wiley and Sons, New York, 291.
- JHINGRAN, A. G. 1989. Role of exotic fishes in capture fishery waters of India. In : *Conservation and management of inland capture fisheries resources of India*. (Jhingran, A. G. and Sugunan, V. V. Eds.) p. 275. Inland Fisheries Society of India, CIFRI, Barrackpore, 74 : 3101.
- JHINGRAN, A. G. 1991. Performance of tilapia in Indian waters and its possible impact on the native ichthyofauna. *IPFC Proceedings*, Bogor, Indonesia. FAO Fisheries Report No. 458. FAO, Rome, 143-161.
- PECHSIRI, J. and YAKUPITTIYAGE, A. 2005. A comparative study of growth and feed utilization efficiency of sex-reversed diploid and triploid Nile tilapia, *Oreochromis niloticus* L. *Aquacult. Res.*, 36 : 45-51.
- SHELTON, W. L., HOPKINS, K. D. and JENSEN, G. L. 1978. Use of hormones to produce monosex tilapia for aquaculture. In: *The Second International Symposium on Tilapia in Aquaculture*. (Pullin, R. S. V., Bhukaswan, T., Tonguthai, K. and Maclean, J. L. Eds.) ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines : 10-33.
- SREENIVASAN, A. 1967. *Tilapia mossambica*: its ecology and status in Madras State, India. *Madras J. Fish.*, 3 : 33-39.
- YASHOUV, A. 1958. On the possibility of mixed cultivation of various kinds of tilapia with carp. *Bamidgeh*, 10(2).

STRATEGY OF METAL ACCUMULATION IN FISH WITH VARIOUS FOOD PREFERENCES

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ABSTRACT

The potential transfer of food borne metals by fish may pose serious health threat to man. Increasing pollutant levels especially the non degradable metals in the ecosystem has seriously affected the aquatic fauna and may pass on to the higher tropic levels. In water metals may either bind to organic ligands to settle at the bottom or may remain as ions in the overlying waters. Food preferences largely affect the port of entry of metals in fish and thereby its accumulation in the various tissues. Benthic fish accumulate more metals through food than the surface dwellers. Essential metals like Cu and Zn accumulate more in the liver and gills respectively while non essential metals like Pb and Cd concentrate uniformly over time in the non exchangeable pools of the body tissues. Benthic fish concentrate more Cu and Pb while surface feeders accumulate Zn in excess. With long term exposure, these metals tend to accumulate with the age of fish especially in the liver, gills and kidney. In the pollution free environment metals are depurated according to the metabolic status of the tissues. Essential metals are depurated faster than the non essential ones. Cu incompletely eliminated from muscle followed by Zn while Pb and Cd concentration falls by 50%. Different reduction rates are observed for various fish species at different stages of their life. Protective measures to release body burden of metals in fish is essential from the human health point of view.

Keywords : bioaccumulation, sewage-fed fish, Cu, Cd, Pb, Zn, water pollution.

INTRODUCTION

Kolkata nurtures one of the largest sewage-fed wetlands of the sub-continent where raw untreated domestic sewage and effluents from about 11,000 industries are fed regularly for cultivation of fish. These wetlands covering an area of 2500 hectares, fringes the entire eastern low lying lowlands of the city with an annual production of 7000 tonnes of fish (Gupta and Mitra, 1997). The practice spells prosperity to farmers as the huge organic load provide excellent nutrients to the growing fish but indiscriminate disposal of raw untreated sewage has added enormous pollutants including metals that are subsequently passed

on to the human food chain. This continuous toxic input leads to both ecological imbalances along with serious health risk for the fish loving people of Kolkata. Skin disease, hypertension, paralysis, kidney failure or cancer is thus common. Protective measures to release metal body burden from fish is a priority which will depend not only on the sewage input regulation but also on the metal depuration and their subsequent elimination from the body of the fish. Bioaccumulation of metals in fish depends on pH, temperature, alkalinity and hardness of water along with the feeding habit and nutritional status of the fish species. Fish with different food habits thus accumulate various levels of metals. (Newman and

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McIntosh, 1983, Kotze 1999) The first part of our study thus concerns with the quantitative estimation of Cu, Pb, Zn and Cd in the various tissues of three species of Indian major carp having different nutritional status and occupying different trophic levels of the wastewater wetlands. *Labeo rohita* is a column feeder, *Catla catla* are surface planktivore while *Cirrhinus mrigala* is a benthic detritivorous fish. The second part of our study comes with a possible suggestion for remedial measures against metal build-up in fish tissues. Sewage input in the system was temporarily stopped for a period of six months that allowed the declining of the metal levels in the system, making them unavailable to the residing fish population. This helped us to study the pattern and rate of metal depuration from fish in the uncontaminated environment following metal exposure in the polluted system.

MATERIALS AND METHODS

STUDY SITE

The study was carried out in a sewage-fed farm "The East Calcutta Fisherman's Cooperative Society", situated at the Eastern Metropolitan Bypass near the Kasba connector (22°30' N; 88°25' E), Kolkata, West Bengal. The farm covers an area of 44.55 hectares and supports about 109 sewage-fed ponds. Samples of water from wastewater ponds and the three fish species were collected for determination of metal concentration in their tissues. *Labeo rohita* (Ham.), *Catla catla* (Ham.) and *Cirrhinus mrigala* (Ham.) were caught by professional fishermen. Fish chosen were around 800g in weight. Fresh fish were kept in ice and packed in plastic bags. The tissues were then dissected out and subjected to wet digestion for analysis of metal concentration in them.

(a) Wet digestion of fish tissue, for estimation of metals : Muscle, liver, kidney, skin, gills and intestine of fishes were properly processed for analysis of Cu, Pb, Zn and Cd in them. Tissues were wiped dry and weighed accurately to 1 g each for acid digestion,

following the procedure of Chernoff (1975). Samples of fish tissues were taken in Borosil hard glass test tubes. For each gram of the sample, 5 ml of conc. HNO₃ acid was added and then digested overnight at room temperature. The mixture was placed in a hot plate at 85° + 5°C and 5 ml (3 : 2 conc. Sulfuric acid : Perchloric acid) was then added to it. The digestion was carried out until the mixture turned into a pale yellow transparent solution. The mixture was cooled and filtered through an acid soaked filter paper and was adjusted to the required volume with distilled water. Metals were detected in atomic absorption spectrophotometer (Varian AA.575).

The actual concentration was calculated on the basis of total amount of the sample taken and expressed in µg/g. Mean and standard deviation was calculated.

(b) Acid digestion of water and soil samples, for estimation of metals : Water samples from various sewage-fed ponds were collected in 1 liter tarson bottles and were fixed by adding few drops of nitric acid. Quantitative estimation of Cu, Pb, Zn and Cd in water samples was done following the standard methods (APHA, 1995) by atomic absorption spectrophotometer. Soil analysis was done by following the standard method. (Nafde, et. al. 1998) The actual concentration was calculated on the basis of total amount of the sample taken and expressed in µg/g. Mean and standard deviation was calculated.

RESULTS

Accumulation of Cu, Pb Zn and Cd in muscle, liver, kidney, skin, gills and intestine of *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* before and after the stoppage of sewage is shown in Figure 1,2,3 and 4. Results expressed as mean(µg/g) ± SD of five different observations P< 0.05. Depuration % of metals from tissues are shown in Tables 1, 2 and 3. Metal content in soil and water samples of sewage fed wetlands are shown in Tables 5 and 6.

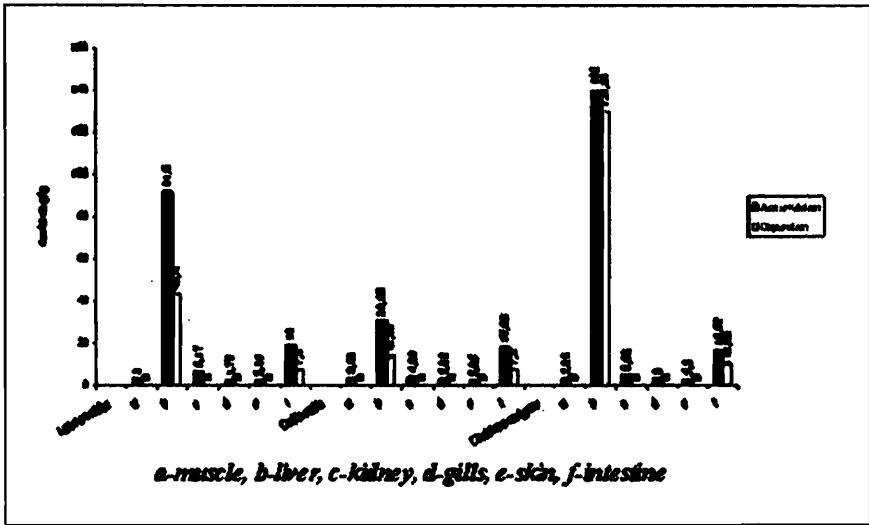


Fig. 1. Depuration pattern of accumulated copper in the different tissues of fish of 800g of body weight

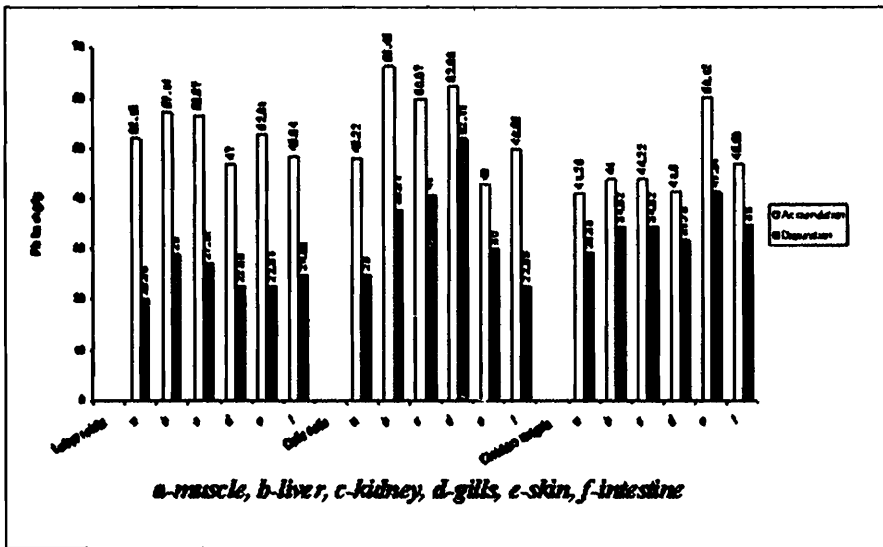


Fig. 2. Depuration pattern of accumulated lead in the different tissues of fish of 800g of body weight

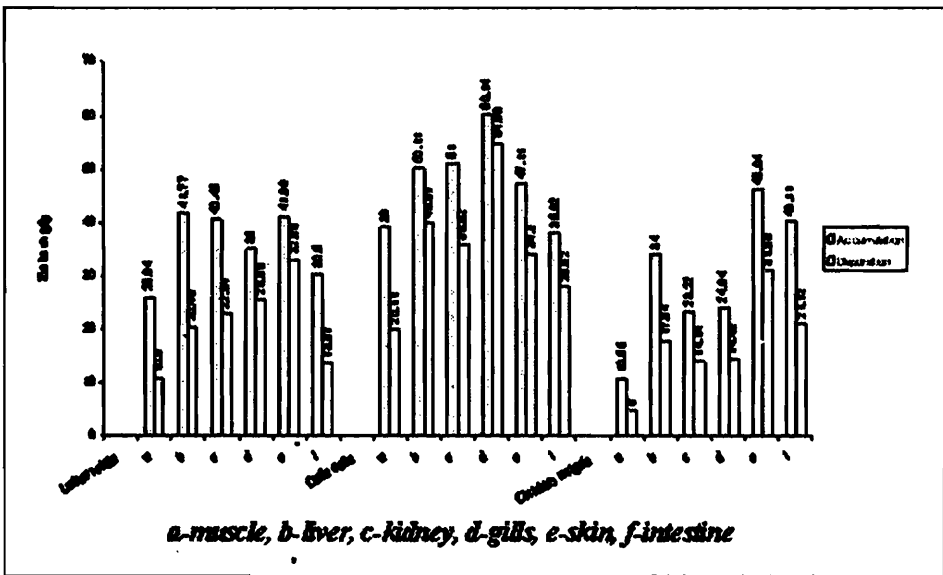


Fig. 3. Depuration pattern of accumulated zinc in the different tissues of fish of 800g of body weight

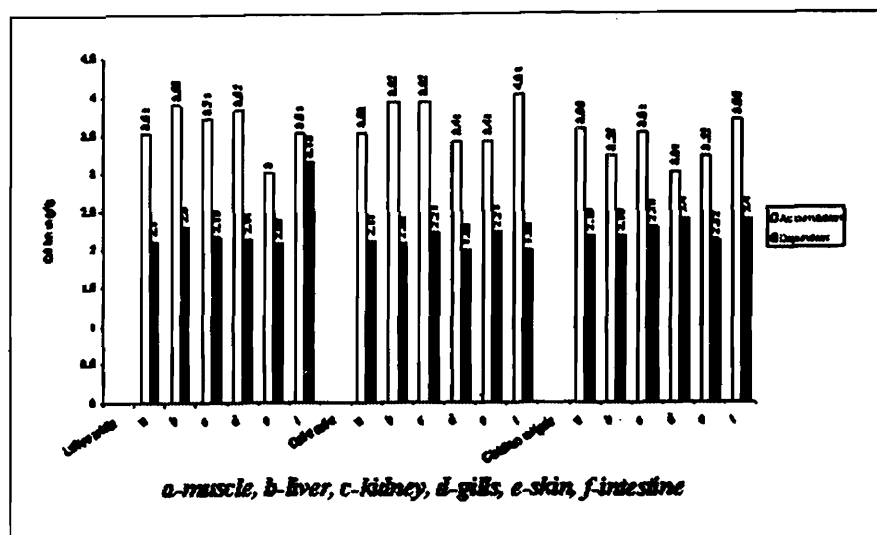


Fig. 4. Depuration pattern of accumulated cadmium in the different tissues of fish of 800g of body weight

Table-1. Depuration % of metals in the tissues of *Labeo rohita*

TISSUES	Copper	Lead	Zinc	Cadmium
Muscle	100	62.78	58.14	40.17
Liver	57.72	49.25	51.04	40.72
Kidney	100	52.14	43.30	41.72
Gills	100	51.94	26.89	43.98
Skin	100	56.70	19.71	31.67
Intestine	62.63	48.80	55.38	10.83

Table-2. Depuration % of metals in the tissues of *catla catla*

TISSUES	Copper	Lead	Zinc	Cadmium
Muscle	100	48.15	48.44	40.22
Liver	55.29	42.49	20.16	46.93
Kidney	100	31.75	29.76	43.62
Gills	100	16.74	8.72	41.94
Skin	100	30.23	27.62	35.19
Intestine	60.34	54.13	26.30	50.37

Table-3. Depuration % of metals in the tissues of *cirrhinus mrigala*

TISSUES	Copper	Lead	Zinc	Cadmium
Muscle	100	28.95	55.00	38.59
Liver	7.25	21.31	47.53	32.91
Kidney	100	21.71	39.10	35.05
Gills	100	23.73	39.72	20.26
Skin	100	31.24	32.49	34.16
Intestine	39.28	25.35	47.34	34.78

Table-4. Metal concentrations ($\mu\text{g/g}$) in the different component waste water ecosystem

	Cu	Pb	Zn	Cd
Water	10.97 ± 2.68	93.33 ± 3.33	16.44 ± 3.40	2.23 ± 0.71
Soil	41.00 ± 5.00	32.00 ± 2.18	60.80 ± 9.11	3.48 ± 1.1
Planktons	2.45 ± 0.95	33.04 ± 5.50	26.70 ± 8.00	4.33 ± 1.22

Table-5. Maximum permissible limits for metals

Metal	Standard for discharge of metals in inland water ($\mu\text{g/l}$)	Median international Standards for metals in fish flesh ($\mu\text{g/g}$ wet weight)
Cu	3	20
Pb	0.1	2
Zn	5	45
Cd	2	0.3

DISCUSSION

When metals from sewage are released into the aquacultural ponds they are exposed to different hydrological conditions that lead to changes in metal speciation and thereby their bioavailability. Metal accumulation in fish tissues depends on their various physiological roles and also on the ambient concentration. In polluted system a fish can accumulate excess xenobiotics that produce harmful effects. Liver, kidney and gills are primary storage and detoxification centers, while kidney, gills and intestine are also important excretory routes. Contribution of water and food to metal uptake in fish is reflected by their relative concentration in the gills and liver respectively. High level of dietary Cu contribute about 99% of the whole body Cu concentration, while water borne metal contributes only 60%. (Kumuda, 2002) Depuration of metal depend on the relative abilities of the organs for their metabolic transformation.

Homeostatic regulation exists for essential metals and Cu concentration in fish is maintained within narrow limits by coordinated uptake, transport and excretory mechanism (Grahl *et al.*, 1985). Cu is maximally accumulated in fish liver (De Boek *et al.*, 2004) where it is finally stored (Buckley *et al.*, 1982). Food is the main source of Cu and the present study reveals that, *C. mrigala* accumulates large quantities of the metal in its liver from its

benthic food. ($140\mu\text{g/g}$). Cu has maximum affinity for organic ligands and in a sewage-fed system, the metal is mostly bound to the soil matrix which makes it readily available to the benthic organism *C. catla* accumulates less ($30.85 \mu\text{g/g}$) of Cu due to its planktivorous feeding habit, as the metal is lowly available in the surface waters. In, *L. rohita*, ($90.8 \mu\text{g/g}$) the metal accumulation is intermediate for its occasional detritus feeding affinity.

Muscle offers homeostatic regulation for Cu and Zn. Cu remains low in the tissues while Zn concentration rises considerably. Muscle gets contaminated with high oral exposure of metals but Buckley *et al.* (1982) opined that accumulated Cu in the various tissues is chronically removed by the liver. So excepting in liver and intestine, Cu remains low in all the tissues. Accumulation of metals in muscle seems to become important only when the maximal storage capacity of the liver is reached (Lauren and McDonald, 1986) Storage of Zn in the muscular tissue may be possibly due to breakdown of the regulatory mechanism in fish during its long term exposure to elevated metal levels. Pb and Zn accumulates considerably in the muscle. From human health point of view Cu level remains below the set international standard, while Pb, Zn and Cd level rises above this range (Table 6).

The main route of Zn entry is through the gills although dietary uptake can also be considerably high (Velcheva, 2006). Zn accumulates maximally in the gills of *C. catla* (800 µg/g) complementing the observations of Hughes and Floss (1978) who observed that fish residing in the upper surface of water and exposed to normoxic condition accumulate more Zn in gills. It has the ability to bind maximally with the gill epithelium (Reid and MacDonald, 1991). The bioavailability of the metals by the gills is inversely proportional to the degree of complex with which it binds to the ligands in water.

Pb and Zn show modest accumulation in liver, Kidney, gills and skin. According to Czauderna and Rochalska (1989), fish in Zn contaminated areas accumulate about 40% metal into liver. In teleost, skin and gills act as potential uptake sites for these metals. Pb, do not induce the formation of metallothionein and there exists no target tissue for accumulation. So the metal accumulation seems to be closely constant in all the tissues of the three fish species. Tao *et al.* (1999) reports that body Pb accumulation increases with increasing level of the metal in the medium.

Cd concentration keeps low and constant in all the fish species under study, thereby showing low bioaccumulation potential (Maiti and Banerjee, 2002). According to Choudhury *et al.* (2005) variation of accumulation depends on the route of Cd entry. In spite of this low bioaccumulation potential the metal shows high concentration factor in relation to its level in the water and its average concentration in fish tissue rises above the mean international standard for metals in fish flesh. (Table 6).

In the present study, temporary stoppage of sewage effluents in the pond for three months, helped in the progressive decline of the metals in water (Table 5), thereby making them unavailable to the fish. It would allow us to measure the depuration of metals from these tissues. Depuration is the ridding of the toxicant from the body in an uncontaminated medium (Heath, 1995) and it may occur across body surface, gills, kidney or through faeces. It can

be noted that the metal concentration in the soil did not appreciably decrease during this study period although those in the pond water changed considerably. Prevention of pollution is the centre of our approach, where active steps are adopted to 'minimize the metal body burden.

From the observation it, that Cu content in the muscle, gills, skin and kidney decreased to almost a null value after the period of three months following stoppage of sewage input in the water. However, depuration from liver and intestine is low where *C. catla* and *L. rohita* depurated about 50% of the metal. But in *C. mrigala* depuration was negligible as the fish continues to intake Cu from the available food from the soil. The rate of depuration is rapid in all the tissues excepting in liver as the organ is the main storage site for the metal. It chronically removes the metal where it is finally stored. According to the spill over theory accumulated hepatic Cu is partly spilled out in the digestive tract which is either reabsorbed from the intestinal wall or excreted through the faeces (Heath, 1995). This accounts for the intestinal content of metals even in the pollution free environment. Rapid clearance of Cu suggests multiple elimination routes including urinary and branchial or faecal.

Pb and Zn levels reduced to about 50% of their initial value in the uncontaminated system while decrease of Cd was around 28-47%. Turnover rate of Cd is low in biological system so depuration rate is also rather slow (Hamilton and Klaverkamp, 1989). Schulz, (1974) opines that rate of Pb uptake is constant but the rate of depuration is dependent on the body concentration of the metals. Concentration of Pb in *C. mrigala* does not decrease appreciably as it continues to intake the metal from its benthic food. Most of the Zn is eliminated very slowly. Wicklund (1991) opines that low depuration of Zn may not occur during initial exposure in the uncontaminated environment. Mucus binding to metals in gills and skin help in their considerable reduction. Least Zn was depurated from *C. catla* gills (8%) as the organ has the highest affinity for the metal. Excess

Zn is excreted through bile a while urinary loss is minimal (Handy, 1993). Kidney excreted only 43. %, 29. %, and 39. % in *L. rohita*, *C. catla*, and *C. mrigala* respectively. Body Pb is excreted in the mucus of skin and gills. Retention of metals in fish tissues, even at lower ambient metal concentration is due to their binding in the non-exchangeable or slowly exchangeable pools. It shows that non essential metals like Pb and Cd are excreted rather slowly while essential metals like Cu and Zn are homeostatically regulated.

It is difficult to draw any generalized remark regarding the excretion of any foreign chemical because of complex interaction of metals, and for the diverse modes of excretory routes in fish. Pelgrom *et al.* (1994) opines that low level of one metal helps in the depuration of others. On the other hand higher level of one particular metal may prevent the entry of others.

Fish species with different nutritional status show variable degree of metal accumulation. Thus habitat dependent choice of fish offers less contamination to the consumers. There exist

complex relationship between metal chemistry in water and effects of metals in fish. Investigation may provide results to aid decision regarding the potential safety of fish in the diet of man and also determine acceptable concentration of metals in natural water. Depuration is a common biological phenomenon which is dependent on the strategies adopted by different organisms in the stressed environment. Fish from sewage-fed ecosystem rapidly depurate metals if offered a metal free environment. However, harvested fish if kept in uncontaminated environment for a period of at least three months can help in eliminating of considerable amount of metals. This strategy may provide necessary precaution against metal poisoning in the human population through food.

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LITERATURE CITED

- American Public Health Association 1995. *Standard methods for the examination of water and wastewater*. 19th edition.
- BUCKLEY, J.T., ROCH, M., MC CARTER, J.A., RENDEL, C.A. and MATHIESON, A.T. 1982. Chronic exposure of coho salmon to sublethal concentration of copper. Effect on growth on accumulation and distribution of copper tolerance. *Comp. Biochem. Physiol.*, 72C(1) : 15-19.
- CHERNOFF, B. 1975. A method for wet digestion of fish tissue for heavy metal analyses. *Trans. Am. Fish. Soc.*, 4 : 803-804.
- CZAUDEANA, M. and ROCHALKA, M. 1989. Effect of cadmium on tissue levels of selenium, zinc, iron, cobalt and rubidium. *Appl. Radiat.*, 40 : 177-182.
- CHOUDHURY, M.J., BAISEROTTO, B., WOOD, C.M. 2005. Tissue specific Cd and metallothionein in rainbow trout chronically acclimated to water borne or dietary Cd. *Arch. Environ. Contam. Toxicol.*, 381-390.
- DE BOEK G, MEEUW, D. COEN. W, BLUST R. 2004. Tissue specific Cu bioaccumulation patterns and differences in sensitivity to water borne Cu in three fresh water fish: rainbow trout (*Onchyrhynchus mykiss*) common carp (*Cyprinus carpio*) and gibel carp (*Carassius auratus gibelio*). *Aquat Toxicol.*, 70(3) : 179-188.
- GOMEZ, K.A. and GOMEZ, A. A. 1984. *Statistical Procedures for Agricultural Research*, 2nd ed. Wiley/Interscience, New York.
- GRAHL, K., FRANKE, P. and HALLEBACH, R. 1985. The excretion of heavy metals by fish. *Symp. Biol. Hung.*, 29 : 357-364.

- GUPTA, S.K. and MITRA, A. 1997. Utilization of solid and liquid wastes of Calcutta city for Agricultural uses. *J. Ind. Soc. Soil Sci.*, 52-56.
- HANDY, R. D. 1993. The effect of acute exposure to dietary Cd and Cu on organ toxicant concentrations in rainbow trout, (*Oncorhynchus mykiss*). *Aquat. Toxicol.*, 27 : 1-44.
- HEATH, A. G. 1995. *Water pollution and Fish Physiology*. CRC Press, NC. Florida, USA.
- HUGHES, G. M. and FLOSS, R. 1978. Zn treatment of the gills of rainbow trout (*S. Gairdneri*) after treatment with zinc solutions under normoxic and hypoxic conditions. *J. Fish. Biol.*, 13 : 717-728.
- KLAVERKAMP, J.F., MACDONALD, W.A., DUNCAN, D.A. and WAGEMANN, R. 1984. Metallothionein and acclimation to heavy metals in fish: a review. In: *Contaminant effects on fisheries* (Cairns, V.W., Hodson, P.V. and Nriagu, J.O., Eds.). John Wiley and Sons, New York.
- KOTZE, P., Du PREEZ, H.H. and VAN VUREN, J. H. J. (1999). Bioaccumulation of copper and zinc in *Oreochromis mossambicus* and *Clarias gariepinus* from the Olifants River, Mpumalanga, South Africa. *Water S.A.* 25(1) : 99-110.
- KUMUDA, C., CLAYTON, C. and WOOD, C.M. 2002. Water borne vs. dietary Cu uptake in rainbow trout and effects of previous water borne Cu exposure. *Am. J. Physiol. Regul. Integr. Comp. Physiol.*, 283(1) : 69-78.
- LAUREN, D. J. and MC DONALD, D.G. 1986. Acclimation to Cu by rainbow trout (*Salmo gairdneri* Richardson). *J. Exp. Biol.*, 38 : 447-455.
- MAITI, P. and BANERJEE, S. 2002. Bioaccumulation of metals in different food fishes in wastewater fed wetlands. In : *Ecology of Polluted waters* (Arvind, K. ed.). Vol. I, A.P.H. Publishing Corporation, New Delhi : 217-230.
- NAFDE A.S., KONDAWAR, V.K. and HASAN, M.Z. 1998 Precision and control in the determination of heavy metals in sediment and water by atomic absorption spectrophotometry. *J. IAEM.* 25 : 83-91.
- NEWMAN, M.C. and MCINTOSH, A.W. 1983. Lead elimination and size effects on accumulation by two freshwater gastropods. *Arch. Environ. Contam. Toxicol.*, 12 : 25-59.
- PELGROM, S.M.G.J., LAMERS, L.P.M., GARRITSEN, J. A. M., PELS, LOCK, R.A.C. BALM, P.H.M. and WENDELAR BONGA, S.E. 1994. Interactions between copper and cadmium during single and combined exposure in juvenile tilapia, *Oreochromis mossambicus*. Influence of feeding condition on whole body metal accumulation and the effect of the metals on tissue, water and ion content. *Aquat. Toxicol.*, 30 : 117-135.
- REID, S.D. and MCDONALD, D.G. 1991. Metal binding activity of the gills of rainbow trout (*Oncorhynchus mykiss*). *Can. J. Fish. Aquat. Sci.*, 48 : 1061-1068.
- SOLBE, J. F., DE, L. G. and COOPER, V. A. 1976. Studies on the toxicity of copper sulphate in stone loach, *Naemacheilus barbatulus* (L.) in hard water. *Wat. Res.*, 10 : 523-527.
- SCHULZ, B.M. 1974. Lead uptake from sea water and food and lead loss in common mussel, *Mytilus edulis*. *Mar. Biol.*, 25 : 177-193
- TAO, S., LIANG, T., CAO, J., DAWSON, R.W. and Liu, C. 1999. Synergistic effect of Cu and Pb uptake by Fish. *Ecotoxicol. Environ. Saf.*, 44 : 190-195.
- VELCHEVA, I. G. 2006. Zn contamination in the organs and tissues of fish from the Kardjali and Studenkladenet Dam Lakes in Bulgaria. *Turk J. Zool.*, 30 : 1-7
- WICKLUND, GLYNN, A. 1991. Cadmium and Zinc kinetics in fish: studies on water borne ^{100}Cd and ^{65}Zn turnover and intracellular distribution in minnows, *Phoxinus phoxinus*. *Pharmacol. and Toxicol.*, 69 : 485-491.

DYNAMICS OF HAEMOCYTE SUBPOPULATION OF LAMELLIDENS MARGINALIS EXPOSED TO A NEEM BASED PESTICIDE

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ABSTRACT

Haemocytes, the chief immuno-effector cells of blood of bivalve are capable of performing diverse physiological functions including phagocytosis, encapsulation, nonself surface adhesion and wound healing. Toxicity of azadirachtin was screened in *Lamellidens marginalis* in relation to the dynamics of haemocyte subpopulation. Healthy adult *Lamellidens marginalis* were exposed to sublethal concentrations of 0.03, 0.06 and 0.09 ppm of azadirachtin for 24, 48, 72 and 96 hours and compared to the control. Post-treated animals were bled and haemocytes were enumerated and detailed analyses of diverse subpopulations were carried out under light microscope. Hyalinocyte, granulocyte, agranulocyte and asterocyte were identified as discrete subpopulations and enumerated. Highest increase of total count of haemocyte was recorded as 29.02×10^5 cells/ml. at 0.09 ppm of azadirachtin/72 hours followed by a decline as 12.5×10^5 cells/ml at 96 hours against the control value of 8×10^5 cells/ml. Total count of haemocyte expressed an increasing trend in 48 and 72 hours of exposure against all the three concentrations. However, a depletion of haemocyte density were recorded against 0.03, 0.06 and 0.09 ppm/96 hours of exposure. This nonlinear response is indicative of "phase of adaptation" in blood cell homeostasis. Data is indicative of persistent stress in *Lamellidens marginalis* as reflected by fluctuations in total and differential count of haemocyte. Persistent contamination of natural habitat of *Lamellidens marginalis* by azadirachtin may lead to a possible shift in immunological status of animal.

Key words : *Lamellidens marginalis*, Haemocyte, Azadirachtin.

INTRODUCTION

Lamellidens marginalis is an economically important species and considered as an important dietary item of human. Human population of urban and rural sector of India consume the species in various forms. Flesh of *Lamellidens marginalis* constitutes an important supplement of fish and poultry feed. This species faces an ecological threat due to shrinkage of its natural habitat. Rapid urbanization and contamination of water bodies by xenobiotics are regarded as major threats of bivalves and allied species of aquatic ecosystem. Azadirachtin based biopesticides are efficient in controlling pest population and considered

as relatively less hazardous in relation to environmental stability and bioaccumulation (Schmutter, 1990). Multineem is an azadirachtin based biopesticide which is being frequently used by the farmers for the purpose of protection of crops from pests. Azadirachtin (steroid-like limonoid) is the active ingredients of neem based pesticide and is capable of controlling insect pest at low concentration. Chemically azadirachtin is a tetraterpenoid which is present in the seed kernal of neem tree (*Azadirachta indica*). During monsoon, agricultural runoff containing azadirachtin often contaminates the freshwater ponds and lakes inhabited by *Lamellidens marginalis*. No data is available regarding hematotoxicity of

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azadirachtin in freshwater bivalves of India. In this present study, we have examined total and differential haemocyte count of *Lamellidens marginalis* exposed to sublethal concentrations of azadirachtin in different spans of exposure. Defence mechanism of molluscs is characterized by two distinct limbs namely cellular and humoral (Couch *et al.*, 1990). Cell mediated immune response of *Lamellidens marginalis* is elicited through discrete subpopulation under the exposure of pathogen and toxins. Haemocytes are reported to be chief immuno-effector cells of bivalve which are capable of performing recognition, adhesion and phagocytosis of nonself particles (Sauve *et al.*, 2002). Exposure to azadirachtin yielded differential response to varied subpopulation of haemocytes. Shift in subpopulation spectrum is indicative of destabilization of dynamic equilibrium of different components of molluscan blood.

MATERIALS AND METHODS

Live adult healthy *Lamellidens marginalis* were collected from selected wetlands of district of South 24 Parganas of West Bengal with minimum anthropogenic interference. After manual collection, species were transported to the laboratory in plastic aquaria with proper care (Mukherjee *et al.*, 2006). Animals were acclimatized for seven days in laboratory condition prior to experiment. During acclimatization, animals were fed with chopped *Hydrilla sp.* and received uniform illumination (Raut, 1991). Commercial formulation of azadirachtin was procured from the market under brand name of Multineem (Azadirachtin E.C. 0.03%, Multiplex Private Limited, India). *Lamellidens marginalis* of uniform size were exposed to pesticide at a concentration of 0.03, 0.06 and 0.09 ppm of azadirachtin along with a batch of control. The control set received olive oil exposure of identical volume as routine protocol. Separate sets of acclimatized animals were exposed to different concentrations of azadirachtin to determine the LC_{50} (Shibu Vardhan and Radhakrishnan, 2002). Each batch comprised of ten individuals and span of exposure ranged as 24, 48, 72 and 96 hours.

Hemolymph was collected from adductor muscles using sterile syringe with 23 gauge needle (Brousseau *et al.*, 1999). Enumeration of haemocyte was done microscopically using Neubauer hemocytometer. For identification of hemocytes, cells were fixed with methanol and stained with Giemsa's stain (Cheng *et al.*, 1995). Examination and photo documentation of haemocytes were carried out by light microscope (Axiostar plus, Zeiss, Germany) fitted with digital camera.

RESULTS AND DISCUSSION

Prior to determine the dynamics of hemocyte subpopulation, LC_{50} for 96 hours of exposure were estimated in *Lamellidens marginalis* in static water environment. LC_{50} for 96 hours of exposure was estimated as 1.5ppm and selection of concentration of azadirachtin were made accordingly for experiment. Hemolymph of *Lamellidens marginalis* contains diverse populations of hemocytes viz. prohemocyte, agranulocyte, granulocyte, asterocyte and hyalinocyte (Fig. 1). Morphological classification and allied nomenclature of haemocyte subpopulation raised confusion and contradiction (Cheng *et al.*, 1995) among the workers of this field. However, we have classified the haemocytes on the basis of morphological characters tinctoriality and size (Corniek *et al.*, 1978). Granulocyte, asterocyte and hyalinocyte are reported as potential phagocytes (Eatner *et al.*, 1983) which are capable of engulfing foreign particulates. Prohaemocyte are blast like cells (George *et al.*, 1950) which differentiate into subpopulation with discrete functional significance. In this study, dynamics of haemocyte subpopulation was examined under the sublethal exposure of azadirachtin. Density of prohaemocyte was increased significantly against 0.03, 0.06 and 0.09 ppm of azadirachtin in all three durations of exposures specified (Fig. 3). This depression in count of agranulocytes, granulocyte, asterocyte and hyalinocyte were recorded against 0.03, 0.06 and 0.09 ppm of azadirachtin for three spans of exposure. Pattern of decrease in subpopulation count was uniform. Highest decrease in count of agranulocyte was recorded as 3% in 0.06ppm/72 hours against control. For

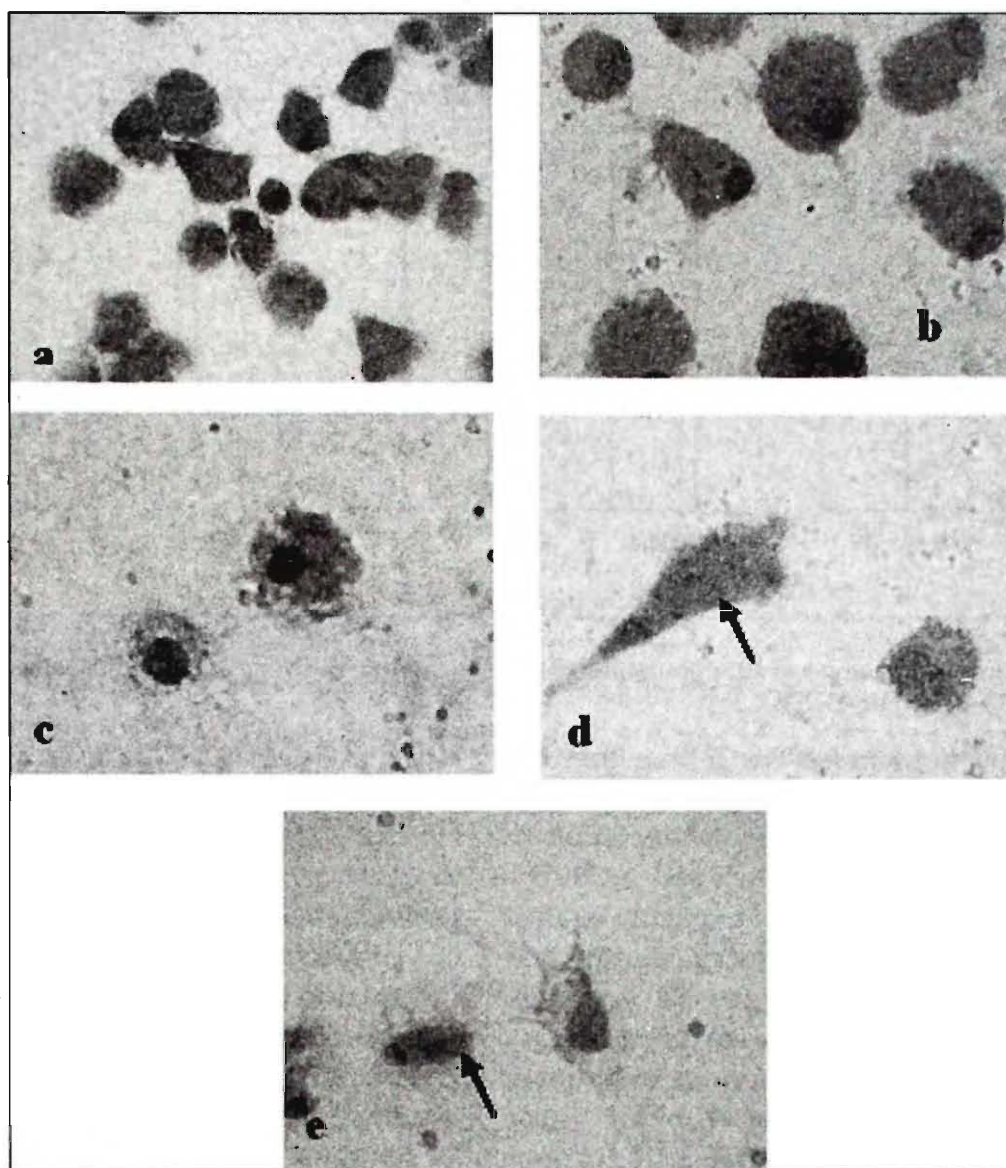


Fig. 1. Haemocyte population of *Lamellidens marginalis* (a) Prohaemocyte, (b) Agranulocyte (c) Granulocyte (d) Hyalinocyte and (e) Asterocyte.

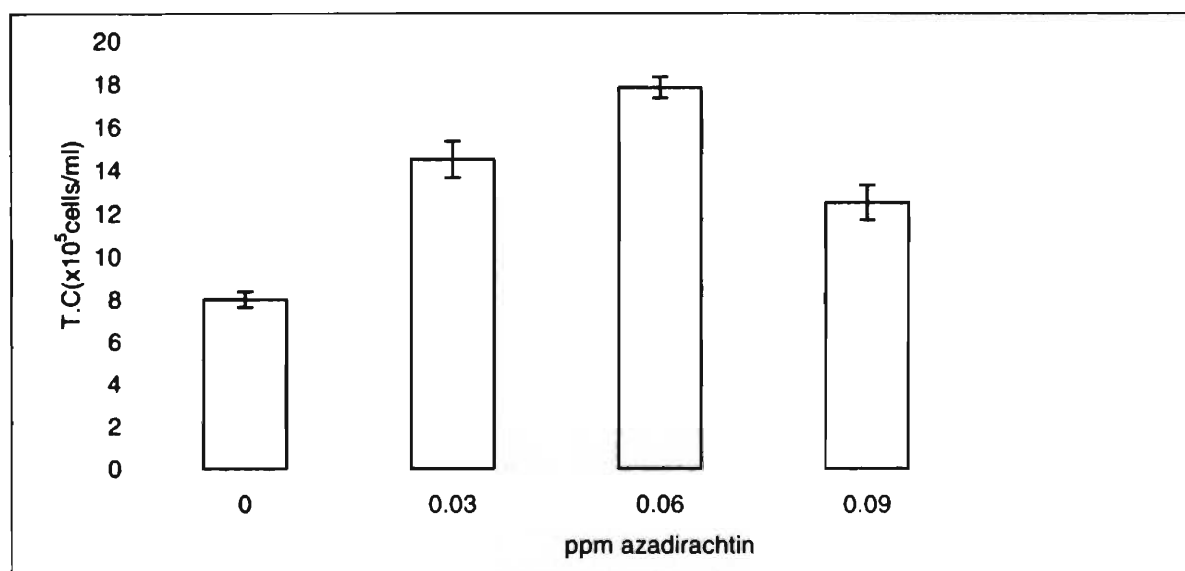


Fig. 2. Modulation of total count (T.C.) of hemocytes of *Lamellidens marginalis* exposed to azadirachtin for 96 hrs. Values reported as Mean $\pm$ S.D.

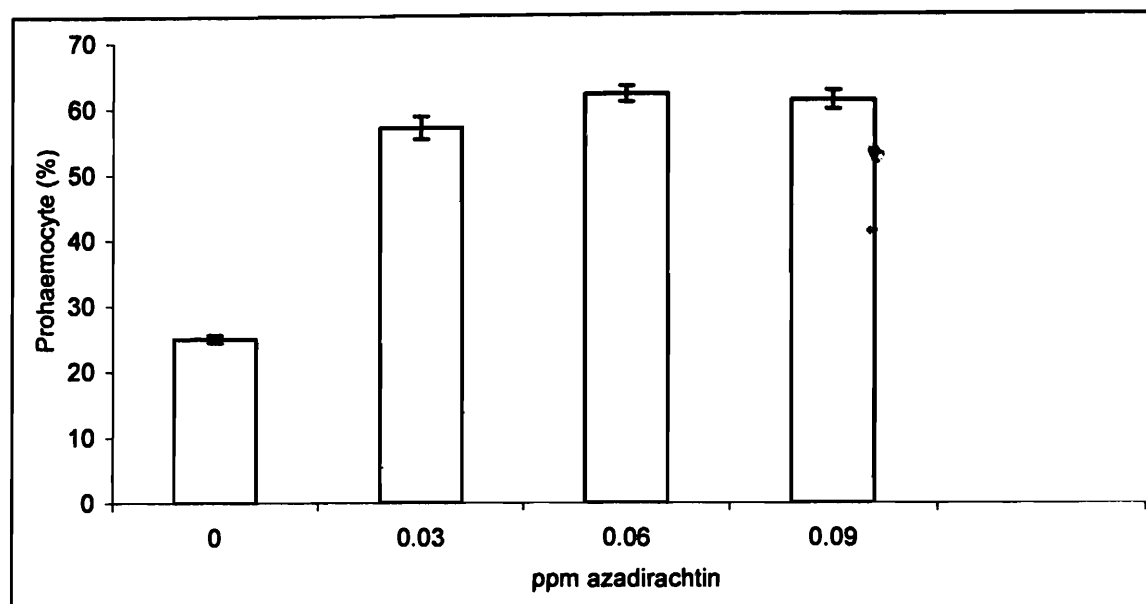


Fig. 3. Variation of prohaemocyte subpopulation exposed to azadirachtin for 72 hrs. Values reported as Mean $\pm$ S.D.

granulocyte, count was least as 33% against 0.06 ppm of azadirachtin for 72 hours of exposure against control (Fig. 4). Highest depletion in count of asterocyte was recorded as 0.75% against 0.06 ppm/72 hours of exposure against the control (Fig. 5). For hyalinocyte, density was lowest against 0.06 ppm for 72 hours of exposure against the control set (Fig. 6). Marginal elevation of cell count in 96 hours of exposures were recorded for all three concentrations of azadirachtin (Fig. 2). Increase in count of total circulating haemocytes and proliferation of prohaemocytes in all the doses

clearly demonstrated the neoplastic transformation of hemocytopoietic organ (Victor, 1993). Decrease in the count of granulocyte, asterocyte and hyalinocyte population at 72 hours of exposure may be due to degranulation, vacuolization of the cytoplasm and nuclear pycnosis of the mentioned cell types. Highest increase of total count of haemocyte at 0.09 ppm of azadirachtin/72 hours followed by decline at 96 hours of exposure may be due to decrease in prohaemocyte count. Depletion in count of haemocyte subpopulation is indicative of

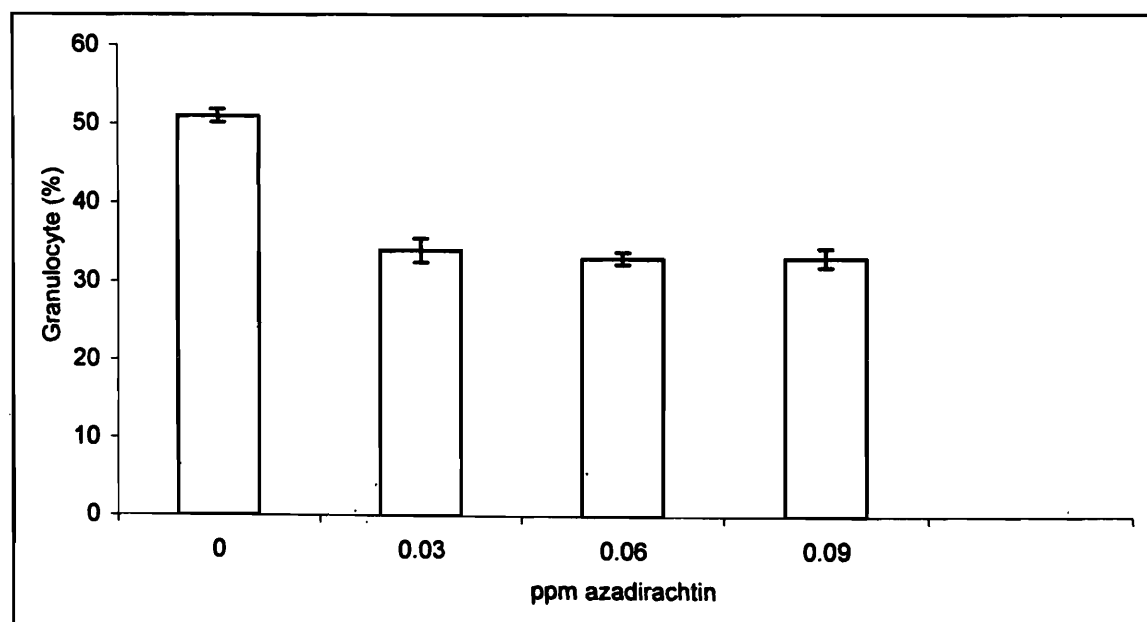


Fig. 4. Variation of granulocyte subpopulation exposed to azadirachtin for 72 hrs. Values reported as Mean $\pm$ S.D.

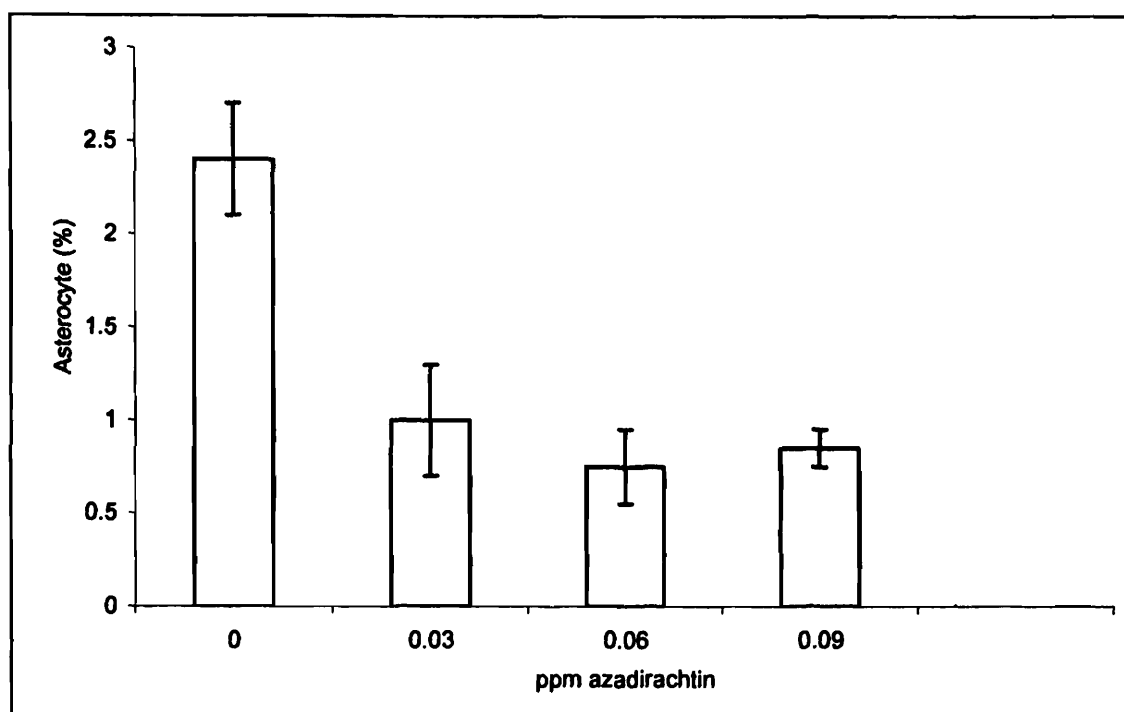


Fig. 5. Variation of asterocyte subpopulation exposed to azadirachtin for 72 hrs. Values reported as Mean $\pm$ S.D.

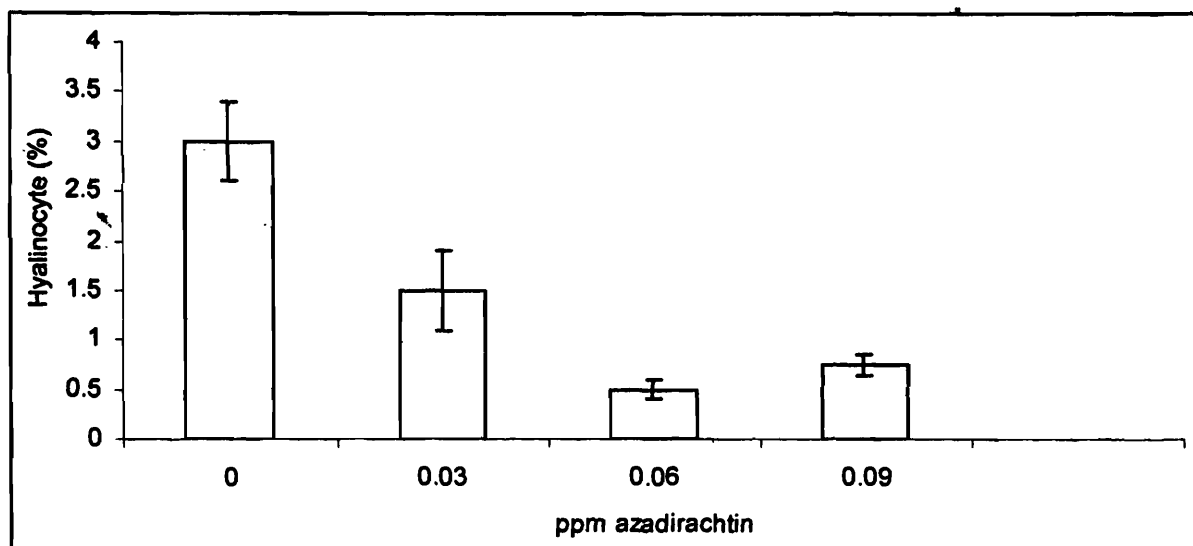


Fig. 6. Variation of hyalinocyte subpopulation exposed to azadirachtin for 72 hrs. Values reported as Mean $\pm$ S.D.

impairment of cell associated immunological functions i.e. immunoadhesion, nonself phagocytosis, cell aggregation and encapsulation reaction. Elicitation of haemocyte mediated immune response demands participation of discrete subpopulation with larger density. Azadirachtin induced depletion in densities of agranulocyte, granulocyte, asterocyte and hyalinocyte is indicative of a possible impairment of haemocytic function in *Lamellidens marginalis* distributed in polluted environment. Moreover, present data would

provide an information base in formulating a sustainable strategy of culturing the species in biosafe environment and in establishing the suitability of the species as biomarker of aquatic pollution.

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LITERATURE CITED

- BROUSSEAU, P., PAYETTE, Y., TRYPHONAS, H., BLAKLEY, B., BOERNAUS, H., FLIPO, D. and FOURNIER, M., 1999. *Manual of Immunological Methods*. CRC Press, Boca Raton, FL.
- CHENG, J. H. and BAYNE, C. J. 1995. Bivalve Mollusc Hemocyte Behaviours : Characterization of Hemocyte Aggregation and Adhesion and Their Inhibition in the California Mussel (*Mytilus californianus*). *Biol. Bull.*, **188** : 255-256.
- CORNIEK, J.W. and STEWART, J.S. 1978. Lobster (*Homarus americanus*) hemocytes : classification, differential counts and associated agglutinin activity. *J. Invertebr. Pathol.*, **31** : 194-203.
- COUCH, L., HERTEL, L. A. and LOKER, E. S. 1990. Humoral response of the snail *Biomphalaria glabrata* to trematode infections : observations on a circulating hemagglutinin. *J. Exp. Zool.*, **255** : 340-349.
- EATNER, S., and VINSON, S. B. 1983. Encapsulation reactions *in vitro* by hemocytes of *Heliothis virescens*. *J. Insect. Physiol.*, **29** : 855-863.
- GEORGE, W.C., AND FERGUSON, J.H. 1950. The blood of gastropod mollusc. *J. Morph.*, **86** : 315-327.
- MUKHERJEE, S., RAY, M., and RAY, S. 2006. Azadirachtin induced modulation of total count of haemocytes of an edible bivalve *Lamellidens marginalis*. *Proc. Zool. Soc. Calcutta*, **59**(2) : 37-39.
- RAUT, S. K. 1991. Laboratory Rearing of Medically and Economically Important Molluscs. In "Snails, Flukes and Man" (M.S. Jairajpuri, Ed.), pp.79-83. Zoological Survey of India Pub.
- SAUVE, S, BROUSSEAU, P., PELLERIN, J., MORIN, Y., SENEAL, L., GOUDREAU, P. and FOURNIER, M. 2002. Phagocytic activity of marine and fresh water bivalves : *in vitro* exposure of hemocytes to metals (Ag, Cd, Hg and Zn). *Aquat. Toxicol.*, **508**(3-4) : 189-200.
- SCHMUTTER, H. 1990. Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. *Ann. Rev. Entomol.*, **35** : 271-97.
- SHIBU VARDHANNAN, Y. and RADHAKRISHNAN, T. 2002. Acute toxicity of copper, arsenic and HCH to paddy field crab, *Paratelphusa hyydromus* (Herb.). *J. Environ. Biol.*, **23**(4) : 387-392.
- VICTOR, B. 1993. Responses of hemocytes and gill tissues to sublethal cadmium chloride poisoning in the crab *Paratelphusa hydromous* (Herbst). *Arch. Environ. Contam. Toxicol.*, **24** : 432-439.

ESTERASE POLYMORPHISM ANALYSIS IN RESPONSE TO HEAVY METAL STRESS IN FISH *Cirrhinus mrigala* (HAMILTON) IN AND AROUND THE KOLKATA METROPOLIS

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ABSTRACT

The wetland, in the eastern fringe of Kolkata Metropolis and some places of Howrah district, West Bengal (India), is being subjected of onslaught for a long time, which resulted from the deposition of anthropological, urban and industrial wastes, including heavy metals, which got admixed with the water bodies that resulted in large-scale pollution of the aquatic environment. Fishes in such aquatic environments are directly in touch with the pollutants through water exchange. The fish *Cirrhinus mrigala* constitute an important group of fishes with intense diversity and potential for commercial aquaculture for the consumable fishes.

Here, we have undertaken to measure genetic diversity of the fish *Cirrhinus mrigala*, collected from different water bodies by the analysis of allozymes of the animals. The heavy metal concentrations present in water bodies of the Kolkata metropolis were measured for record.

Our results reveal that heavy metals are accumulated and resulted allozyme polymorphism. For this, we assessed and compare the accumulation in the individuals of this species collected from the ponds in Garia, Bypass and Howrah region. The tissue sample, along with the water samples were subjected to atomic absorption spectrophotometry (AAS). It was observed that the concentration of the two heavy metals such as Lead (Pb) and Zinc (Zn), in the tissues of these fishes and in water bodies were causes of concern. To determine, whether it affect any metabolic change in the fish's isozyme (esterase) analysis was conducted by Non-denaturing Polyacrylamide Gel Electrophoresis.

It was observed that esterase variation in major Carp *Cirrhinus mrigala* can be the potential biomarker of heavy metal pollution in the aquatic environment of this metropolis.

Keywords : Esterase, Polymorphism, *Cirrhinus mrigala*, Isozyme, Allozyme.

INTRODUCTION

The dynamics of evolutionary process of adaptation and speciation is based on the underlying molecular structure and differentiation of genetic diversity at the DNA levels and its derivative proteins, which drive the molecular machinery of organisms and thus generate and maintain polymorphism as adaptive strategies to cope with variable environment (Sarkar *et al.*, 2004). Pollution can

cause toxic effects on organisms, which comes in contact with it. The effects of such toxins on these individuals appear to depend upon its concentration in the water and the involvement of the toxins in the metabolic pattern. At present, heavy-metals have gained considerable importance as well known pollutants in any ecosystem (Achyuthan *et al.*, 2002). They act as a conservative pollutants and often bio-magnify in the food chain (Stanley and Bang, 1987; Sood *et al.*, 1994). The surface of the hydrosphere act

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as the first site of chemical interaction, which harbour high concentrations of surface-active molecules, that act as heavy traps. To survive in this toxic environment, organism has adapted by increasing their tolerance to metal pollution. These tolerant organisms ultimately give rise to the prevailing heterogeneity within and among the species. The changes in isozyme/allozyme markers of the tolerant organisms can be sensitive to and vary adaptively to the level, type and concentration of pollutants (Nevo, 1988).

To assess the genetic diversity that has resulted in these heterogeneous individuals due to acclimatization against the stresses of these pollutants, isozyme analysis is very good technique because some of the isozymes are stress specific. This view was first proposed by Ben-Sholmo and E. Nevo (1988), who suggested that the effects of heavy metals in vitro can be related to population data and it can also offer a biochemical basis for maintenance of isozyme polymorphism in *Palaemon elegans*.

It has been suggested that the organisms who are present in the higher trophic level in the food chain/web acquires more toxic elements than the other organisms due to biomagnifying effects of these toxins. In the present investigation we have used *Cirrhinus mrigala* as a model organism which is a dominant tertiary consumer in fresh water ecosystems.

MATERIALS AND METHODS

The samples were collected from three different places viz. Garia, Bypass and Howrah which are prone to heavy metal exposure due to surrounding industries and vehicular traffic. The fish *Cirrhinus mrigala* (Hamilton) was chosen for our investigation for the analysis of esterase polymorphism. Three sites were chosen for our present study. They are Howrah, Garia and E. M. Bypass. These three zones are highly polluted with industrial wastes, heavy vehicular traffics and anthropogenic wastes. Lead (Pb) and Zinc (Zn) were two selected heavy metals for present investigation.

A) Quantitative Determination of Heavy Metal Concentrations by atomic absorption spectrophotometry (AAS)

I. In water samples

Freshwater samples (50 ml) were collected from the three above mentioned sites. The samples were then pretreated before analysis, to remove any suspended materials. The pretreatment was done following the standard methods. (American Public Health Association, American Waterworks Association and Water Pollution Control Federation, 1989).

II. In tissue samples

Pretreatment were needed for tissue samples, to remove the organic substances. We use liver tissues for present investigation. The tissue was then charred on a hot plate and treated with concentrated Sulphuric acid and Perchloric acid, for repeated times, till the sediments become white. There after sediments were treated with concentrated Nitric acid. The materials were then washed with distilled water and then taken in a sterilized bottle. Both the water and tissue samples were then subjected to Spectra AA55 atomic absorption spectrophotometer (Varian Techtron Pvt. Ltd) to measure the concentration of heavy metals in the collected water and tissue samples.

B) Enzyme analysis

Electrophoretic analysis of Isozyme-Esterase was performed by non-denaturing 7.5% Polyacrylamide Gel Electrophoresis (Mukherjee *et. al.*, 2004). Five individual fishes from each site were dissected out to obtain 50 mg liver tissue from each, which was then homogenized in homogenizing buffer (500 µl of 0.5 M Tris-HCl pH-6.8 with 100µl of Glycerol) in 1.5 ml Eppendorf tube in 0°C to 4°C and centrifuged at 10,000 r.p.m. for 10 minutes at 4°C. The supernatant was saved and used for gel fractionation. Each sample was divided into five aliquot for each site were loaded in five different lanes in three separate 7.5% non-denaturing resolving gel. After completion of electrophoresis, active protein in the gel was reacted with α naphthyl acetate (substrate) in

phosphate buffer and then stained with Fast Blue RR salt (Vallejos, 1983; Brewer and Sing 1970). The run was repeated several times with an equal sample pool for a particular set to avoid any technological artifact.

C) Statistical analysis

Atomic Absorption spectrophotometry was repeated three times for each sample ($n = 3$). Results were expressed as mean $\pm$ SEM. Allele frequencies were calculated according to Hardy-Weinberg theorem ($n = 5$) (Ferguson, 1980).

RESULTS AND DISCUSSION

Atomic Absorption Spectrophotometry

The results of AAS showed that, the concentration of lead and zinc varied greatly in both water and tissue samples from different sites (Table 1). As it appears from the data in Table 1, in case of water samples, the maximum levels of Lead and Zinc concentrations were detected in Garia and Howrah samples (0.1932 ± 0.011 mg.L⁻¹ and 0.4486 ± 0.081 mg.L⁻¹ respectively). While the Bypass sample showed the minimum amount of lead (0.1159 ± 0.003 mg.L⁻¹) and zinc (0.0320 ± 0.012 mg.L⁻¹). These values were represented in Table 1.

Data in Figures 1, 2, and 3 in case of tissue samples reveal that the lead and zinc concentrations were maximum in the fishes from Garia (0.5622 ± 0.055 mg.L⁻¹) and Bypass (4.8258 ± 0.132 mg.L⁻¹) respectively. The minimum amount of lead was present in the livers of fishes from Howrah population (0.2116 ± 0.012 mg.L⁻¹) and minimum amount of zinc was present in Garia population (1.3397 ± 0.192 mg.L⁻¹). These heavy metals concentrations

were represented diagrammatically in Figure 1, 2 and 3.

Esterase Polymorphism

The enzyme analysis revealed that the enzyme Esterase expresses itself in 10 zones of activities in the liver tissue of *C. mrigala* from different aquatic niche, that were studied but the lack of uniformity in the expression of the alleles of these zones were prominent in Figure 4 (Howrah population), Figure 5 (Garia population) and Figure 6 (Bypass population).

Esterase polymorphism in the Liver tissue of the fishes from Howrah population

Eight zones of Esterase activities could be recognized from the gel (Figure 4). There is a single monomorphic band in Zone I, in all the individuals of this population, such similarity was also found in Zones II and VIII. Zones V and VII were observed to have only one band in lane 3 and 2 respectively. Zone III can be characterized by paired bands and designated as EST-IIIS and EST-IIIF in the 3rd. lane and other lanes exhibit EST- IIIS (lanes 2, 4 and 5) and EST-IIIF (lane 1). Zone IV was single monomorphic in lanes 1, 2, 4 and 5. This zone was absent in lane 3. Zone VI exhibited single bands in lanes 2 and 5; it did not show any activity in lanes 1, 3 and 4 (Calculations are in Annexure I).

Esterase polymorphism in the Liver tissue of the fishes from Garia population

As it appears from Figure 5 ten zones of Esterase activities are predominant. Zones I, II, III, V and X were represented by prominent monomorphic bands present in all the individuals. However zones VI, VII and VIII

Table 1. The concentration (mean $\pm$ SE) of heavy metals in water samples (mg.L⁻¹) and liver tissue samples (mg.kg⁻¹) of different sites ($n = 3$).

Metals	HOWRAH		GARIA		BYPASS	
	Water	Tissue	Water	Tissue	Water	Tissue
Zinc	0.4486 ± 0.081	1.4632 ± 0.186	0.2547 ± 0.012	1.3397 ± 0.192	0.0320 ± 0.012	4.8258 ± 0.132
Lead	0.1403 ± 0.008	0.2116 ± 0.012	0.1932 ± 0.011	0.5622 ± 0.055	0.1159 ± 0.003	0.2574 ± 0.038

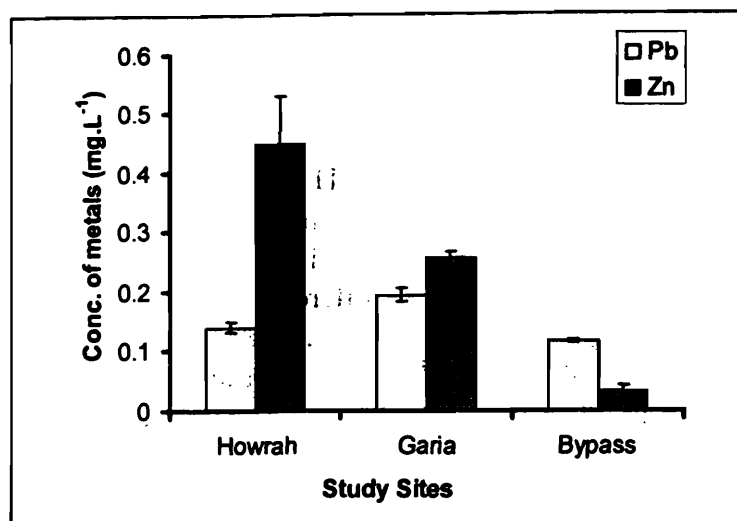


Fig. 1. Concentration of different heavy metals in the specific water sample of the three sites.

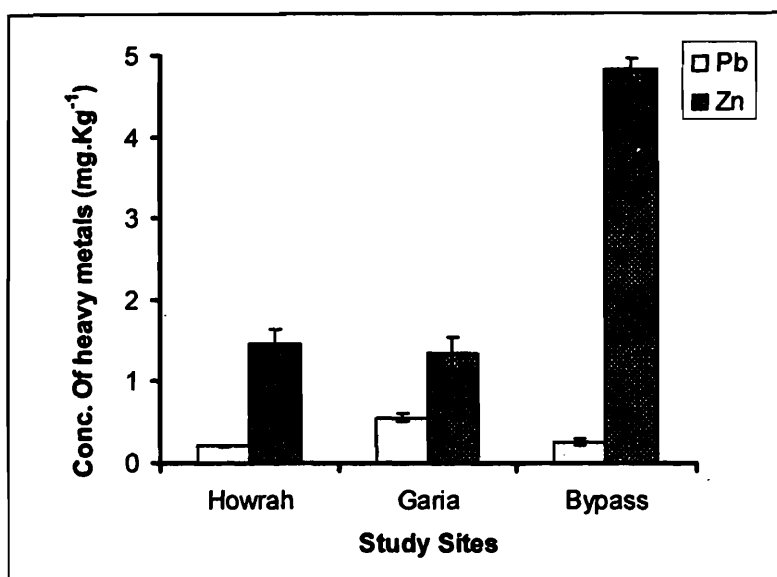


Fig. 2. Concentration of different heavy metals in the specific tissue sample of the three sites.

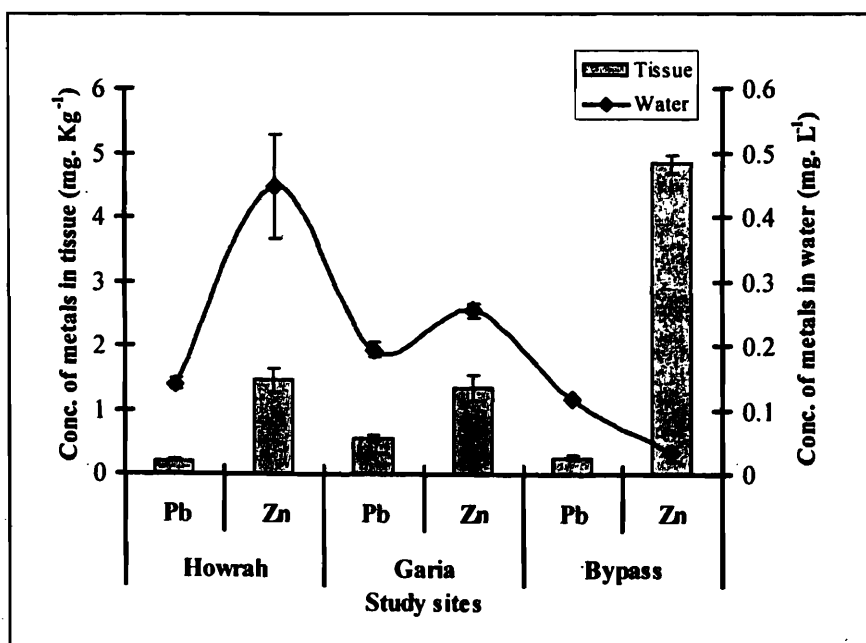


Fig. 3. Comparative representation of concentrations of two metals in water and tissues of *C. mrigala* of the three study sites.

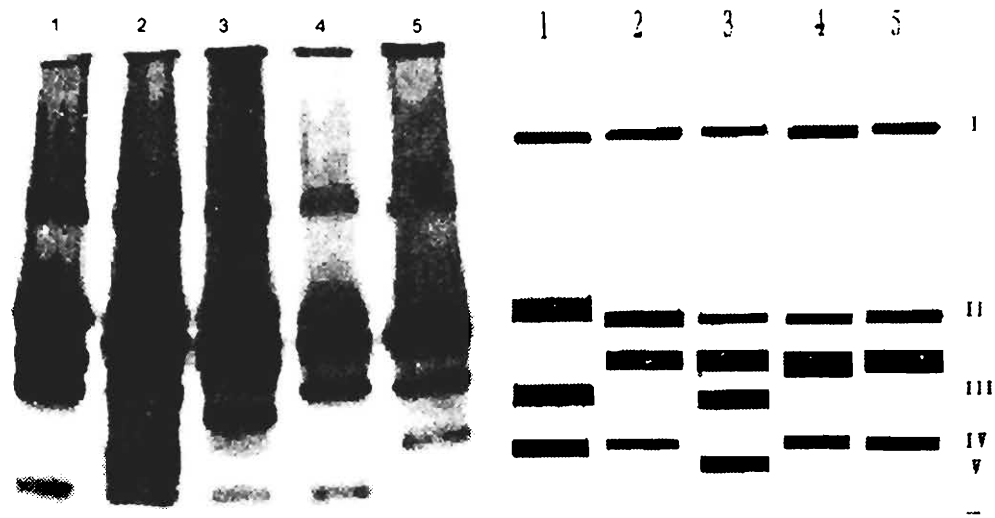


Fig. 4. Esterase isozyme pattern and corresponding line diagram of the liver tissue of *C. mrigala* from Howrah population.

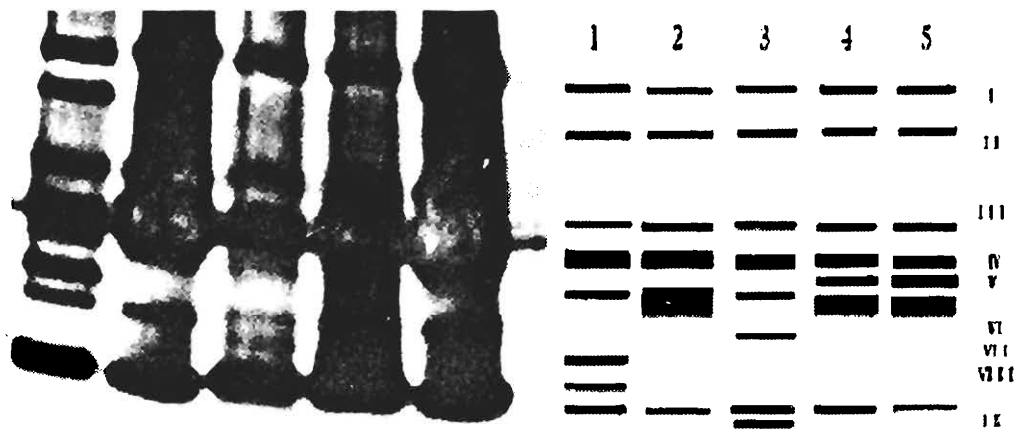


Fig. 5. Esterase isozyme pattern and corresponding line diagram of the liver tissue of *C. mrigala* from Garia population.

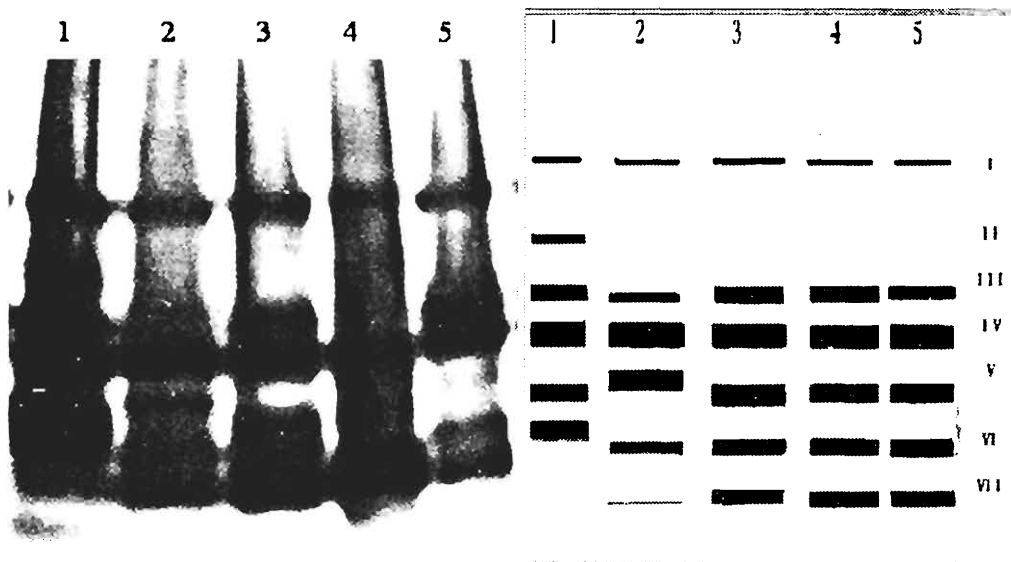


Fig. 6. Esterase isozyme pattern and corresponding line diagram of the liver tissue of *C. mrigala* from Bypass population.

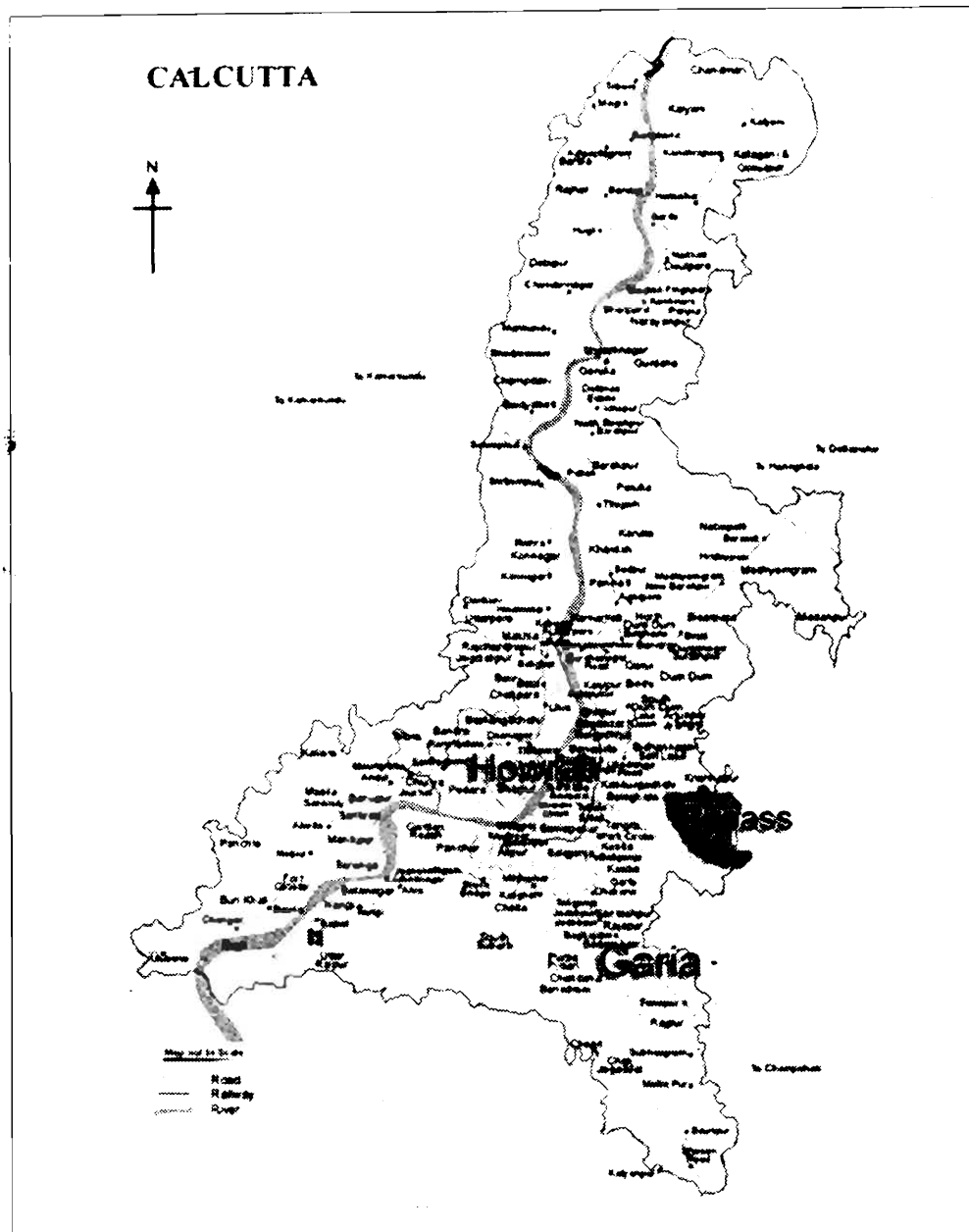


Fig. 7. Map of the sampling sites of Kolkata Metropolis.

alleles were present only one of 5 individuals i.e. the individuals of lane1 of zone VII and VIII and lane 3 in case of zone VI should be recognized. Zone IX exhibited a dimorphic expression, in lanes 1, 2, 4 and 5 this zone expressed only the slower alleles, but in lane 3 this zone was found to be heterozygous, represented by both faster and slower alleles (Calculations are in **Annexure II**).

Esterase polymorphism in the Liver tissue of the fishes from Bypass population

Seven zones of Esterase activity may be recognized from the gel (Figure 6). Zones I, III and IV were represented by a single

monomorphic band that is present in all the individuals. But Zones II and V have only one band in individuals of lane 1 and 2 respectively. Zone VI allele exhibited a dimorphic feature in which lanes 1, 3, 4 and 5 showed heterozygosity in having both faster and slower alleles and lane 2 exhibited only the faster allele. Zone VII was also single monomorphic in activity pattern in all the lanes except in lane 1 it was absent (Calculations are in **Annexure III**).

By comparing the isozyme activities in *C. mrigala* of the three different sites (Howrah, Bypass and Garia), it may appear that zone I allele was represented by a single monomorphic

band in all the three population. This band seems to be highly specific for this species.

Zone II allele was present in all the individuals of Howrah and Garia, but was present in only one individual of the Bypass population, this may be due to the high amount of Zinc in the tissue of the fishes from Bypass population. It was found that, water samples from here had negligible amount of Zinc in comparison to those from Garia and Howrah. Such a high concentration of Zinc in the tissue must therefore be the result of Biomagnifications and might be for that reason the maximum heterozygosity was accounted in this population.

Both the water and the tissue samples in Garia had the maximum amount of Lead, which is reflected in the isozyme pattern from this population of fishes. Here we observed that the number of zones of esterase activities were more.

Thus the specificity of the isozyme alleles can be a reflection of the adaptive polymorphism, in response to specific heavy metals (Nevo, 1984).

From the entire findings one can therefore reasonably argue that there is a positive correlation between genetic and environmental variation and that such diversities are related to the specificity of a population adjusted in a particular niche, confirming the niche-width variation hypothesis (Joppa *et al.*, 1995). In such informational background it can be said that "such a minority system, based on changes on population genetic structure, is not only theoretically commendable, but also radically feasible" (Nevo, 1986). This conclusion is supported by the rapid and precise genetic

changes that follow the effect of pollution. Ideally, use of in-situ population of different species specific genetic loci, either single or in combination, may prove sensitive to different pollutants and would easily be assayed by relatively quick and easy electrophoretic tests. Such direct genetic monitoring may become an indispensable tool, sometime preferable to the chemical ones used routinely, would alert us to both the short and long term genetic changes that populations undergo, before their final extermination as a result of pollution.

CONCLUSION

The genetic heterogeneity, variation and correlation of ecological parameters and life history, together serve as an important mechanism for broadening the environmental tolerance of a species. Our data shows samples of species, taken from the different niches, differ significantly in their allelic frequencies with respect to one or more enzymes and thus can serve as a very important parameter for establishing the adaptive ability of a genome to environmental stresses and fluctuations. Our investigations on *Cirrihinus mrigala* in and around the Kolkata Metropolis lead us to conclude that specific isoenzyme markers might help to detect the status of a pollution contaminated niche.

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LITERATURE CITED

- ACHYUTHAN, H., RICHARDMOHAN, D., SRINIVASUL, S. and SELVARAJ, K. 2002. Trace metal as concentrations in the sediment cores of estuary and tidal zones between Chennai and Pondicherry, along the east coast of India. *Indian J. Mar. Sci.*, 31.
- APHA. 1989. Standard Methods: Toxicity Test Methods for the Examination of Water and Waste water, Seventeenth ed. American Public Health Association, Washington, DC.

- BEN-SHOLMO, R. and NEVO, E. 1988. Isozyme polymorphism as monitoring of marine environment : The interactive effects of Cadmium and Mercury pollution on the shrimp, (*Palaemon elegans*). *Mar Pollut Bull.*, **19** : 314-17.
- BREWER, G. J. and SING, F. G. 1970. An Introduction to isozyme techniques. New York; Academic Press.
- FERGUSON, A. 1980. Biochemical systematics and evolution. Glasgow Blakie X, 194.
- JOPPA, L. R., NEVO, E. and BEILES, E. 1995. Chromosome translocations in wild populations of tetraploid wheat in Israel and Turkey. *Theor. Appl. Genet.*, **91** : 713-719.
- MUKHERJEE, S., MUKHERJEE, S., BHATTACHARYYA, P. and DUTTAGUPTA, A. K. 2004. Heavy metal levels and esterase variations between metals-exposed and unexposed duckweed *Lemna minor* : field and laboratory study. *Environ. International*, **30** : 811-814.
- NEVO, E. 1988. Genetic diversity in nature: Pattern and Theory. *Evol. Biol.*, **23** : 217-247.
- NEVO, E. 1986. Genetic diversity and resistance to marine pollution, *Bio J-Linn. Soc.*, **29** : 139-144.
- NEVO, E., BEN-SHOLMO, R. and LAVIE, B. 1984. Mercury selection of allozymes in marine organisms : prediction and verification in nature. *Proc Natl. Acad. Sci USA*, **81** : 1258-1259.
- SARKAR, S., DUTTAGUPTA, A. K., MAL, T. K. 2004. Effects of heavy metals on population growth and metallothionein gene expression in mosquito *Culex quinquefasciatus* from Calcutta India. *Environmental Pollution*, **127** : 183-193.
- SOOD, I. S., SINDHU, R. S. and SHARMA, K. K. 1994. Bioaccumulation of heavy metals by some aquatic plants. *Pollut Res.*, **13**(4) : 331-43.
- STANLEY, M. P. and BANG, M. K. 1987. The role of heavy metals in human health : environment and health : adverse health and toxic effects. New York : Academic Press : 367-409. [Chap. 11].
- VALLEJOS, C. E. 1983. Enzyme activity staining. In : Orton TJ, editor. Isozymes in plants genetics and breeding. Amsterdam; Elsevier : 469-516.

Annexure-I**Calculation of allele frequencies of *C. mrigala* in Howrah population :****Zone I :** Monomeric single allele**Zone II :** As same as zone I**Zone III :**

$$p^2 = SS = 3/5 = 0.60$$

$$2pq = SF = 1/5 = 0.20 \quad [S = \text{Slower allele and } F = \text{Faster allele}]$$

$$q^2 = FF = 1/5 = 0.20$$

$$\text{Total: } p^2 + 2pq + q^2 = 0.60 + 0.20 + 0.20 = 1.00$$

$$\text{Therefore } H_1 (\text{heterozygosity}) = 1 - (p^2 + q^2) = 1 - (0.60 + 0.20) = 0.20$$

Zone IV : $4/5 = 0.80$; Null = $1/5 = 0.20$ (monomeric single allele)**Zone V :** $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone VI :** $2/5 = 0.40$; Null = $3/5 = 0.60$ (monomeric single allele)**Zone VII :** $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone VIII :** Monomeric single allele**Annexure-II****Calculation of allele frequencies of *C. mrigala* in Garia population :****Zone I :** Monomeric single allele**Zone II :** Monomeric single allele**Zone III :** Monomeric single allele**Zone IV :**

$$p^2 = SS = 3/5 = 0.60$$

$$2pq = SF = 2/5 = 0.40 \quad [S = \text{Slower allele and } F = \text{Faster allele}]$$

$$q^2 = FF = 0.00$$

$$\text{Total: } p^2 + 2pq + q^2 = 0.60 + 0.40 + 0.00 = 1.00$$

$$\text{Therefore } H_1 (\text{heterozygosity}) = 1 - (p^2 + q^2) =$$

$$1 - (0.60 + 0.00) = 0.40$$

Zone VI : $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone VII :** $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone VIII :** $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone IX :**

$$p^2 = SS = 4/5 = 0.80$$

$$2pq = SF = 1/5 = 0.20 \quad [S = \text{Slower allele and } F = \text{Faster allele}]$$

$$q^2 = FF = 0.00$$

$$\text{Total: } p^2 + 2pq + q^2 = 0.80 + 0.20 + 0.00 = 1.00$$

$$\text{Therefore } H_1 (\text{heterozygosity}) = 1 - (p^2 + q^2) = 1 - (0.80 + 0.00) = 0.20$$

Zone X : Monomeric single allele**Annexure III****Calculation of allele frequencies of *C. mrigala* in Bypass population :****Zone I :** Monomeric single allele**Zone II :** $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone III :** Monomeric single allele**Zone IV :** Monomeric single allele**Zone V :** $1/5 = 0.20$; Null = $4/5 = 0.80$ (monomeric single allele)**Zone VI :**

$$p^2 = SS = 0.00$$

$$2pq = SF = 4/5 = 0.80 \quad [S = \text{Slower allele and } F = \text{Faster allele}]$$

$$q^2 = FF = 1/5 = 0.20$$

$$\text{Total: } p^2 + 2pq + q^2 = 0.00 + 0.80 + 0.20 = 1.00$$

$$\text{Therefore } H_1 (\text{heterozygosity}) = 1 - (p^2 + q^2) = 1 - (0.00 + 0.20) = 0.80$$

Zone VII : $4/5 = 0.80$; Null = $1/5 = 0.20$ (monomeric single allele)

A STUDY OF COLLEMBOLA COMMUNITIES IN STEEL PLANT AND THERMAL POWER PLANT SITES IN BOKARO DISTRICT OF JHARKHAND IN RELATION TO SOME EDAPHIC FACTORS

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ABSTRACT

The aim of the study was to investigate the species composition, seasonal abundance and diversity of collembolan community as well as role of some edaphic factors in the population fluctuation of Collembola fauna in two different industrial sites of Bokaro, Jharkhand, India. Two sites namely Bokaro Steel Plant (BSP) area and Chandrapura Thermal Power Station (CTPS) area were investigated for a period of one year (November, 2005–October, 2006). The study revealed the presence of 11 species belonging to 10 genera of the families Entomobryidae, Isotomidae, and Sminthuridae. Of which the species *Isotomina thermophila*, *Cyphoderus assimilis*, *Folsomides pervulus*, *Lepidocyrtus* sp. and *Entomobrya* sp. representing 17.56%, 21.21%, 11.46 %, 10.48 % and 10.97% of total population respectively were common in both the sites. The species like *Sphaeridia cornuta* (4.09%) and *Sminthurinus* sp. (3.86%) were extracted from BSP site and the species like *Isotomedes dagamne* (5.55%), *Isotomurus balteatus* (3.86%), *Isotomella minor* (4.82%) and *Cyphoderus javanus* (5.79 %) were found only in CTPS site. The collembolan population found in both the industrial sites were numerically low and showed irregular trend of fluctuation being maximum in November and minimum during July. The species diversity index of Shannon-Wiener showed that the diversity values in the CTPS site was more than the BSP site. Among the five edaphic factors organic carbon showed positive correlation with collembolan population in both the sites.

Keywords : *Collembola*, steel plant, thermal power plant, edaphic factors, Jharkhand.

INTRODUCTION

Quite a good number of workers like Grony (1975), Bhattacharya and Banerjee (1980), Hazra *et al.* (1982), Chattopadhyay and Hazra (1983), Hopkins (1986), Sieg *et al.* (1998), and Dey *et al.* (2006) studied the impact of industrial effluents on soil arthropods in general. A few workers like Hazra and Choudhuri (1990), Shome and Ghosh (2006), Russel and Alberti (1998), Chauvat and Ponge (2001), Chagon *et al.* (2001) also studied the impact of heavy metals and other soil factors on collembolan communities in some industrial areas of India and abroad.

However, no serious attempt have been made so far to investigate particularly the ecology of Collembola inhabiting two different industrial areas like the thermal power plant area and steel plant area in the district of Bokaro, Jharkhand. Therefore, to fill up these lacunae the present investigation has been taken up to investigate the species composition, seasonal abundance and diversity of Collembola fauna in relation to different soil factors at Chandrapura Thermal Power Plant area and Bokaro Steel Plant area in the district of Bokaro, Jharkhand, India.

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MATERIAL AND METHODS

Study site

Two different industrial sites in the district of Bokaro, Jharkhand have been chosen. The site-I is located at Bokaro Steel Plant (BSP) area. The area is an open large field, where industrial effluents are continuously discharged from the Steel Plant. This area was covered mainly with *Ipoma* sp., *Cynodon dactylon* and few scattered *Accacia* sp. trees. The site-II is the fly ash damping site, released from the Chandrapura Thermal Power Station (CTPS). This site was a vast open field covered with vegetation of thorny bushes as well as few scattered small trees like *Dalbergia sisoo*, *Albizia* sp. and *Acacia* sp. Soils of these two sites were black in colour (due to industrial pollutants) and sandy loam in texture. Mechanical analysis of soils of the study sites showed high percentage of fine sand in both the sites (Table 1). The pH of soil varied between 6.82-7.31 in site-I and 6.3-7.34 in site-II.

Sampling and identification

Three plots each measuring 25 sq. m. were selected for sampling in each industrial site. From each plot three soil samples were taken at random. Therefore, 216 soil samples from the two sites were drawn at an interval of 30 days for a period of one year (Nov, 2005– Oct, 2006). The soil samples were drawn by using stainless steel corers having the inner cross sectional diameter of 8.5 sq. cm. The extraction of soil samples were carried out by expedition funnel modified by Macfadyen (1953). A 40 watt bulb was used for heat and light source. Collection tubes (100ml) containing approximately 50 ml 70% ethanol plus 5% glycerine were attached below the funnels. The extraction period was 48 hours. The Collembola,

wherever possible, were identified up to species level.

Analysis of soil factors

The temperature of soil was recorded by soil thermometer and the soil moisture was estimated by an Infrared moisture balance. The pH of the soil was determined by using an electronic pH meter. Hygrometer method (Piper, 1942) was employed for the mechanical analysis of the soil samples. Soil nitrate was determined by using the microprocessor based universally accepted standard single beamed photometer SQ 118 (E. mark, Germany made) employing tungsten halogen lamp as the light source. Walkley and Black's (1934) method was followed for organic carbon determination.

RESULTS

Collembolan population

Collembolans extracted from BSP site belonged to seven species such as *Cyphoderus assimilis*, *Isotomina thermophila*, *Folsomides pervulus*, *Sphaerida cornuta*, *Lepidocyrtus* sp., *Entomobrya* sp. and *Sminthurians* sp. (Table 2). While the collembolans extracted from CTPS site belonged to eight genera and nine species such as *Cyphoderus assimilis*, *Cyphoderus javanus*, *Isotomina thermophila*, *Isotomedes thermophila*, *Folsomides pervulus*, *Lepidocyrtus* sp., *Entomobrya* sp., *Isotomurus balteatus* and *Isotomella minor* (Table 2). The species *Isotomina thermophila* was most dominant occupying 21.21% of the total collembolan population obtained from both the sites. The *Cyphoderus assimilis* comprising 17.5%, *Folsomides purvulus* comprising 11.46%, *Entomobrya* sp. comprising 10.97% occupied the second, third and fourth position respectively in order of dominance of the total Collembola obtained from both the sites. The species

Table 1. Showing mechanical analysis of soil

	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
Site-I (BSP)	24.4	42.3	8.2	24.1
Site-II (CTPS)	23.2	41.4	9.6	25.8

Table 2. Monthly abundance (%) of Collembola species at two different industrial effluents site of Bokaro, Jaharkhand.

	C.a.		I.t.		F.p.		S.c.		Lep.		Ent.		Smi		I.d.		I.b.		I.m.		C.j.	
	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II
Nov,05	1.95	1.7	1.7	1.95		1.21			1.46	0.73	0.97	0.73	0.73		0.97							0.73
Dec,05	0.97	0.97	0.97	0.97	0.48	0.48			0.73	0.48	0.48	0.48	0.48		0.48				0.24			0.48
Jan,06	0.97	0.48	0.73	0.48	0.48	0.48	0.48			0.73	0.24		0.24		0.48		0.24		0.48			
Feb,06	0.48	0.24	0.73	0.73	0.24	0.48	0.73		0.48		0.48	0.73			0.73		0.24		0.48			0.24
Mar,06	0.97	0.73	0.97	0.97	0.48	0.24	0.48		0.73	0.48	0.24	0.48	0.24		0.48		0.48		0.24			0.48
Apr,06	0.97	0.73	1.21	0.73	0.73	0.24			0.48	0.48	0.48	0.24			0.73				0.24			0.48
May,06	0.48	0.48	0.73	0.73	0.48	0.48	0.24			0.24	0.73	0.48	0.24		0.24		0.24		0.48			0.24
Jun,06			0.48	0.48	0.48	0.48	0.48		0.73		0.48				0.48		0.48		0.48			0.48
Jul,06				0.48	0.24		0.48		0.73				0.97		0.48		0.24		0.48			0.73
Aug,06		0.48	0.48	0.73	0.73	0.24	0.24		0.48		0.48	0.24	0.48				0.48		0.97			0.48
Sep,06	0.97	0.97	1.21	0.97	0.48	0.48	0.48		0.24		0.73	0.48	0.24				0.73		0.73			0.48
Oct,06	1.46	1.46	1.46	1.21	0.97	0.73	0.48		0.73	0.48	0.73	0.97	0.24		0.48		0.73					0.97

Abbreviation: C.a. : *Cyphoderus assimilis*, I.t. : *Isotomina thermophila*, F.p. : *Folsomides pervulus*, S.c. : *Sphaeridia cornuta*, Lep. : *Lepidocyrtus* sp., Ent. : *Entomobrya* sp., Smi. : *Sminthurians* sp., I.d. : *Isotomedes dagamae*, I.b. : *Isotomurus balteatus*, I.m. : *Isotomella minor*, C.j. : *Cyphoderus javanus*.

Sphaerida cornuta (4.09%) and *Sminthurinus* sp. (3.86%) were found only in the BSP site and *Isotomedes dagamae*, *Isotomurus balteatus*, *Isotomella minor* and *Cyphoderus javanus* were reported only from CTPS site (Table 2).

Monthly fluctuation of Collembola

The total collembolan abundance showed maximum peak during in the month of November and minimum in the month of July in both the sites (Fig. 1). Figures 2 & 3 show the seasonal changes in the abundance of each species of Collembola obtained from both the sites. The most dominant species *Isotomina thermophila* and *Cyphoderus assimilis* had a peak in the month of November and the minimum in the month of July in both the sites. The *Sminthurinus* sp. showed maximum peak

during the month of July in BSP site. The other species of Collembola in both the sites showed irregular trends of fluctuation usually showing maximum during November and minimum during Jun-July and slightly higher in October during the entire sampling period in both the sites.

Monthly fluctuation of edaphic factors

Soil factors in the study sites exhibited fairly wide range of variation during different months of the year (Fig. 4a and Fig. 4b). The lowest temperature of soil was 17°C during January in both the sites and highest was 35°C during May at BSP site. The moisture content of the soil was maximum (24.98%) in November at CTPS and minimum (9.04%) in June at the same site. The soil pH varied from 6.82 in October to

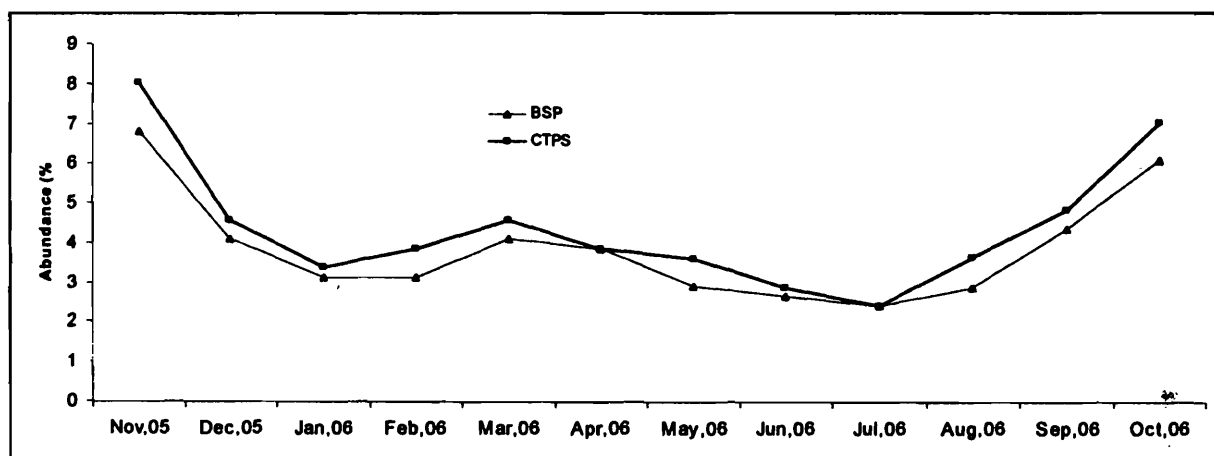


Fig. 1. Showing the monthly fluctuation of abundance (%) of collembola in BSP and CTPS site

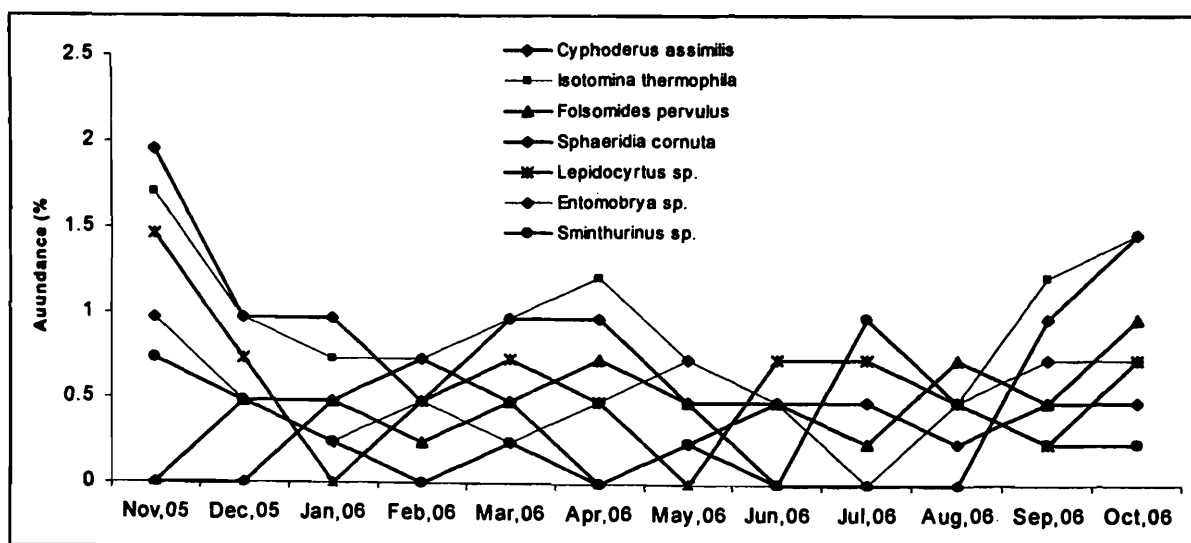


Fig. 2. Showing monthly fluctuation of collembola species in BSP site

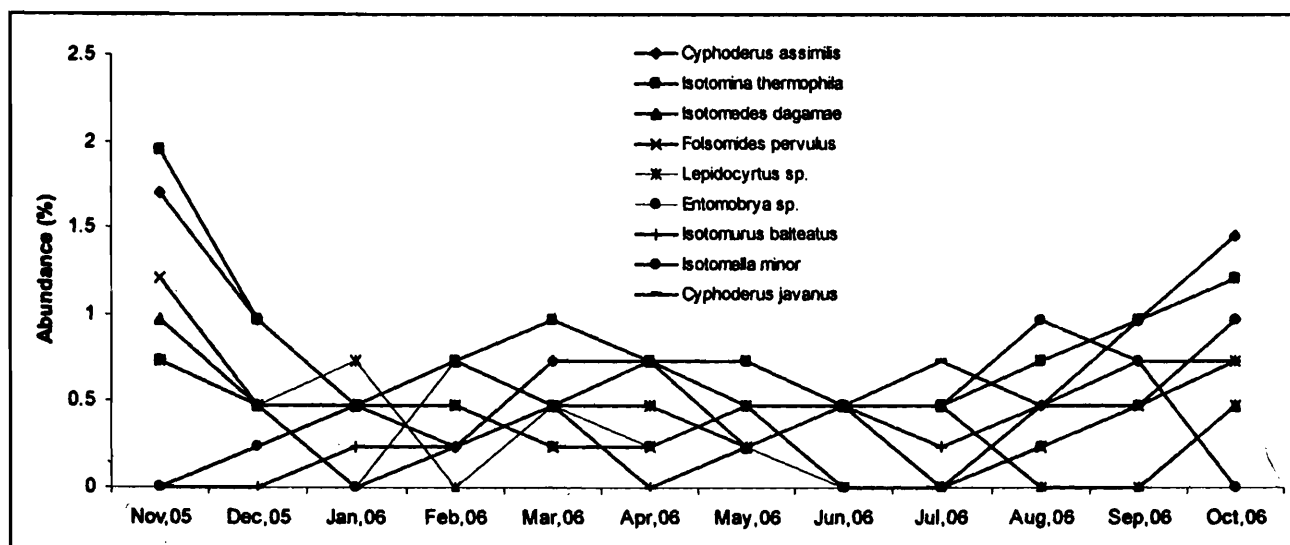


Fig. 3. Showing monthly fluctuation of collembola species in CTPS site

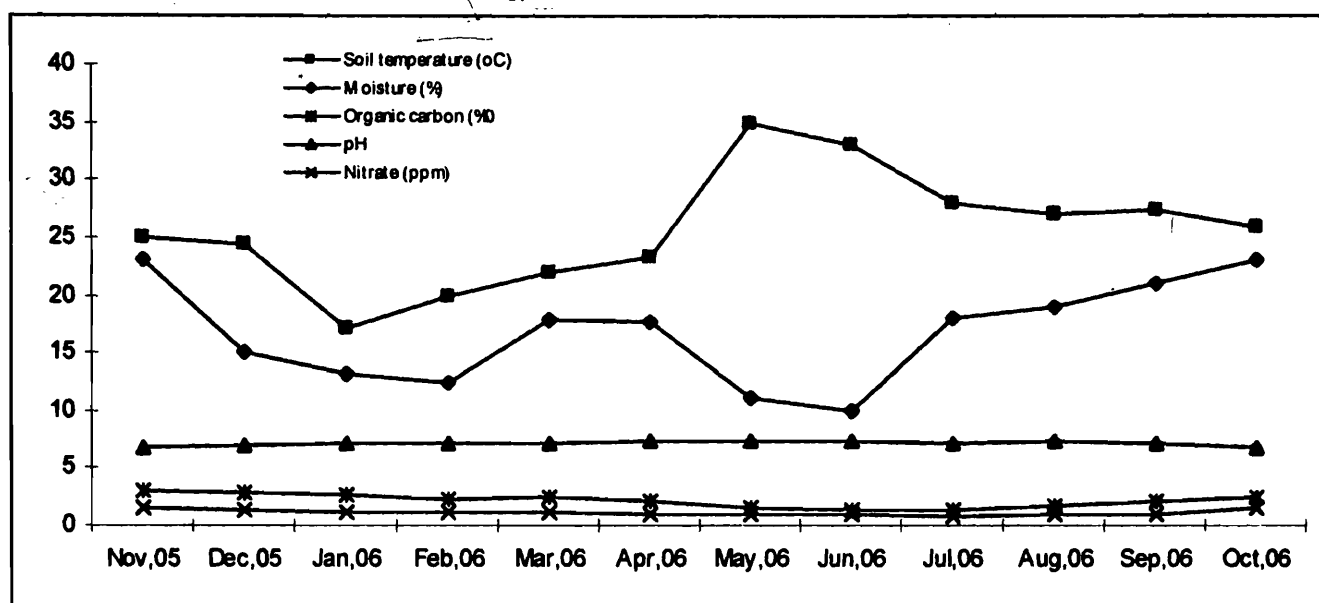


Fig. 4a. Monthly fluctuation of soil factors in BSP site

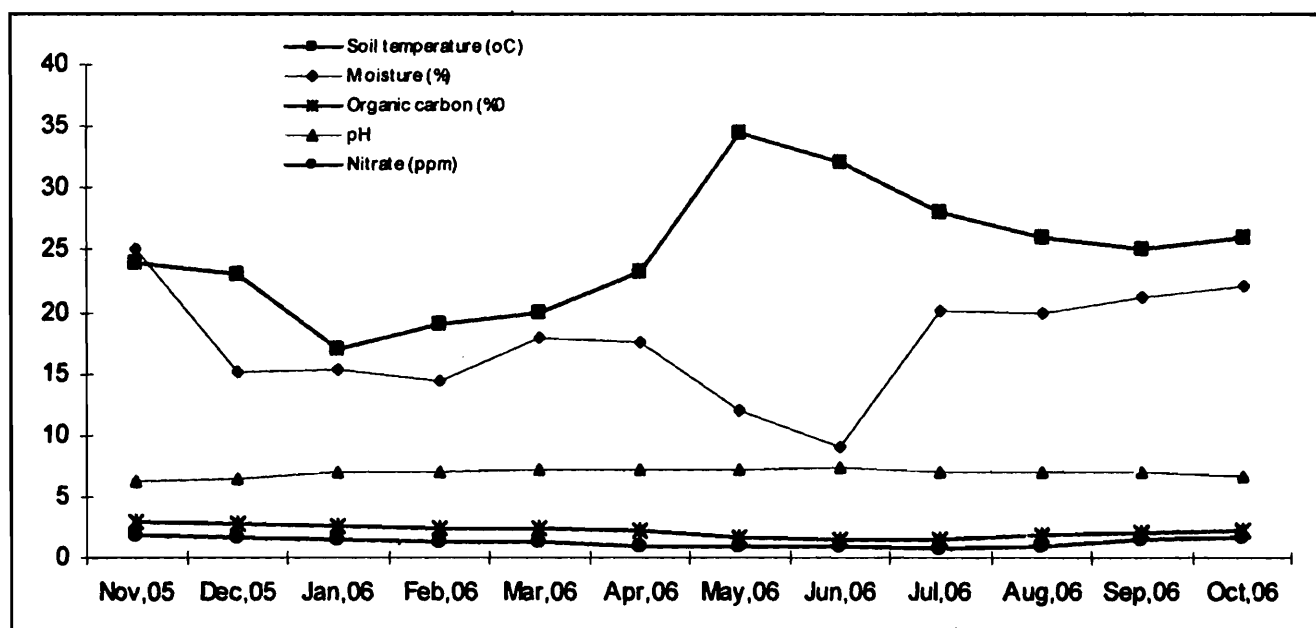


Fig. 4b. Monthly fluctuation of edaphic factors in CTPS site

7.31 in July at BSP site. While at CTPS site the minimum pH of soil were 6.3 in the month of November and maximum was 7.29 in the month of June. The content of soil organic carbon (%) varied from 1.28 (in July) to 2.98 (in November) at BSP site and 1.39 (in July) to 2.88 (in November) at CTPS site. The nitrate content of soil also varied from 0.78 ppm (in July) to 1.5 ppm (in October) at BSP site and 0.82 ppm (in July) to 1.82 ppm (in November) at CTPS site.

Regression and correlation between Collembola and edaphic factors

The data involving soil factors and population density were subjected to statistical analysis separately for each site in order to find out regression and correlation. The dependence of number of Collembola (Y) on each of the five variables (soil factors) considered here was studied. First, by means of a statistical test it was verified whether the relationships between total number and dominant species of Collembola (Y) and different variables remained constant throughout. Study of correlation coefficient (fourth column of Table 3) indicate that only the soil organic carbon in both the sampling sites showed positive correlation with the population density. While the correlation between individual species population and the variables showed irregular relationship in different sites (Table 3).

DISCUSSION

The results presented here were based on sample survey of Collembola from two different industrial areas of Bokaro, Jharkhand over a period of 12 months (November, 2005-October, 2006). Collembolan fauna encountered in this study belonged to 10 genera of the families Entomobryidae, Isotomidae and Sminthuridae. Some forms markedly differed in their abundance from one site to other (Table 2). Moreover, numbers of species were maximum in CTPS site (9) than BSP site (7). The species *Isotomina thermophila*, *Cyphoderus assimilis*, *Folsomides pervulus*, *Lepidocyrtus* sp. and *Entomobrya* sp. were extracted from both the sites. *Sphaeridia cornuta* and *Sminthurinus* sp.

obtained only from BSP site and *Isotomedes dagamae*, *Isotomurus balteatus*, *Isotomella minor* and *Cyphoderus javanus* were restricted to the CTPS site. Among the colembolan species *Isotomina thermophila* and *Folsomides pervulus* occurred throughout the year in CTPS and BSP site respectively (Table 2). The population of both the sites when taken together exhibited a more or less irregular trend of fluctuation attaining its peak during November followed by a decline and reaching its lowest level during July (Table 2). This trend of fluctuation as observed in this study quite similar to those reported by Hazra and Choudhuri (1990), Shome and Ghosh (2006) while working on Collembola population in Durgapur steel plant area, West Bengal.

Further the number of species (11) extracted from both the plots were relatively low. Collembola in many instances are known to occur in aggregated, patchy or sporadic distribution, occurring in a large number at a particular spot. Due to industrial pollutants this peculiar behaviour might have excluded the Collembola from many of the samples resulting smaller number of species. Moreover, the study areas were located in the same district with similar climatic and soil conditions and they did not exhibit remarkable variation in the species diversity. The species diversity index evaluated by Shannon-Wiener method showed that diversity values in the study sites ranged between 1.89505 to 2.14163 (Table 4).

Among the five edaphic factors analyzed, the organic carbon showed positive correlation with the collembolan population in both the study sites. This also coincides with the earlier results obtained by Chattopadhyay and Hazra (1983), Hazra and Choudhuri (1990) and Shome and Ghosh (2006). In general acidity of soil led to differentiation of humus type and thus the abundance of Collembola was also minimum in BSP site because the soil of this site was more alkaline than CTPS site (Hazra *et al.*, 1976).

It can be concluded from the present study that the steel plant effluents exert more effects on the population structure of Collembola fauna. However definite conclusion can only

Table 3. Showing relationship between total Collembola population including their three dominant species population and soil factors.

Sites	Parameters	Mean	r' value	Regression equation ($Y = a + bx$)
BSP	Y : no. of collembola	16		
	Nitrate (ppm)	1.08	0.849330306	$Y = -5.04 + 19.33x$
	Soil temperature (°C)	25.69	-0.182695828	$Y = 21.19 - 0.20x$
	Moisture (%)	16.94	0.74448309**	$Y = 0.41 + 0.92x$
	Organic carbon (%)	2.12	0.731760733**	$Y = 0.63 + 7.22x$
	pH	7.07	-0.846519515	$Y = 220.73 - 0.92x$
	Y:no. of <i>I. thermophila</i>	3.66		
	Nitrate (ppm)	1.08	0.738009368**	$Y = -2.63 + 5.79x$
	Soil temperature (°C)	25.69	-0.219739442	$Y = 5.81 - 0.08x$
	Moisture (%)	16.94	0.572852439	$Y = -0.46 + 0.24x$
	Organic carbon (%)	2.12	0.754798307	$Y = -1.79 + 2.56x$
	pH	7.07	-0.637943327	$Y = 56.86 - 7.46x$
	Y:no. of <i>C. assimilis</i>	3.16		
	Nitrate (ppm)	1.08	0.826519038	$Y = -5.94 + 8.36x$
	Soil temperature (°C)	25.69	-0.385890449	$Y = 8.04 - 0.18x$
	Moisture (%)	16.94	0.582558884*	$Y = -2.25 + 0.32x$
	Organic carbon (%)	2.12	0.862249276	$Y = -4.88 + 3.78x$
	pH	7.07	-0.781247079	$Y = 87.21 - 11.79x$
	Y:no. of <i>Lepidocyrtus sp.</i>	2.33		
	Nitrate (ppm)	1.08	0.491232595	$Y = -1.19 + 3.23x$
	Soil temperature (°C)	25.69	-0.00856271	$Y = 2.40 - 0.002x$
	Moisture (%)	16.94	0.501187769	$Y = -0.70 + 0.18x$
	Organic carbon (%)	2.12	0.320384407	$Y = 0.38 + 0.91x$
	pH	7.07	-0.580436688*	$Y = 42.97 - 5.7x$
CTPS	Y:no. of collembola	18.16		
	Nitrate (ppm)	1.09	0.805418683	$Y = 0.05 + 14.24x$
	Soil temperature (°C)	24.81	-0.162562043	$Y = 23.49 - 0.21x$
	Moisture (%)	17.2	0.66763339	$Y = 0.89 + 0.99x$
	Organic carbon (%)	2.14	0.604247278*	$Y = 0.43 + 8.26x$
	pH	6.98	-0.755848279	$Y = 127.60 - 15.63x$
	Y : no. of <i>I. thermophila</i>	3.58		
	Nitrate (ppm)	1.09	0.721114261**	$Y = -0.47 + 3.19x$
	Soil temperature (°C)	24.81	-0.114623146	$Y = 4.52 - 0.03x$
	Moisture (%)	17.2	0.680018371	$Y = -0.81 + 0.25x$
	Organic carbon (%)	2.14	0.594690032*	$Y = 0.78 + 2.03x$
	pH	6.98	-0.767572116	$Y = 31.39 - 3.97x$
	Y:no. of <i>C. assimilis</i>	2.83		
	Nitrate (ppm)	1.09	0.815234891	$Y = -3.09 + 4.66x$
	Soil temperature (°C)	24.81	-0.197467432	$Y = 4.92 - 0.08x$
	Moisture (%)	17.2	0.687172425	$Y = -2.91 + 0.32x$
	Organic carbon (%)	2.14	0.659502851	$Y = -3.42 + 2.91x$
	pH	6.98	-0.75404495	$Y = 38.15 - 5.04x$

Table 3. Contd.

Sites	Parameters	Mean	r' value	Regression equation (Y= a+bx)
	Y : no. of <i>C. javanus</i>	2		
	Nitrate (ppm)	1.09	0.229732742	Y = 1.19 + 0.63x
	Soil temperature (°C)	24.81	0.28327109	Y = 0.55 + 0.05x
	Moisture (%)	17.2	0.622580254*	Y = -0.51+ 0.14
	Organic carbon (%)	2.14	-0.145668765	Y = 2.66 - 0.31x
	pH	6.98	-0.416577872	Y= 11.40 -1.43x

* significant at 5% level ; ** significant at 1% level

Table 4. Species diversity, measured here by H' (the Shannon - Weiner index) of two industrialsites of Bokaro District, Jharkhand.

Site	Taxa / Specimen	ni	Pi ln Pi	H'
BSP	<i>Cyphoderus assimilis</i>	38	-0.320607032	-1.89505
	<i>Isotomina thermophila</i>	48	-0.34657359	
	<i>Folsomides pervulus</i>	24	-0.259930193	
	<i>Sphaeridia cornuta</i>	17	-0.214649971	
	<i>Lepidocyrtus sp.</i>	28	-0.280771584	
	<i>Entomobrya sp.</i>	25	-0.265445254	
	<i>Sminthurinus sp.</i>	16	-0.207075554	
N = 192				
CTPS	<i>Cyphoderus assimilis</i>	34	-0.2898008	-2.14163
	<i>Isotomina thermophila</i>	43	-0.320191205	
	<i>Isotomedes dagamae</i>	23	-0.237279906	
	<i>Folsomides pervulus</i>	23	-0.237279906	
	<i>Lepidocyrtus sp.</i>	15	-0.18415905	
	<i>Entomobrya sp.</i>	20	-0.219152549	
	<i>Isotomurus balteatus</i>	16	-0.191699548	
	<i>Isotomella minor</i>	20	-0.219152549	
	<i>Cyphoderus javanus</i>	24	-0.242910961	
N = 218				

be made after the study heavy metal concentration in the study site which is under progress.

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LITERATURE CITED

- BHATTACHARYA, T. and BANERJEE, R. 1980. A preliminary survey of the effect of smoke emission from am husking mill on the soil microarthropods. *Newsletter Soil Biology and Ecology*, 1(1) : 15-17.
- CHAGON, M., PARE, D., HEBERT, C., and CAMIRE, C. 2001. Effects of experimental liming on collembolan communities and soil microbial biomass in a southern Quebec sugar maple (*Acer saccharum* Marsh) stand. *Appl. Soil. Ecol.*, 17 : 81-90.
- CHATTOPADHYAY, A. and HAZRA, A. K. 1983. Subterranean arthropod communities in sewage effluents contaminated soil environment near Calcutta. *Environment & Ecology*, 1 : 121-124.
- CHAUVAT, M. and PONGE, J. F. 2002. Colonization of heavy metal polluted soils by Collembola: Preliminary experiments in compartmental boxes. *Applied Soil Ecol.*, 21 : 91-106.
- DEY, M. K., PAHARI, D., HAZRA, A. K. and CHAKROBORTY, S. K. 2006. Effects of thermal power fly ashes on the population structure of soil microarthropods at Kolaghat, East Midnapore District, West Bengal. *Rec. zool. Surv. India*, 106 (pt-4) : 13-19.
- GRONY, M. 1975. Studies on the influence of industrial pollution on soil animals in pine Stands. *Progress in soil Zoology*, ed. J. Vanek, *Proc. 5th Int. Colloq. Zoology*, Prague : 357-362.
- HAZRA, A. K., CHOUDHURI, D. K., and ROY, S. 1976. Influence of soil pH on the collembolan fauna of two uncultivated fields of Gangetic West Bengal. *J. Biol. Sci.*, 19(1) : 19-24.
- HAZRA, A. K., MUKHOPADHYAY, P., GUHA, D. K., and SYNAL, A. K. 1982. Effects of industrial effluents on the population structure of soil microarthropods at Durgapur steel plant area, a preliminary report. *Ecology of Animal Population., Zool. Surv. India.*, Part 3 : 93-98
- HAZRA, A. K. and CHOUDHURI, D. K. 1990. Ecology of subterranean macro and microarthropod fauna in different degraded and polluted environment of West Bengal, India. *Rec. zool. Surv. India. Occasional Paper No.*, 120 : 1-295.
- HOPKINS, S. P. 1986. Ecophysiological strategies of Terrestrial arthropods for surviving heavy metal pollution. *Proc. 5th European Cong. Entomol.* Amsterdam, : 263-266.
- MACFADYEN, A., 1953. Notes on methods for the extraction of soil arthropods. *J. Anim. Ecol.*, 22 : 65-77.
- PIPER, C. S. 1942. Soil and plant analysis. Hans Publishers.
- SIEG, H. C., URESK, W. D. and HANSEN, M. R. 1998. Impact of Bentonite Mining on Selecting Arthropods. *Journal of range Management*. Vol. 40. No 2 : 128-131.
- SHOME, N. and GHOSH. A. R. 2006. Role of edaphic factors and two heavy metal (Zinc and Copper) in the population fluctuation of soil arthropod fauna in areas adjacent to Nullah at Durgapur Industrial Complex. *Environment & Ecology*, 24(4) : 758-764.
- WALKLEY, A. and BLACK, I. A. 1934. An extraction of the Degjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil. Sci.*, 37 : 29-38.

STUDIES ON REMEDY OF IN VIVO ARSENIC CYTOTOXICITY

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ABSTRACT

In recent times, Arsenic is one of the most important toxicants, affecting the population of West Bengal and Bangladesh mainly through geogenically contaminated drinking water. Among the inorganic arsenicals, trivalent arsenic is more toxic than pentavalent forms; liver, spleen, kidneys, lungs and gastro-intestinal tract being their major sites of absorption. Although it is rapidly cleared from these sites, it leaves a residue in keratin-rich tissues like skin, hair and nails. Inside the cells, trivalent arsenic inhibits critical sulfhydryl-containing enzymes resulting in hyperkeratosis, hyperpigmentation, exfoliative dermatitis, Blackfoot disease and skin cancer. Curcumin, with a long history of use in traditional Asian medicine, is a powerful antioxidant that can alter gene expression, stop cell cycle, and induce self-destruction of cancer cells without affecting healthy ones. It also inhibits cancer cell growth by blocking kinase activity. The primary mission of this study was to identify an effective and safe anti-clastogenic and antigenotoxic agent that will facilitate the development of arsenic cytotoxicity-preventive strategies and its future application in a clinical setting. In this study, Sodium arsenite (NaAsO_2) treated Swiss Albino mice (*Mus musculus*) showed a significant induction of chromosomal aberrations and spermatozoan anomalies with decrease in mitotic index. However, in curcumin-supplemented mice, no significant induction in cytotoxic damage or change in mitotic index was recorded. These findings establish the anti-cytotoxic properties of curcumin as a protective agent against arsenic toxicity. This study inspires us for further investigations with curcumin for future clinical trials and raises hopes that curcumin will find application as a novel drug to control arsenic toxicity.

Keywords : Sodium arsenite, mice, chromosomal aberrations, spermatozoan abnormalities, curcumin

INTRODUCTION

The long history of arsenic in science, medicine and technology has been overshadowed by its notoriety as a preferred poison in homicides. In modern parlance, arsenic is often viewed as being synonymous with 'toxic'. Arsenic toxicity in the groundwater of southern West Bengal India, and southern and eastern parts of Bangladesh, is an alarming environmental problem that was first recognized about two decades ago. The presence of arsenic in the groundwater at concentrations that exceed the WHO permissible limit of 0.01 mg/l for human consumption, was first recorded in West Bengal

in 1978, and the first case of arsenic poisoning was diagnosed in 1983. Within a span of twenty years, over 3 to 4 million people in six districts in southern West Bengal, which are located to the east of the Bhagirathi River, were found to be affected by arsenic poisoning in groundwater. Several hypotheses have been proposed to explain the release of arsenic from aquifer material to the groundwater of the Ganges delta. These are as follows :

- (a) oxidation of arsenical poisons
- (b) competitive anion exchange of sorbed arsenic with phosphate from fertilizer
- (c) reductive dissolution of iron oxy-

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hydroxides and release of the sorbed arsenic into the groundwater.

The toxicity of arsenic compounds is generally linked to the soluble inorganic trivalent forms. The toxicity of pentavalent inorganic compounds seems related to the *in vivo* reduction of As(V) to As(III). Inorganic arsenic compounds react with sulfhydryl (-SH) groups of cellular proteins, thereby inhibiting cellular oxidative processes (pyruvate and succinate oxidative pathways). Competition with phosphorus in the oxidative phosphorylation process is caused by inorganic compounds, mainly in the pentavalent form. The diffuse toxic process of arsenic poisoning causes widespread endothelial cellular toxicity, resulting in capillary damage and tissue hypoxia precipitating generalized vasodilatation and transudation of plasma. Gastrointestinal, cardiac, renal, bone marrow, central nervous system, and hepatic damage may be noted at different stages of arsenic poisoning.

Arsenic has been shown to be genotoxic as well as cytotoxic in a wide variety of experimental set-ups using animal models and biological endpoints. Among the inorganic salts of Arsenic, Sodium arsenite (NaAsO_2) has so far been reported to be most toxic. With respect to induction of Sister Chromatid Exchange (SCE), significantly high SCE frequencies were shown after arsenite treatment in experiments with HPL 250 mice (Gebel *et al.*, 1997; Rasmussen and Menzel, 1997) as well as, with Syrian Hamster Embryonic cells. The aberrations found in most studies were true DNA breaks (Lee *et al.*, 1985b; 1986a; 1991; Beckman *et al.*, 1977; Dulout *et al.*, 1996; Gurr *et al.*, 1993; Jha *et al.*, 1992; Kochhar *et al.*, 1996; Nakamuro and Sayato, 1981; Nordenson *et al.*, 1981; 1982; Wiencke and Yagar, 1992). Sodium arsenite was shown to produce increased SCE in CHO cells and increased chromosome breakage (Soukup *et al.*, 1982). Exposed human fibroblasts in culture showed a significant number of chromosome pulverizations in most metaphases (Ochi *et al.*, 1996).

Information on the reproductive and

developmental toxicity of inorganic arsenic is available primarily from studies in animals using arsenite and arsenate salts and arsenic trioxide. A characteristic pattern of malformations is produced, and the developmental toxicity effects are dependent on dose, route, and the day of gestation when exposure occurs. Death and growth retardation are produced by oral arsenic exposure. Arsenic is readily transferred to the fetus and produces developmental toxicity in embryo culture (Golub *et al.*, 1998; Minoru, 2002). Sodium arsenite administered to mice (*Mus musculus*) via drinking water caused a decrease in the absolute and relative testicular weight. A decrease in sperm count and sperm motility, along with an increase in abnormal sperm, was observed in arsenite-exposed mice. A significant accumulation of arsenic in testes, epididymis, seminal vesicle and prostate gland was observed in treated animals (Pant *et al.*, 2001; 2004).

With respect to all the information and reviews on Arsenic toxicity, it was seen that not much work has been done regarding its counter mechanism. In the present study, we tried to explore the possibilities of counter mechanism of arsenite toxicity by Curcumin. Turmeric (*Curcuma Zanga L.*) is a medicinal plant is a medicinal plant extensively used in Ayurveda, Unani and Siddha medicine as home remedy for various diseases (Ammon and Wahl, 1991; Eigner and Scholz, 1999). Turmeric is used as a food additive (spice), preservative and colouring agent in Asian countries, including China and South-East Asia. It is also considered as auspicious and is a part of religious rituals. In old Hindu medicine, it is extensively used for the treatment of sprains and swelling caused by injury. In recent times, traditional Indian medicine uses turmeric powder for the treatment of biliary disorders, anorexia, coryza, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis (Ammon *et al.*, 1992).

The antioxidant effect of curcumin was reported as early as 1975 (Sharma, 1976). It acts as a scavenger of oxygen free radicals (Ruby *et al.*, 1995; Subramanian *et al.*, 1994). *In vitro*,

curcumin can significantly inhibit the generation of reactive oxygen species (ROS) like superoxide anions, H_2O_2 and nitrite radical generation by activated macrophages, which play an important role in inflammation. Curcumin also lowers the production of ROS *in vivo* (Joe and Lokesh, 1994). Curcumin exerts powerful inhibitory effects against H_2O_2 -induced DNA damage in human keratinocytes and fibroblasts (Phan *et al.*, 2001) and in NG 108-15 cells (Mahakunakorn *et al.*, 2003). It also maintains the activities of antioxidant enzymes like superoxide dismutase, catalase and glutathione peroxidase (Pulla Reddy and Lokesh, 1992). Several studies have been carried out where curcumin was successful as an anti-clastogenic, antigenotoxic and anti-mutagenic agent (Mukhopadhyay *et al.*, 1998; Shukla *et al.*, 2002; Abraham *et al.*, 1993; Araujo *et al.*, 1999; Antunes *et al.*, 2000; Subramanian *et al.*, 1994; el Hamss *et al.*, 1999). The anti-angiogenic (Gururaj *et al.*, 2002; Sharma *et al.*, 2005), anti-tumour (Anto *et al.*, 1996; Khar *et al.*, 1999) and chemopreventive properties (Campbell and Collett, 2005; Singh and Khar, 2006; Joe *et al.*, 2004; Lin and Lin-Shiau, 2001; Karunagaran *et al.*, 2005; Huang *et al.*, 1997; Kawamori *et al.*, 1999) of curcumin-are being thoroughly investigated to elucidate the molecular mechanisms behind these pathways. With regard to all these studies on curcumin, we were curious to investigate if curcumin could prove to a successful agent against arsenic-related cytotoxicity.

MATERIALS AND METHODS

a) Drug schedule

Outbred male Swiss albino mice (*Mus musculus*) of same age group and weight (25 gms.) were used as animal model. They were kept in animal house for 3 weeks in separate cages under controlled condition for acclimatization. The mice were injected intraperitoneally with 3 separate doses of Sodium arsenite @ 1 mg/kg body wt., 3 mg/kg body wt. and 5 mg/kg body wt. respectively (in a set of 12 mice for each dose). The mice were sacrificed after 24 hours of drug exposure.

The dose with the highest response was followed by 3 doses of curcumin (in DMSO) injection (selected after several trials) @ 0.1 mg/kg body wt. i.p., 0.5 mg/kg body wt. i.p. and 1 mg/kg body wt. i.p. as a counter drug and sacrificed after 24 hours of drug exposure. A separate batch of mice was maintained as solvent control (with DMSO) and control with only curcumin. Each experiment was repeated 5 times.

b) Experimental Protocol

Mice (both treated and control series) were injected with Colchicine @ 2 mg/kg body wt., 1 hour 30 minutes prior to sacrifice. Metaphase plates were prepared by conventional hypotonic-fixative-flame drying protocol (Adler, 1984) and the dried slides were stained in buffered Giemsa stain (pH-6.8). For the preparation of sperm head films, Epididymes of sacrificed mice were dissected out and the teased contents were kept in a mixture of 0.85% saline and 0.1% Glucose solutions to prevent swelling of spermatozoa. After removal of all debris the suspension was sprayed smoothly over the slides. Air-dried slides were stained in Giemsa (1 : 15 dilution).

Well spread metaphase plates and sperm head films were scored under the oil immersion lens of an Olympus binocular microscope. The structural and numerical abnormalities of the metaphase chromosomes and sperm head morphological abnormalities were screened with careful examination. Student's t-test and Chi-square analysis were applied to evaluate the level of significance between treated and control results.

RESULTS

Different types of clastogenic manifestations were considered as endpoints, for example, chromatid gaps, chromatid breaks, pulverizations, fusions, fragmentations, etc. Morphological abnormalities of sperm head were also scored at different doses. These data were compared with that of control mice (treated with curcumin and DMSO separately) to evaluate the cytotoxic potentiality. The

comparison of the pooled data with the control, curcumin control and curcumin + arsenite-treated mice helped to indicate the anti-clastogenic potentiality of curcumin.

About 1200 metaphase plates (400 each for 3 doses) from arsenite-treated mice were meticulously scanned which revealed various structural and numerical aberrations like chromatid gaps, breaks, fragmentations, aneuploidy, Robertsonian fusion, Ring chromosome, deletion, pulverizations (both partial and complete), etc (Table 1). 7.25% abnormalities were recorded in the 1st dose against a control of only 3.5%, which sharply increased to 13.75% for 2nd dose and 27.75% for 3rd dose. The mitotic index has also been noted to fluctuate drastically during the experiment. From a normal value of 4.1, it was only 0.75, 0.75 and 0.74 for the 3 doses respectively. The variation of mitotic index is a good indicator of cytotoxic effect of arsenite. The application of curcumin in 3 selected doses as a counter to the highest arsenite dose (5 mg/kg body wt.) was seen to be highly effective. The first two counter doses @ 0.1 mg/kg body wt. and 0.5 mg/kg body wt. were successful to check the percentage of aberrations to only 19% and 9.75% with a mitotic index of 2.2 and 2.8 respectively. But with the application of the 3rd dose @ 1 mg/kg body wt. i.p. the percentage came down sharply to 5.75% almost near the control level, and the mitotic index was also seen to reach an almost normal value of 3.9. Application of Student's t-test with the occurrence of aberrations showed that they were highly significant at 5% level of significance (Table 1). A separate control batch maintained for Curcumin and only DMSO produced no visual or behavioral changes in mice and resulted in minor chromosomal aberrations of 3.5% and 4.25% respectively.

Various types of sperm head abnormalities were observed with increase in dose of Sodium arsenite like slender head, loss of head, round head and blunt head. The frequency of abnormalities increased to 8%, 14% and 26% as compared to 4% in control series, but with application of curcumin in 3 doses @ 0.1 mg/

kg body wt. i.p., 0.5 mg/kg body wt. i.p. and 1mg/kg body wt. i.p, the abnormalities gradually decreased to 16%, 10% and 6% respectively (Table 2). All the abnormalities were proved to be statistically significant at 95% level of significance.

DISCUSSION

Arsenic containing drinking water has recently posed a worldwide threat, especially to the residents of Bangladesh and Eastern India, who are regularly suffering from a variety of skin and internal organ cancers (Giri *et al.*, 2001). The wide human exposure to this compound through drinking water causes great concern for human health. A worldwide effort is going on to check this curse on mankind by the use of different novel and beneficial drugs. The present study has been carried out with the same objective with curcumin as the counter drug. In this context, the success of the present study has significant implications.

The study was divided into 2 parts. The 1st part dealt with arsenite injection in 3 different doses, which reported several clastogenic manifestations. The general trend showed that the percentage of aberrations increased at the rate of about 2 times for each dose, which also increases at the same rate, reflecting the magnitude of arsenite-assault. The clastogenic effects may be explained by the interference with spindle fibres and disruption of the mitotic spindle (Lee and Huang, 1998; Ramirez *et al.*, 1997; Yih and Lee, 1999; 2003; Sciandrello *et al.*, 2002). Consistent with the cellular effect, the *in vitro* microtubule assembly assay showed that prior treatment of monomeric tubulin with As_2O_3 markedly inhibits GTP-induced polymerization and microtubule formation. Arsenic slightly decreases background tubulin polymerization in the absence of added GTP. These findings suggest that arsenic targets free tubulin in a manner similar to colchicines. This does not rule out the possibility that arsenic may bind to polymerized tubulins and stabilize microtubules (Li and Broome, 1999). A major target site of arsenic action on tubulin may account for the observation that the mitotic-

Table 1. Dose-response relationship in mice with Sodium arsenite and its attenuation by Curcumin on somatic chromosomes.

Metaphase scored: 400 per dose	A	C.G.	C.B.	F	R.F.	R.C.	P	Mitotic index	Total Aberration (%)	Mean	S.D.
Control with DMSO	7	2	2	3	0	0	0	4.1	3.5	2	2.516
Control with Curcumin	4	3	"	5	2	0	0	4.1	4.25	2.42	1.902
Treated Dose I 1 mg/kg body wt.	12	3	5	7	2	0	0	0.75	7.25	4.14	4.298
Treated Dose II 3mg/kg body wt.	25	2	7	10	5	2	4	0.75	13.75	7.85	8.701
Treated Dose III 5 mg/kg body wt.	35	5	15	21	11	12	10	0.74	27.25	15.5	9.863
NaAsO ₂ + Cu : 0.1 mg/kg body wt.	29	3	11	15	7	6	5	2.2	19	10.8	8.952
NaAsO ₂ + Cu: 0.5 mg/kg body wt.	17	5	5	2	7	0	3	2.8	9.75	5.57	5.533
NaAsO ₂ + Cu: 1 mg/kg body wt.	7	6	3	5	2	0	0	3.9	5.75	3.28	2.812

A = Aneuploidy; C.G. = Chromatid gap; C.B. = Chromatid break; F = Fragmentation; R.F. = Robertsonian Fusion; R.C. = Ring Chromosome; P = Pulverization; S.D. = Standard Deviation; Cu = Curcumin.

Table-2. Dose-response relationship in mice with Sodium arsenite and its attenuation by Curcumin on sperm head morphology.

Dose given at different schedules	Types of Sperm head morphological abnormalities				
	Slender head	Loss of head	Round head	Blunt head	Total aberrations (%)
Control with DMSO	2	0	1	1	4
Control with Curcumin	1	2	0	2	5
Treated Dose I : 1 mg/kg body wt.	2	3	2	1	8
Treated Dose II : 3mg/kg body wt.	4	4	2	4	14
Treated Dose III : 5 mg/kg body wt.	7	5	6	8	26
NaAsO ₂ + Cu : 1 mg/kg body wt.	2	1	1	2	6
NaAsO ₂ + Cu : 0.5 mg/kg body wt.	0	4	3	3	10
NaAsO ₂ + Cu : 0.1 mg/kg body wt.	2	6	6	2	16

Cu = Curcumin

arrest of arsenic-treated cells resembles the effects of both the tubulin polymerization inhibitor and promoter. Because arsenic prevents tubulin polymerization but does not depolymerize the GTP-stabilized microtubule, it is possible that arsenic binds both tubulin monomer and polymer and stabilizes them. The relatively narrow range of the effective concentration of arsenic could be determined by the availability of arsenic-binding sites, which would depend on the intracellular GTP level.

Similar observations were recorded in case of spermatozoan morphology in response to arsenic assault, because Arsenite causes significant dose-dependent decreases in the accessory sex organ weights, epididymal sperm count and plasma concentrations of LH, FSH and testosterone with massive degeneration of spermatozoa, showing that arsenic has a suppressive influence on spermatogenesis in mice (Sarkar *et al.*, 2003), leading to various types of abnormalities in sperm head morphology.

The molecular mechanisms behind the action of inorganic arsenic leading to cancer are thought to be very complex. Both hypo- and hypermethylation of genes (such as oncogenes or tumour-suppressor genes), which in turn cause abnormality in cell proliferation leading to carcinogenesis. It was known from previous studies that arsenic exposure methylates the promoter region of p53 gene. It was further evident from the observation that, expression of tumour-suppressor gene p53 in different cell lines was increased with arsenic and mutation in p53 was shown to increase sensitivity to arsenic cytotoxicity (Choudhuri *et al.*, 2002; 2005).

The 2nd part consisted of the counter mechanism by Curcumin. In the present study, Curcumin was successful to a considerable extent in checking the clastogenic effects produced by NaAsO₂. We know that Curcumin acts as a potent anti-carcinogenic compound. Among various mechanisms, induction of apoptosis plays an important role in its anti-carcinogenic effect. It induces apoptosis and inhibits cell-cycle progression, both of which are instrumental in preventing cancerous cell

growth (Chen and Huang, 1998). Curcumin also induces apoptotic cell death by DNA damage in human cancer cell lines by acting as topoisomerase II poison (Martin Cordero *et al.*, 2003). In colorectal carcinoma cell line, Curcumin delays apoptosis along with the arrest of cell cycle at G1 phase (Chen *et al.*, 1996). Curcumin reduces p53 gene expression, which is accompanied with the induction of HSP-70 gene through initial depletion of intracellular Ca²⁺. Curcumin produces non-selective inhibition of proliferation in several leukemia, nontransformed haematopoietic progenitor cells and fibroblast cell lines (Gautam *et al.*, 1998). Curcumin also downregulates matrix metalloproteinase (MMP)-2 and upregulates tissue inhibitor of metalloproteinase (TIMP)-1, two common effector molecules involved in cell invasion (Shao *et al.*, 2002). In the present study, we assume that curcumin blocks the hypomethylation pathway of arsenic and checks its clastogenicity by p53 downregulation. Cytotoxicity was also checked by an increased antioxidant level, which is brought by Curcumin-stimulated increase of Glutathione level in the body (Sharma *et al.*, 2001). It was also noticed that the percentage of both chromosomal aberrations and sperm head abnormalities lowered down gradually with the increase in the dose of curcumin injection. However, the amount of arsenic consumed by man through drinking water (50 microgram/litre) is far below the range that could produce such severe damages like chromosomal or sperm head abnormalities. We assume that in case of man such low cytotoxic manifestations can be checked by application of much lower doses of Curcumin than what was applied for checking Arsenic cytotoxicity in the murine system. This study therefore, supports our previous notions about arsenic toxicity and shows a new direction regarding its future treatment for the benefit of mankind.

CONCLUSION

The primary mission of this study was to identify an effective and safe anti-clastogenic and antigenotoxic agent that will facilitate the

development of arsenic cytotoxicity-preventive strategies and its future application in a clinical setting. Curcumin is a non-toxic, highly promising natural antioxidant compound having a wide spectrum of biological functions. In this cytotoxicity assay, curcumin was largely successful as a preventive agent against arsenic-clastogenicity. These findings inspire us for further investigations with curcumin using different experimental set-ups to establish a dose-response relationship for clinical trials. We

expect that curcumin will find application as a novel drug in the near future to control the assault of arsenic toxicity.

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LITERATURE CITED

- ABRAHAM, S. K., SARMA, L. and KESAVAN, P. C. 1993. Protective effects of chlorogenic acid, curcumin and beta-carotene against gamma-radiation-induced in vivo chromosomal damage. *Mutat. Res.*, **303** : 109-12.
- ADLER, I.D. 1984. Cytogenetic tests in Mammals. In: *Mutagenicity Testing : a Practical Approach*. (Venitt S. and Parry J.M.) IRL Press, Oxford, Washington DC, : 275-306.
- AMMON, H. P. T. and WAHL, M. A. 1991. Pharmacology of *Curcuma longa*. *Planta Med.*, **57** : 1-7.
- AMMON, H. P. T., ANAZODO, M. I., SAFAYHI, H., DHAWAN, B. N. and SRIMAL, R. C. 1992. Curcumin: a potent inhibitor of leukotriene B₄ formation in rat peritoneal polymorphonuclear neutrophils (PMNL). *Planta Med.*, **58** : 226.
- ANTO, R. J., GEORGE, J. and BABU, K. V., RAJASEKHARAN, K.N. and KUTTAN, R. 1996. Antimutagenic and anticarcinogenic activity of natural and synthetic curcuminoids. *Mutat. Res.*, **370** : 127-31.
- ANTUNES, L.M., ARAUJO, M. C., DARIN, J.D. and BIANCHI, M.L. 2000. Effects of the antioxidants curcumin and vitamin C on cisplatin-induced clastogenesis in Wistar rat bone marrow cells. *Mutat. Res.*, **465** : 131-137.
- ARAUJO, M.C., DIAS, F. L. and TAKAHASHI, C.S. 1999. Potentiation by turmeric and curcumin of gamma-radiation-induced chromosome aberrations in Chinese hamster ovary cells. *Teratog. Carcinog. Mutagen.*, **19** : 9-18.
- BECKMAN, G., BECKMAN, L. and NORDENSON, I. 1977. Chromosome aberrations in workers exposed to arsenic. *Environ Health Perspect.*, **19** : 145-146.
- CAMPBELL, F. C. and COLLETT, G.P. 2005. Chemopreventive properties of curcumin. *Future Oncol.*, **1** : 405-14.
- CHEN, Y-C., KUO, T. C., LIN-SHIAU, S. Y. and LIN, J. K. 1996. Induction of HSP70 gene expression by modulation of Ca²⁺ ion and cellular P53 protein by curcumin in colorectal carcinoma cells. *Mol. Carcinogenesis*. **17** : 224-234.
- CHEN, H. W. and HUANG, H. C. 1998. Effect of curcumin on cell cycle progression and apoptosis in vascular smooth cells. *Br. J. Pharmacol.*, **124** : 1029-1040.
- CHOUDHURI, T., PAL, S., AGWARWAL, M.L., DAS, T. and SA, G. 2002. Curcumin induces apoptosis in human breast cancer cells through p53-dependent Bax induction. *FEBS Lett.*, **512** : 334-40.
- CHOUDHURI, T., PAL, S., DAS, T. and SA, G. 2005. Curcumin selectively induces apoptosis in deregulated cyclin D1-expressed cells at G2 phase of cell cycle in a p53-dependent manner. *J Biol. Chem.*, **280** : 20059-68.

- DULOUT, F. N., GRILLO, C. A., SEOANE, A.I., MADERNA, C.R., NILSSON, R., VAHTER, M., DARROUDI, F. and NATARAJAN, A.T. 1996. Chromosomal aberrations from peripheral blood lymphocytes from native Andean women and children from north-western Argentina exposed to Arsenic in drinking water. *Mutat. Res.*, **370** : 151-158.
- EIGNER, D. and SCHOLZ, D. 1999. *Ferula asa-foetida* and *Curcuma longa* in traditional medicinal treatment and diet in Nepal. *J Ethnopharmacol.*, **67** : 1-6.
- EL HAMSS, R., ANALLA, M., CAMPOS-SANCHEZ, J., ALONSO-MORAGA, A., MUNOZ-SERRANO, A. and IDAOMAR, M. 1999. A dose dependent anti-genotoxic effect of turmeric. *Mutat. Res.*, **446** : 135-9.
- GAUTAM, S. C., XU, Y. X., PINDOLIA, K. R., JANAKIRAMAN, N. and CHAPMAN, R. A. 1998. Nonselective inhibition of proliferation of transformed and nontransformed cells by the anticancer agent curcumin (diferuloylmethane). *Biochem. Pharmacol.*, **55** : 1333-1337.
- GOLUB, M. S., MACINTOSH, M. S. and BAUMRIND, N. 1998. Developmental and reproductive toxicity of inorganic arsenic: animal studies and human concerns. *J Toxicol. Environ. Health B. Crit. Rev.*, **1** : 199-241.
- GEBEL, T., CHRISTIANSEN, S. and DENKELBERG, H. 1997. Comparative and environmental genotoxicity of antimony and arsenic. *Anticancer Res.*, **17** : 2603-2607.
- GIRI, A.K., GUPTA, J., MAHATA, J. and BASU, A. 2001. Genetic toxicology of a paradoxical human carcinogen, arsenic: a review. *Mutat Res.*, **488** : 171-194.
- GURR, J.R., LIN, Y.C., HO, I.C., JAN K. Y. and LEE, T. C. 1993. Induction of chromatid breaks and tetraploidy in Chinese Hamster Ovary cells by treatment with Sodium arsenite during G2 phase. *Mutat Res.*, **319** : 135-142.
- GURURAJ, A. E., BELAKAVADI, M., VENKATESH, D. A., MARME, D. and SALIMATH, B. P. 2002. Molecular mechanisms of anti-angiogenic effect of curcumin. *Biochem. Biophys. Res. Commun.*, **297** : 934-42.
- HUANG, M. T., NEWMARK, H. L. and FRENKEL, K. 1997. Inhibitory effects of curcumin on tumorigenesis in mice. *J Cell. Biochem. Suppl.*, **27** : 26-34.
- JHA, A.N., NODITI, N., NILSSON, R. and NATARAJAN, A.T. 1992. Genotoxic effects of Sodium arsenite on human cells. *Mutat Res.*, **284** : 215-221.
- JOE, B. and LOKESH, B. R. 1994. Role of capsaicin, curcumin and dietary *n*-3 fatty acids in lowering the generation of reactive oxygen species in rat peritoneal macrophages. *Biochim. Biophys. Acta.*, **1224** : 255-263.
- JOE, B., VIJAYKUMAR, M. and LOKESH, B.R 2004. Biological properties of curcumin-cellular and molecular mechanisms of action. *Crit. Rev. Food Sci. Nutr.*, **44** : 97-111.
- KOCHHAR, T.S., HOWARD, W., HOFFMAN, S. and BRAMMER-CARLT on, L. 1996. Effect of trivalent and pentavalent arsenic in causing chromosome alterations in cultured Chinese Hamster Ovary (CHO) cells. *Toxicol. Lett.*, **84** : 37-42.
- KHAR, A. ALI, A. M., PARDHASARADHI, B.V., BEGUM, Z. and ANJUM, R. 1999. Antitumor activity of curcumin is mediated through the induction of apoptosis in AK-5 tumor cells. *FEBS Lett.*, **445** : 165-8.
- KARUNAGARAN, D., RASHMI, R and KUMAR, T. R 2005. Induction of apoptosis by curcumin and its implications for cancer therapy. *Curro Cancer Drug Targets.*, **5** : 117-29.
- KAWAMORI, T., LUBET, R., STEELE, V. E., KELLOFF, G. J., KASKEY, R. B., RAO, C. V. and REDDY, B.S. 1999. Chemopreventive effect of curcumin, a naturally occurring anti-inflammatory agent, during the promotion/progression stages of colon cancer. *Cancer Res.*, **59** : 597-601.

- LEE, T. C., OSHIMURA, M. and BARRETT, J. C. 1985. Comparison of arsenic-induced cell transformation, cytotoxicity, mutation and cytogenetic effects in Syrian Hamster Embryo cells in culture. *Carcinogenesis*, 6 : 1421-1426.
- LEE, T.C., LEE, K.C., TZENG, Y.J., HUANG, R.Y. and JAN, K.Y. 1986a. Sodium arsenite potentiates the clastogenicity and mutagenicity of DNA-crosslinking agents. *Environ Mutagen.*, 8 : 119-128.
- LEE, T.C., LEE, K.C., TZENG, Y.J., HUANG, R.Y. and JAN, K.Y. 1991. Sodium arsenite mediated synergistical increase in chromosome aberrations induced by alkylating agents in mammalian cells. In : *Biological monitoring of Exposure Chemicals : Metals*. (Dillon, H. K. and Mat, H. H. Ed.) John Wiley & Sons Inc.: New York : 110-118.
- LEE, T.C. and HUANG, S.C. 1998. Arsenite inhibits mitotic division and perturbs spindle dynamics in HeLa S3 cells. *Carcinogenesis*, 19 : 889-896.
- LI, Y.M., and BROOME, J.D. 1999. Arsenic targets tubulins to induce apoptosis in Myeloid Leukemia cells. *Cancer Res.*, 59 : 776-780.
- LIN, J. K. and LIN-SHIAU, S.Y. 2001. Mechanisms of cancer chemoprevention by curcumin. *Proc. Natl. Sci. Counc. Repub. China B.*, 25 : 59-66.
- MARTIN-CORDERO, C., Lopez-Lazaro, M., GALVEZ, M. and AYUSO, M. J. 2003. Curcumin as a DNA topoisomerase II poison. *J. Enzyme Inhib. Med. Chem.*, 18 : 505-509.
- MAHAKUNAKORN, P., TOHDA, M., MURAKAMI, Y., MATSUMOTO, K., WATANABE, H. and VAJRAGUPTA, O. 2003. Cytoprotective and cytotoxic effects of curcumin: dual action on H2O2 induced oxidative cell damage in NG108-15 cells. *Biol. Pharm. Bull.*, 26 : 725-728.
- MINORU, O. 2002. Arsenic and reproductive toxicity. *Biomed. Res. Trace. Elem.*, 13 : 149-157.
- MUKHOPADHYAY, M. J., SAHA, A. and MUKHERJEE, A. 1998. Studies on the anticlastogenic effect of turmeric and curcumin on cyclophosphamide and mitomycin C *in vivo*. *Food Chem. Toxicol.*, 36 : 73-6.
- NAKAMURO, I. and SAYATO, Y. 1981. Comparative studies of chromosomal aberrations induced by trivalent and pentavalent arsenic. *Mutat Res.*, 88 : 73-80.
- NORDENSON, I., SWIENS, A. and BECKMAN, L. 1981. Chromosome aberrations in cultured human lymphocytes exposed to trivalent and pentavalent arsenic. *Scand. J. Work Environ. Health*, 7 : 277-281.
- NORDENSON, I. and BECKMAN, L. 1982. Is the genotoxic effect of arsenic mediated by oxygen free radicals? *Human Hered.*, 41 : 71-73.
- OCHI, T., KAISE, T. and OYA-OHTA, Y. 1996. Induction of chromosomal aberrations in cultured human fibroblasts in organic and inorganic arsenic compounds and the different roles of Glutathione in such induction, *Mutat Res.*, 357 : 123-129.
- PANT, N., KUMAR, R., MURTHY, R. C. and SRIVASTAVA, S. P. 2001. Male reproductive effect of arsenic in mice. *Biometals.*, 14 : 113-7.
- PANT, N., MURTHY, R. C., SRIVASTAVA, S. P. 2004. Male reproductive toxicity of sodium arsenite in mice. *Hum. Exp. Toxicol.*, 23 : 399-403.
- PHAN, T. T., SEE, P., LEE, S. T. and CHAN, S. Y. 2001. Protective effects of curcumin against oxidative damage on skin cell *in vitro*: its implication for wound healing. *J. Trauma*, 51 : 927-931.

- PULLA REDDY, ACH. and LOKESH, B. R. 1992. Studies on spice principles as antioxidant in the inhibition of lipid peroxidation of rat liver microsomes. *Mol. Cell. Biochem.*, 111: 117-124.
- Ramirez, P., Easrmond, D.A., Laclette, J.P. and Ostrosky-Wegman, P. 1997. Disruption of microtubule assembly and spindle formation as a mechanism for the induction of aneuploid cells by sodium arsenite and vanadium pentoxide. *Mutat Res.*, 386 : 299-306.
- RASMUSSEN, A.E. and MENZEL, D.B. 1997. Variation in arsenic induced sister chromatid exchange in human lymphocytes and lymphoblastoid cell lines. *Mutat Res.*, 86 : 299-306.
- RUBY, A. J., KUTTAN, G., DINESH BABU, K., RAJASEKHARAN, K. N. and KUTTAN, R. 1995. Antitumor and antioxidant activity of natural curcuminoids. *Cancer Left.*, 94 : 79-83.
- SARKAR, M., CHAUDHURI, G. R., CHATTOPADHYAY, A. and BISWAS, N. M. 2003. Effect of sodium arsenite on spermatogenesis, plasma gonadotrophins and testosterone in rats. *Asian J Androl.*, 5 : 27-31.
- SCIANDRELLO, G., BARBARO, R., CARADONNA, F. and BARBATA, G. 2002. Early induction of genetic instability and apoptosis by arsenic in cultured Chinese Hamster Cells. *Mutagenesis*, 17 : 99-103.
- SHARMA, O. P. 1976. Antioxidant activity of curcumin and related compounds. *Biochem. Pharmacol.*, 25 : 1811-1812.
- SHARMA, R. A., IRESON, C. R., VERSCHOYLE, R. D., HILL, K. A., WILLIAMS, M. L., LEURATTI, C., MANSON, M. M., MARNETT, L. J., STEWARD, W. P. and GESCHER, A. 2001. Effects of Dietary Curcumin on Glutathione-S- Transferase and Malondialdehyde-DNA Adducts in Rat Liver and Colon Mucosa: Relationship with Drug Levels. *Clin. Can. Res.*, 7 : 1452-1458.
- SHARMA, R. A., GESCHER, A. J. and STEWARD, W. P. 2005. Curcumin : the story so far. *Eur. J. Cancer*, 41 : 1955-68.
- SHAO, Z. M., SHEN, Z. Z., LIU, C. H., SARTIPPOUR, M. R., GO, V. L., HEBER, D. and NGUYEN, M. 2002. Curcumin exerts multiple suppressive effects on human breast carcinoma cells. *Int. J. Cancer*, 98 : 234-240.
- SINGH, S. and KHAR, A. 2006. Biological effects of curcumin and its role in cancer chemoprevention and therapy. *Anticancer Agents Med. Chem.*, 6 : 259-70.
- SHUKLA, Y., ARORA, A. and TANEJA P. 2002. Antimutagenic potential of curcumin on chromosomal aberrations in Wistar rats. *Mutat Res.*, 515 : 197-202.
- SOUKUP, S.W., CHRISTIAN, R.T. and WAN, B. 1982. Studies of cytogenetic effects of sodium arsenicals on mammalian cells *in vitro*. *Environ Mutagen.*, 4 : 493-498.
- SUBRAMANIAN, M., SREEJAYAN RAO, M. N. A., DEVASAGAYAM, T. P. A. and SINGH, B. 1994. Diminution of singlet oxygen induced DNA damage by curcumin and related antioxidants. *Mutat. Res.*, 311 : 249-55.
- WIENEKE, J.K. and YAGAR, J.W. 1992. Specificity of arsenic in potentiating cytogenetic damage induced by DNA cross-linking agents. *Environ. Mol. Mutagen.*, 19 : 195-200.
- YIH, L. H. and LEE, T. C. 1999. Sodium arsenite disturbs mitosis and induces chromosome aneuploidy in human fibroblasts. *Cancer Res.*, 57 : 5051-5059.
- YIH, L. H. and LEE, T. C. 2003. Induction of C-anaphase and Diplochromosome through dysregulation of spindle assembly checkpoint by Sodium arsenite in human fibroblasts. *Cancer Res*, 2003, 63 : 6680-6688.

NITRIC OXIDE GENERATION BY IMMUNOCYTES OF MUD CRAB EXPOSED TO SODIUM ARSENITE

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ABSTRACT

Estuarine mud crab, *Scylla serrata* (Crustacea : Decapoda) exposed to 1, 2 and 3 ppm of sodium arsenite for 24, 48, 72 and 96 hours in controlled laboratory condition indicated that arsenic as a toxicant causes a modulation in nitric oxide (NO) generation by hemocytes. Nitric oxide synthesis by hemocytes before sodium arsenite exposure was recorded as $1.96 \pm 0.05 \mu\text{M}/10^6$ cells. Steady and uniform increase of NO generation was recorded against 1, 2 and 3 ppm of sodium arsenite for 24, 48, 72 and 96 hour of exposures. Pattern of increase in NO generation expressed dose dependence. Highest generation of NO recorded was $18.25 \pm 0.25 \mu\text{M}/10^6$ cells against 3 ppm sodium arsenite for 96 hours. Arsenic induced generation of intraimmunocyte NO is indicative of a state of immunostimulation in *S. serrata*. This parameter may be considered as a suitable biomarker of arsenic pollution in soil and water of Sundarbans mangrove.

Key words : Sodium arsenite, *Scylla serrata*, immunocytes, nitric oxide.

INTRODUCTION

Scylla serrata is an economically important edible species, widely distributed in the intertidal mud flat of Sunderbans biosphere reserves of West Bengal and is considered as one of the large groups of crab in Sundarbans mangrove swamp (Chakraborty, 1986). Heavy metals, pesticides and fertilizers are major contaminants of the aquatic environment of estuarine ecosystem (Rainbow, 1995). Natural habitat of estuarine mud crab bears the risk environmental threat due to exposure of diverse hazardous heavy metals and metalloids including arsenic which originates from chemical weathering, non-ferrous smelters, geothermal power plant and the earth crust (Gomez-Camirero *et al.*, 2001). Arsenic poses a threat not only to the ground water but also to the surface water of the selected plains of West Bengal (Acharyya, 2002). Sublethal exposure of arsenic yields acute and chronic toxicity by

reducing intra and interspecific competitions. Aquatic invertebrates including mud crab elicit the immune response by phagocytosis and killing of pathogen and parasite by discrete populations of immunocytes of blood. In polluted environment, invertebrates are protected against foreign invaders by immunological system consisting of cellular and humoral limbs. Immunocytes are major immunoeffector cells of crab, which are involved in generating cytotoxic molecules capable of degrading the intrahemocyte pathogens. Invertebrates are capable of producing reactive oxygen intermediates (ROIs) upon contact with nonself particulates and xenobiotics (Tafalla *et al.*, 2002). Nitric oxide (NO) is oxygen intermediate, produced from L-arginine by NO-Synthase (NOS), which is generated in hemocytes as a cytotoxic factor for killing the invading the microorganisms (Radomski *et al.*, 1991). In this present study,

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we report that hemocytes of *S. serrata* are able to produce NO as measured by its final end product nitrite (NO_2^-), which expresses antibacterial property. Internal immune properties of peroxynitrite (ONOO^-) and NO are in report (Hahn *et al.*, 2001). Natural habitat of *S. serrata* receives diverse toxins including arsenic. Generation of NO was measured against different concentrations of sodium arsenite exposure in the immunocytes of *S. serrata*.

MATERIALS AND METHODS

Adult specimens of *S. serrata* weighing (70 ± 10 g) were collected from selected habitat of district of south 24 Parganas of West Bengal and were transported to the laboratory. Average length and breadth of the carapace of the specimen were 6 ± 0.5 cm and 9 ± 0.5 cm respectively. Animals were maintained in standard glass aquaria in batches and fed with fresh flesh of molluscs. The water was replenished 24 hourly and animals were acclimatized in laboratory condition for 7 days (Heasman and Fielder, 1983) prior to experimentation. A standard solution of 100 ppm of sodium arsenite (E. Merck, Germany; 99% pure; CAS number 7784-46-5) was prepared in Borosilicate glass containers using arsenic free distilled water. The pH of the solution was maintained as 7.4. Two sets of experiment were conducted with sodium arsenite solution. An acute toxicity bioassay was conducted to determine median lethal (LC_{50}) value of sodium arsenite for *S. serrata* by the method of Karber's after Ghosh (1984). Safe sublethal (LC_0) concentration and safe application rate (SAR) of sodium arsenite were determined by the method of Hart *et al.* (1948) and Basak and Konar (1977). Based on LC_{50} values three sublethal concentrations of sodium arsenite (1, 2 and 3 ppm) were derived to conduct the second (nitric oxide generation) experiment. Each of the second experimental set (1, 2 and 3 ppm) along with control consisted of 10 animals of same age and sex in triplicate forms. Experiment was carried out for 96 hours in static water environment and fresh solutions of sodium arsenite were replenished every 24

hours. Dead crabs were removed immediately from the test medium. Temperature of water was maintained between 26°C – 30°C . Hemolymph was collected aseptically from the base of second appendage of the three different animals in three different Borosilicate containers of same concentration after 24, 48, 72 and 96 hours using a sterile syringe with a 23-gauge needle and was stored in prechilled glass vials with anticoagulant. The volume of collected blood of each animal did not exceed 1ml (Saha and Ray, 2006). Cell viability was estimated with 2% trypan blue following the principle of dye exclusion. Analyses were carried out with cell suspension with greater than 94 % of viable cells. Enumeration of viable immunocytes was carried out microscopically using an improved Neubauer hemocytometer and cell density were adjusted by sterile phosphate buffered saline (PBS, pH 7.4). Generation of NO in hemocytes was assayed spectrophotometrically (CECIL spectrophotometer) by Griess reaction (Green *et al.*, 1982). This reaction involves measurement of nitrite that is one of the primary, stable and nonvolatile breakdown products of NO. Griess reagent system uses sulphanilamide under acidic condition. This system is capable of generating nitrite in variety of biological matrices including serum and cell suspensions. The experiment was repeated for 3 times and the data were interpreted by mean $\pm$ standard deviation and compared in paired Fisher t-test at $P < 0.001$.

RESULTS

Median lethal (LC_{50}) concentration for 96 hours, safe concentration (LC_0) and SAR were 15 ppm, 0.812 ppm and 12.18 ppm respectively. Exposure of *S. serrata* to 1, 2 and 3 ppm of sodium arsenite for 24, 48, 72 and 96 hours resulted in a dose dependent pattern of increase of intrahemocyte NO (Fig. 1). Highest concentration of NO were recorded as 8.83 ± 0.09 , 9.75 ± 0.14 and 18.25 ± 0.25 $\mu\text{M}/10^6$ cells against 1, 2 and 3 ppm of sodium arsenite for 96 hours of exposures respectively (Fig. 1). Generation of NO were lowest as 2.11 ± 0.03 , 2.26 ± 0.06 and 2.71 ± 0.07 $\mu\text{M}/10^6$ cells against 1, 2 and 3 ppm of sodium arsenite for 24 hours

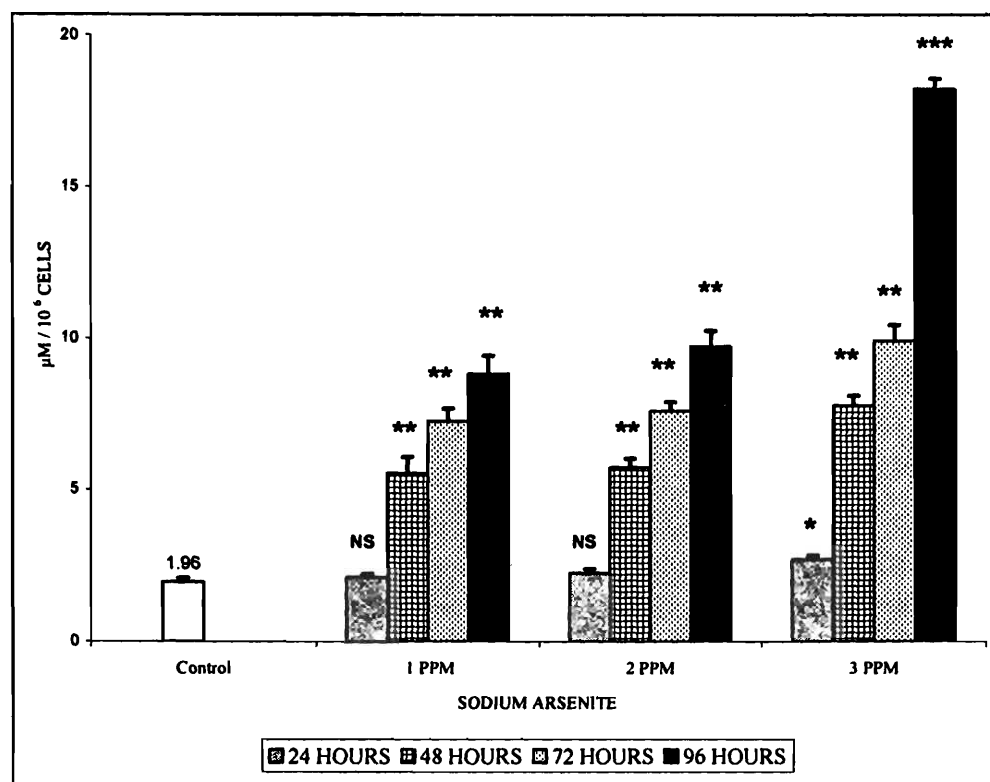


Fig. 1. Intraimmunocyte Nitric Oxide generation under exposure of 1, 2 And 3 Ppm of Sodium Arsenite (*P < 0.05, **P < 0.01, ***P < 0.001, Ns = Not Significant).

of exposures respectively (Fig. 1). Exposures of *S. serrata* to 1, 2 and 3 ppm for 48 and 72 hours of span exhibited intermediate generation of NO against the control value of $1.96 \pm 0.05 \mu\text{M}/10^6$ cells (Fig. 1).

DISCUSSION

The defensive role of reactive nitrogen species in invertebrate was investigated by many workers (Radomski *et al.*, 1991; Yeh *et al.*, 2006) *in vitro*. Immunocytes of invertebrate act as chief effector cells which mediate immunological response under the exposure of parasites and toxins (Ottaviani *et al.*, 1993). Reactive oxygen intermediates are major cytotoxic factor, which is generated, in circulating blood cell in diverse physiological conditions. In this study, generations of nitric oxide were estimated in immunocytes of *S. serrata* under the exposures of 1, 2 and 3 ppm of sodium arsenite for diverse spans of exposures. Exposure to sodium arsenite increased the generation of intraimmunocyte nitric oxide for all three concentrations, which expressed dose dependent response. However, sodium arsenite induced increment of nitric

oxide is indicative of immunostimulation in *S. serrata* inhabiting in contaminated habitat. Natural habitat of the species bears risk of contamination by diverse xenobiotics including arsenic. Arsenic contamination resulted induction of reactive nitrogen species (RNS) in the immunocytes, which is suggestive of increased capability of immunocytes for intracellular killing of pathogen through phagocytosis (Holmblad and Soderhall, 1999). This adaptive response of immunocytes may be considered as cellular stress under the chronic exposure of arsenic in the natural habitat of *S. serrata*. Dose dependent response of immunocytes in generation of nitric oxide is suggestive of the parameter be considered as biomarker of arsenic pollution in Sundarbans delta.

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LITERATURE CITED

- ACHARYYA, S. K. 2002. Arsenic contamination in groundwater affecting major parts of southern West Bengal and parts of western Chattisgarh : Source and mobilization process. *Curr. Sci.*, 82(6) : 740-744.
- BASAK, P. V. and KONAR, S.K. 1977. Estimation of safe concentrations of insecticides, a new method tested on DDT and BHC. *J. Inland Fish. Soc. India*, 9 : 9-29.
- CHAKRABORTY, K. 1986. Fish and fisheries resources in the mangrove swamps of Sundarbans, West Bengal—an in depth study. *Indian Forester*, 112(6) : 538-542.
- GHOSH, M. N. 1984. Fundamentals of experimental pharmacology (Ed : 2nd), pp. 177-190. Scientific Book Agency, Calcutta.
- GOMEZ-CAMINERO, A, HOWE, P, HUGHES, M, KENYON, E, LEWIS, DR, MOOR, M, NAG, J, AITIO, A. and BECKING, G. 2001. Summary in Environmental Health Criteria 224, Arsenic and Arsenic Compounds (Ed : 2nd) : 1-8 : World Health Organization, Geneva.
- GREEN, L. C., WAGNER, D. A., GLOGOWSKI, J., SKIPPER, P. L., WISHNOK, J. S. and TANNENBAUM, S. 1982. Analysis of nitrate, nitrite and (N¹⁵) nitrate in biological fluids. *Anal. Biochem.*, 126 : 131-138.
- HAHN, U. K., BENDER, R. C. and BAYNE, C. J. 2001. Involvement of nitric oxide in killing of *Schistosoma mansoni* sporocysts by hemocytes from resistant *Biomphalaria glabrata*. *J. Parasitol.*, 10 : 778-785.
- HART, W. B., WESTON, R. F. and DEMANN, J. G. 1948. An apparatus for oxygenating test solutions in which fish are used as test animals for evaluating toxicity. *Tran. Am. Fish Soc.*, 75 : 228-239.
- HEASMAN, M. P. and FIELDER, D. R. 1983. Laboratory spawning and mass rearing of the mangrove crab (*Scylla serrata* Forskal), from first zoea to first crab stage. *Aquacult.*, 34 : 303-316.
- HOLMBLAD, T. and SODERHALL, K. 1999. Cell adhesion molecules and antioxidant enzymes in a crustacean, possible role in immunity. *Aquacult.*, 172 : 111-123.
- OTTAVIANI, E., PAEMAN, L. R. P. C. and STEFANO, G. B. 1993. Evidence for nitric oxide production and utilization as a bactericidal agent by invertebrate immunocytes. *Eur. J. Pharmacol.*, 248 : 319-324.
- RADOMSKI, M. W., MARTIN, J. F. and MONCADA, S. 1991. Synthesis of nitric oxide by the hemocytes of the American horseshoe crab (*Limulus polyphemus*). *Philos. Trans. R. Soc. Lon.*, 334 : 129-133.
- RAINBOW, P. S. 1995. Biomonitoring of heavy metal availability in the marine environment. *Mar. Pollut. Bull.*, 31 : 183-192.
- SAHA, S. and RAY, S. 2006. Hemocyte profile of the estuarine mud crab, *Scylla serrata*. *Environ. & Ecol.*, 24S(3A) : 818-819.
- TAFALLA, C., NOVOA, B. and FIGUERAS, A. 2002. Production of nitric oxide by mussel (*Mytilus galloprovincialis*) hemocytes and effect of exogenous nitric oxide on phagocytic functions. *Comp. Biochem. Physiol.*, B 132 : 423-431.
- YEH, F. C., WU, S. H., LAI, C. Y. and LEE, C. Y. 2006. Demonstration of nitric oxide synthase activity in crustacean hemocytes and antimicrobial activity of hemocyte-derived nitric oxide. *Comp. Biochem. Physiol. Biochem. Mol. Biol.*, 144(1) : 11-17.

COMPARATIVE STUDIES OF WATER QUALITY PARAMETERS AND PLANKTON PRODUCTION AFTER THE APPLICATION OF DIFFERENT FERTILIZERS IN CEMENTED AQUACULTURE TANKS AND NATURAL WATER BODIES IN MIDNAPORE, WEST BENGAL

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ABSTRACT

Tremendous pace of development has taken place in different sectors of aquaculture during last couple of decades in order to meet the ever increasing demand of chief protein sources in the form of fishes and other aquatic organisms. An investigation was carried out to assess the efficacy of different fertilizers (vermicompost, cow dung, inorganic fertilizer and vermicompost in combination with inorganic fertilizer) on the environmental quality as well as zooplankton productivity. 15 small-cemented experimental tanks (4' X 4' X 4') were used after applying different types of fertilizers (3 were for vermicompost, 3 were for cow dung, 3 were for chemicals, 3 were for vermicompost in combination with chemical fertilizers and rest three were for control) and 2 natural culturable ponds (1 acre each) were also treated with vermicompost. After the application of both organic and inorganic fertilizers—significant reduction of dissolve oxygen was recorded subsequently (within 24 to 36 hrs). Such application also increased COD and nutrients like total nitrogen and phosphate. Organic inputs considerably decreased water pH and increased in alkalinity, on the other hand inorganic fertilization caused significant increase in pH and alkalinity. The cemented aquaculture tanks treated with inorganic fertilizer showed the development of algal bloom, which was not developed in visible amount in other treatment tanks. The zooplankton communities showed better results in the tanks treated with vermicompost in combination with inorganic fertilizers and also in other fertilizer treated tanks. In natural water bodies, both phytoplankton and zooplankton densities were higher in two vermicompost treated ponds than control.

Keywords : vermicompost, water parameters, zooplankton, fertilizer.

INTRODUCTION

It is known that fishes depend directly or indirectly on plankton for their food (Boney, 1983). Therefore, the study of plankton is necessary in the production of fish. The productivity of any water body is determined by the amount of plankton it contains; thus plankton is of great importance in aquaculture and fisheries. They also play an important role in food chains and food webs. The growth of zooplankton can be induced by the use of fertilizers as it promotes the growth of

phytoplankton, the food of several zooplanktons. Fertilizers are known to supply nutrients required by phytoplankton for primary productivity and they have been reported to increase fish yield 3-4 times (Moses, 1983; Westly, 1984). The quantity of nutrients in a pond plays a major role in determining the amount and quality of plankton (Pearson *et al.*, 1984). Nitrogen was found to be more of a limiting factor in pond productivity in the tropics compared to temperate regions (Henry *et al.*, 1984). In order to develop fresh water

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fisheries and get maximum economical fish yield from limited area, it is essential to use both organic and inorganic fertilizers (Kanwal *et al.*, 2003). Garg and Bhatnagar reported that the effects of five (5000, 10000, 15000, 20000, and 24000 kg/ha/year) different doses of organic fertilizer (cowdung) were studied on the pond productivity in terms of plankton production and fish biomass in fresh water fish ponds.

The recycling of organic wastes for fish culture serves the dual purpose of cleaning the environment (by avoiding the problem of waste disposal) and provide economic benefits. The recycling of animal dung or waste in fish pond for natural fish production is important to sustainable aquaculture and to reduce the expenditure on costly feed and fertilizer which form more than 50% of the total input cost (Dhawan and Kaur 2002). Many studies have been conducted on the development of fish culture technology and the use of organic fertilizers in stillwater pond in India (Choudhury *et al.* 1975; Saha *et al.* 1990; Yadava and Garg 1992; Garg and Bhatnagar 1996; Garg 1996). Few studies have been carried out to determine the fertilizer dosage required in fish ponds for optimum pond productivity and fish production without adversely affecting pond ecology (Hopkins and Cruz 1982; Wolhfarth and Hulata 1987; Garg and Bhatnagar 1996). Nitrogen, phosphorus and occasionally carbon are the limiting nutrients for phytoplankton production in natural waters and also in fish ponds. Organic manures and inorganic fertilizers have been extensively used, either alone or in combination, as nutrient sources in pond fertilization (Sinha and Saha 1980).

The productivity of any water body is determined by the amount of plankton it contains. Thus plankton is of great importance in aquaculture and fisheries. Plankton growth can be induced by the use of fertilizers. Fertilizer (inorganic and organic) application among other things has been used to achieve an increase in the biological productivity of pond. Inorganic fertilizers are more effective than

organic fertilizers; more quantity of organic fertilizers is required to fertilize a pond when compared to inorganic ones (Davies *et al.*, 2006). Increased nutrient concentrations produce algal blooms, which in turn alter concentration of nutrients, gasses, pH, and metal ions in water (Paul *et al.*, 2002).

Cow dung and poultry manures are most commonly used organic manures in pond aquaculture, often used in combination with urea and super phosphate as inorganic nitrogen and phosphorus sources. The conventional dosage followed in the carp culture practice in India usually includes 10-20 t/ha/year cow dung or 3-4 t/ha/year poultry manure alone or in combination with 100 kg/ha urea (approximately) and also in combination with 50 kg/ha super phosphate (approximately) (Das *et al.* 2005). The quantity of nutrients in a pond plays a major role in determining the amount and quality of plankton (Pearson *et al.* 1984). The relative availability of nutrients in aquatic environment is believed to play an important role in the structuring of phytoplanktonic community (Henry *et al.* 1984). Over the last decade, the organic food sector is being seen as one of the most rising industry in the international food market. Most of the aquaculturists apply cattle dung as organic and super phosphate and urea as chemical fertilizers for enriching cultures with nutrients like phosphate and nitrate (Diwan and Ayyappan, 2004).

Although a lot of research works have been done on the utilization of animal manure, in fish culture ponds, particularly farmyard manure, poultry droppings, cowdung and biogas slurry which are suitable substitutes for costly feeds and fertilizers (Schroeder, 1980, Dhawn and Toor 1989), there are few reports on the application of pig dung (Sharma 1988). The present research work was conducted to assess the changes of physicochemical parameters of water as well as zooplankton production after the application of vermicompost and other fertilizers in experimental cemented tanks and in fresh water ponds.

MATERIALS AND METHODS

Selection of study sites

Two fertilizer treated fresh water ponds measuring of 1 acre each were selected. One pond is situated in Keshpur (study site-2) block (87°30' 22°35') and other is located at Gopegarh village (study site-3) (87°20' and 22°25'), near Vidyasagar University Campus (Fig. 1). One pond was kept as control (study site-1) and it was located very near to the fertilizer treated pond of Gopegarh village. Besides, 15 cemented experimental tanks each measuring of 4'×4'×4' at University campus were also utilized for fertilizer treatment, and also to assess different ecological parameters of water as well as biological parameters. Among 15-cemented tanks, 3 were for vermicompost (T₂), 3 were for chemicals (T₃), 3 were for cowdung (T₄), 3 were for vermicompost in combination with chemical fertilizers (T₅) and rest 3 tanks were kept as control tank (T₁).

Standardization of dose

To study the impact of different fertilizers on changes of physicochemical parameters as well as zooplankton production, different doses of both organic and inorganic fertilizers were applied. Before the introduction of vermicompost as fertilizer, only nitrogen content of vermicompost was estimated. Amount of nitrogen present in vermicompost was considered as standard and on this basis, the dose of other fertilizers were determined and applied (Table-1). Vermicompost was applied at the rate of 10 t/ha/year both in

experimental tanks as well as in natural ponds. Other fertilizers such as cow dung (at the rate of 15 t/ha/year), inorganic fertilizers (at the rate of 360 kg/ha/year of urea and 290 kg/ha/year of single super phosphate) and vermicompost in combination with inorganic fertilizers (5 t/ha/year of vermicompost + 180 kg/ha/year urea +145 kg/ha/year single super phosphate) in the experimental tanks at University Campus were applied. 50% of these desirable doses were applied during early of March, 2006 as first dose and the rest 50% were applied in the month of September, 2006 just after six months of first dose.

Monitoring of physicochemical parameters of water

Monthly samplings of different fertilizer treated water tanks have been made from 15 cemented tanks and also from natural fresh water fertilizer treated as well as control ponds. The water samples have been analyzed for estimating different physicochemical parameters [Temperature, Transparency, pH, Alkalinity, Conductivity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN), Total Phosphate Phosphorus (TPP),] of water following standard methods (APHA, 2005; FAO, 1976; Trivedy and Goel, 1984) and with the help of water quality checker (TOA, model No-WQC22A, Japan).

Sampling, Collection, Identification and Quantification of Zooplankton

The zooplankton samples were collected at monthly intervals (Sharma, 2001) after the

Table-1. Nutrient status of vermicompost and cow dung.

Parameters	Nutrient status of Vermicompost	Nutrient status of cow dung
pH	7.2	7.2
Organic carbon (%)	15.4	39.4
Total Kjeldahl Nitrogen (%)	1.65	1.1
Total Potassium (%)	1.2	2
Total Phosphorous (%)	0.92	0.42
C/N ratio (%)	11.24	35.82

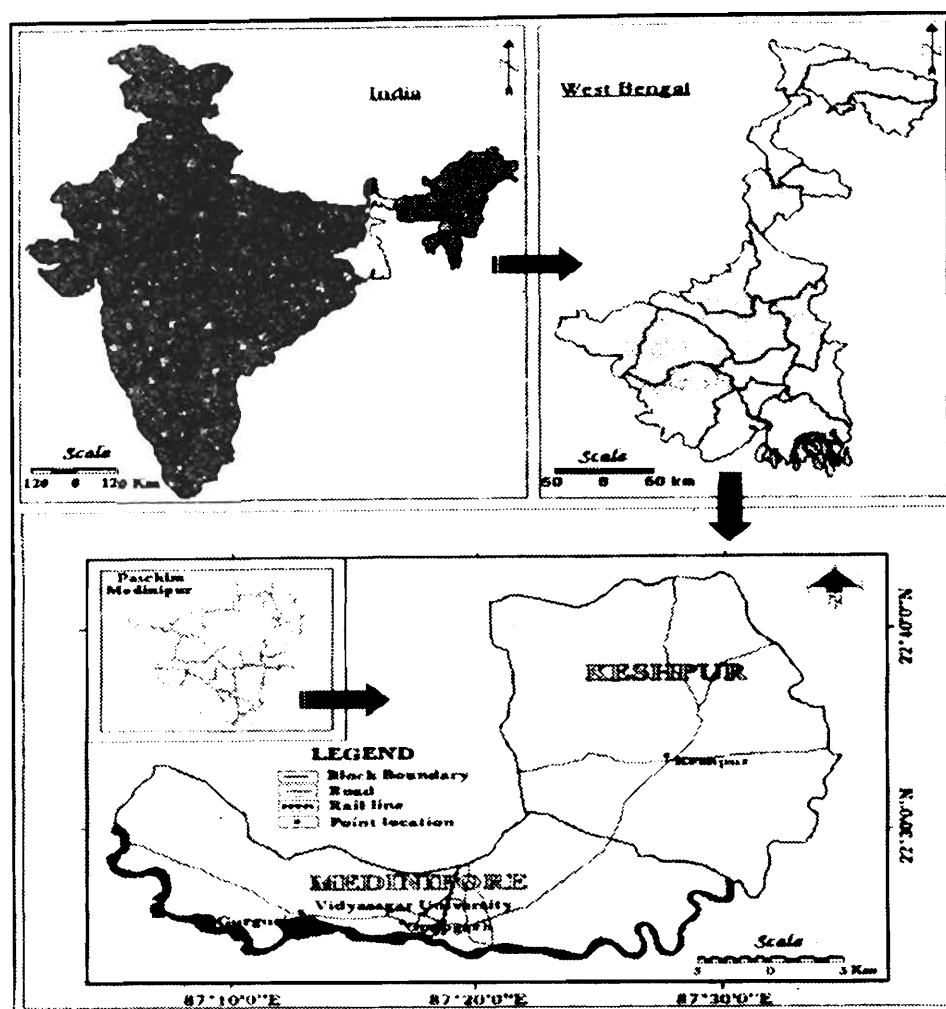


Fig. 1. Map showing the location of study area.

application of vermicompost in selected ponds. Different types of fertilizers as mentioned above were also applied in cemented tanks and the zooplankton samples were also collected from those treated tanks and also from tanks kept as control. Zooplankton samples were collected by filtering 100 liters of water through the bolting nylon cloth (NO.-25, mesh size -54 μ) and were preserved in 5% buffered formalin (APHA, 2005). The zooplankton species were identified following Michael and Sharma 1988; Sharma 2001; Needham and Needham 1962; Edmondson 1959; Reddy 1994; and Battish 1992. "Sedgwick Rafter Counting Cell" was used for enumerating monthly population density (No./L).

RESULTS AND DISCUSSION

Physico-chemical characteristics of pond water

Application of different fertilizers (vermicompost, cow dung, urea and single

super phosphate) in different selected natural water bodies (study site-1, study site-2 and study site-3) as well as in cemented experimental water tanks (T_1 , T_2 , T_3 , T_4 and T_5) have triggered a series of changes of physicochemical and biological parameters. Such changes are in accordance with changing environmental conditions of different months. The minimum Dissolved Oxygen (3.8 mg/l) was observed in the cemented experimental tanks (T_2) treated with vermicompost in May, 2006 and the maximum (9.6 mg/l) was observed in August, 2006 in cemented control tanks (T_1). In natural fresh water bodies, minimum Dissolved Oxygen (4.6 mg/l) was observed in May, 2006 in pond treated with vermicompost (study site-3) and that of maximum (9.39 mg/l) was observed in June, 2006 in control pond (study site-1). These results showed that Dissolved Oxygen was decreased after the application of fertilizers and such

results were in tune with the findings of Garg and Bhatnagar, 1999. Dissolved oxygen (DO) being a major ecological parameter imparts significant role on respiration of different biotic organisms. It controls directly or indirectly many limnological parameters of aquatic ecosystem, and determines the occurrence and abundance of rotifer communities (Dhanapathi 2000). Hofmann (1977) determined oxygen concentration as to be an important factor in determining seasonal, horizontal and vertical variations of rotifers. Total Kjeldahl Nitrogen (TKN) was maximum (5.26 mg/l) in March, 2006 in experimental cemented tanks (T_5) treated with vermicompost in combination with inorganic fertilizers and that of minimum (1.06 mg/l) was in September, 2006 in cemented experimental control tanks (T_1). In natural fresh water bodies, maximum Total Kjeldahl Nitrogen (4.6 mg/l) was recorded in pond treated with vermicompost (study site-2) in March, 2006 and that of minimum (1.28 mg/l) was observed in February, 2007 at the same study site. Total phosphate phosphorus (TPP) was maximum (4.83 mg/l) in the month of October, 2006 in chemical fertilizer treated cemented experimental tanks (T_3) and that of minimum (0.56 mg/l) was observed in the month of July, 2006 in cemented experimental control tanks (T_1). In natural fresh water bodies, minimum total phosphate phosphorus (0.13 mg/l) was recorded in the month of January, 2007 in control pond (study site-1) and that of maximum (2.38 mg/l) was observed in vermicompost treated pond (study site-2) in April, 2006. In natural fresh water bodies, pH showed highest value (9.6) in vermicompost treated pond (study site-3) in November, 2006 and lowest value (5.4) of pH was recorded in September and October, 2006 in control pond (study site-1). Maximum pH (9.6) was observed in the month of December, 2006 in vermicompost in combination with inorganic fertilizer treated cemented experimental tanks (T_5) and minimum (6.2) value of pH was observed in the month of March, 2006 in cemented experimental control tanks (T_1). Alkalinity was maximum (225 mg/l) in the month of January, 2007 in a tank treated with

vermicompost in combination with inorganic fertilizers (T_5) and minimum alkalinity (70 mg/l) was recorded for several months in cemented control tanks (T_1). In natural freshwater pond, alkalinity was maximum (155 mg/l) in the month of September, 2006 in vermicompost treated pond (study site-3) and alkalinity registered minimum value (65 mg/l) for several months in control pond (Study site-1). Highest Biological Oxygen Demand (4.62 mg/l) was recorded in the month of February, 2007 in experimental cemented tank (T_5) treated with vermicompost in combination with inorganic fertilizers and that of lowest value (1.96 mg/l) was recorded in the month of June, 2006 in chemical fertilizer treated cemented experimental tanks (T_3). In natural freshwater bodies, maximum Biological Oxygen Demand (3.63 mg/l) was estimated in May, 2006 in pond treated with vermicompost (study site-2) and that of minimum (1.22 mg/l) was recorded in May, 2006 in vermicompost treated pond (study site-3). In natural freshwater bodies, chemical oxygen demand was maximum (143 mg/l) in the month of December, 2006 in the pond treated with vermicompost (study site-3) and minimum value (37 mg/l) was recorded in February, 2006 in control pond (study site-1). In experimental cemented tanks, maximum chemical oxygen demand (178 mg/l) was observed in cow dung treated tanks (T_4) in January, 2007 and minimum value (42 mg/l) was observed in control tanks (T_1) in October, 2006. Temperature did not display any significant variation with the application of fertilizers (Table-2).

Zooplankton Production

Rotifera, Copepoda and Cladocera represented the zooplankton community of all the studied freshwater bodies whether treated or nontreated with fertilizers. Besides, some other faunal groups like ostracoda, protozoa, nematoda and juvenile stages of some crustaceans marked their scanty appearance. Rotifera were most abundant zooplanktonic group followed by Copepoda and Cladocera in cemented aquaculture tanks as well as in natural freshwater ponds treated with

Table-2. Changes of different physico-chemical and biological parameters of water after being treated with different fertilisers during the study period (Mean $\pm$ S.E., Range)

	TEMP	pH	DO	BOD	COD	ALKA	TKN	TPP	ROTI	COPE	CLADO	Others
Site-1	24.6 $\pm$ 1.40 19.0-34.0	8.6 $\pm$ 0.18 7.8-9.6	5.8 $\pm$ 0.19 4.6-6.8	2.2 $\pm$ 0.16 1.2-3.4	132.9 $\pm$ 3.15 115.0-146.0	137.5 $\pm$ 3.05 120.0-155.0	3.2 $\pm$ 0.19 2.2-4.6	1.2 $\pm$ 0.09 0.8 -1.8	38.40 $\pm$ 5.84 12.30- 69.32	49.61 $\pm$ 1.81 37.46- 57.47	14.38 $\pm$ 1.50 7.82- 23.17	4.06 $\pm$ 0.46 2.13- 7.24
Site-2	24.88 $\pm$ 1.19 18.00-30.50	7.33 $\pm$ 0.20 6.40-8.30	7.68 $\pm$ 0.32 6.20-9.39	2.42 $\pm$ 0.22 1.29-3.60	45.58 $\pm$ 1.72 37.00-56.00	71.67 $\pm$ 1.88 65.00-85.00	2.26 $\pm$ 0.08 1.86-2.86	0.39 $\pm$ 0.13 0.12-1.75	340.25 $\pm$ 27.56 134.50- 469.34	304.61 $\pm$ 24.55 198.25- 472.25	63.32 $\pm$ 8.22 23.31- 132.23	8.58 $\pm$ 0.84 4.25- 13.12
Site-3	24.9 $\pm$ 1.47 19.0-34.0	7.9 $\pm$ 0.14 7.2-8.6	5.8 $\pm$ 0.15 4.8-6.4	3.0 $\pm$ 0.11 2.4-3.6	124.6 $\pm$ 3.77 107.0-146.0	127.1 $\pm$ 4.01 110.0-145.0	2.9 $\pm$ 0.27 1.3-4.7	1.7 $\pm$ 0.17 0.4 -2.4	454.32 $\pm$ 32.61 243.05- 598.62	156.70 $\pm$ 13.48 102.35- 246.35	68.15 $\pm$ 7.45 36.82- 127.23	11.42 $\pm$ 1.71 4.23- 24.25
Tank-1	24.88 $\pm$ 1.26 18.50-31.50	6.93 $\pm$ 0.14 6.20-7.60	7.76 $\pm$ 0.33 6.40-9.60	3.15 $\pm$ 0.25 1.96-4.40	49.17 $\pm$ 1.57 42.00-56.00	76.67 $\pm$ 1.55 70.00-85.00	1.38 $\pm$ 0.06 1.06-1.82	0.83 $\pm$ 0.05 0.56 -1.06	10.29 $\pm$ 1.23 4.46-17.24	24.58 $\pm$ 1.69 17.28 -39.21	12.77 $\pm$ 1.75 6.00 -24.23	4.93 $\pm$ 0.73 2.14 -11.20
Tank-2	25.29 $\pm$ 1.31 18.50-32.00	8.18 $\pm$ 0.17 7.30-9.40	5.58 $\pm$ 0.30 3.80-7.40	3.08 $\pm$ 0.10 2.64-3.62	145.75 $\pm$ 2.61 132.00-161.00	150.00 $\pm$ 3.14 135.00-165.0	3.26 $\pm$ 0.19 2.16-4.34	1.94 $\pm$ 0.12 1.24 -2.60	308.07 $\pm$ 34.17 16.60 -432.24	288.81 $\pm$ 37.02 27.31 -534.27	153.98 $\pm$ 17.33 9.00-246.32	1.62 $\pm$ 1.30 3.40 -19.24
Tank-3	24.54 $\pm$ 1.27 18.50-31.00	7.88 $\pm$ 0.20 6.80-9.20	7.59 $\pm$ 0.29 6.40-9.60	3.15 $\pm$ 0.25 1.96-4.40	163.08 $\pm$ 2.71 147.00-178.00	159.58 $\pm$ 1.68 150.00-170.0	3.19 $\pm$ 0.25 2.40-4.80	2.84 $\pm$ 0.18 1.86 -4.38	220.94 $\pm$ 28.54 46.32 -437.31	136.40 $\pm$ 10.49 34.30 -174.23	116.94 $\pm$ 10.91 17.30 -162.34	10.99 $\pm$ 1.10 6.25 -16.52
Tank-4	24.54 $\pm$ 1.27 18.50-31.00	7.64 $\pm$ 0.13 6.80-8.40	6.46 $\pm$ 0.34 4.21-8.20	2.92 $\pm$ 0.14 2.02-3.68	137.92 $\pm$ 11.67 38.00-172.00	148.33 $\pm$ 2.71 135.00-165.0	3.18 $\pm$ 0.16 2.46 -4.02	1.28 $\pm$ 0.04 1.08 -1.48	327.11 $\pm$ 36.24 46.61 - 542.31	135.57 $\pm$ 11.24 24.32 -174.23	126.20 $\pm$ 14.41 12.30 -183.24	11.78 $\pm$ 1.08 6.25 -18.25
Tank-5	24.54 $\pm$ 1.27 18.50-31.00	8.05 $\pm$ 0.21 7.24-9.60	6.51 $\pm$ 0.46 3.98-8.60	3.06 $\pm$ 0.22 2.18-4.62	146.08 $\pm$ 9.68 46.00-178.00	175.00 $\pm$ 7.46 145.00-225.0	3.64 $\pm$ 0.28 2.46-5.26	2.65 $\pm$ 0.10 2.08 -3.42	327.66 $\pm$ 40.71 64.23 -587.30	143.65 $\pm$ 16.32 42.40 -248.36	78.65 $\pm$ 12.01 21.40 -142.37	12.77 $\pm$ 1.22 7.42 -18.36

Site-1 = Gopegarh Control Pond., Site-2 = Keshpur (vermicompost treated pond), Site-3 = Gopegarh (vermicompost treated pond),
 Tank-1 = Control, Tank-2 = vermicompost treated, Tank-3 = chemical fertilizer treated, Tank-4 = cowdung treated, Tank-5 = vermicompost in combination with
 hemical fertilizer.

Table-3. Multiple Correlation analysis between different physico-chemical and biological parameters

	Temp	pH	DO	BOD	COD	Alka	TKN	TPP	Roti	Cope	Clado	Others
Temp	1.000											
pH	-0.145	1.000										
DO	-0.204	-0.349	1.000									
BOD	-0.256	-0.005	0.087	1.000								
COD	-0.006	0.491*	-0.363	0.045	1.000							
ALKA	-0.016	0.534**	-0.302	0.128	0.848**	1.000						
TKN	0.229	0.315	-0.463*	0.0003	0.634**	0.591**	1.000					
TPP	0.099	0.274	-0.154	0.311	0.666**	0.691**	0.565**	1.000				
Roti	-0.031	0.509**	-0.597**	-0.037	0.593**	0.606**	0.449*	0.346	1.000			
Cope	-0.180	0.365	-0.425*	0.106	0.467*	0.423*	0.214	0.299	0.594**	1.000		
Clado	-0.126	0.319	-0.314	0.099	0.592**	0.611**	0.284	0.430*	0.586**	0.611**	1.000	
Others	-0.114	0.333	-0.155	0.052	0.522**	0.594**	0.304	0.355	0.550**	0.361	0.504**	1.000

** Correlation is significant at the 0.01level (2- tailed)

* Correlation is significant at the 0.05 level (2- tailed)

vermicompost (study sites-2 and 3). The maximum density (1053 no/l) of zooplankton was observed in the tanks treated with vermicompost in combination with inorganic fertilizers (T_3) in November, 2007 and that of minimum (43.66 no/l) was observed in cemented control tank (T_1) in October, 2006. In natural water bodies, maximum density of zooplankton (940.1 no/l) was noted in November, 2006 at study site-3 whereas that of minimum abundance of zooplankton (65.2 no/l) was recorded in July, 2006 in control pond (study site-1). A total of 15 species of rotifera, 5 species of copepoda and 5 cladoceran species constituted the zooplankton community (Table-4).

A multiple correlation (Table-3) analysis revealed highly significant interrelationship among different variables. Dissolved oxygen (D.O.) was found to show significant negative correlation with total Kjeldhal nitrogen, rotifer and copepoda population (Fig-2). pH displayed significant positive correlation with alkalinity (Fig-3) and rotifer population. Chemical Oxygen Demand (COD) enjoyed significant positive correlation with alkalinity, total Kjeldhal nitrogen, total phosphate phosphorus, rotifer, copepoda and cladoceran population. Alkalinity revealed significant positive correlation with total Kjeldhal nitrogen, total phosphate phosphorus, rotifer, copepoda and cladoceran population. Total Kjeldhal nitrogen displayed significant positive correlation with total phosphate phosphorus and rotifer population. Total phosphate phosphorus showed significant positive correlation with cladocera population. Rotifera population expressed significant positive correlation with copepoda and cladocera population. Copepoda enjoyed significant positive correlation with cladocera population. Temperature and BOD did not reveal any significant correlation with physicochemical and biological parameters of water.

In this context, it can be concluded that the application of chemical fertilizers along with vermicompost showed better results with

regard to the enhancement of nutrients which in turn lead to the higher production of zooplankton. However, in vermicompost treated ponds (study sites-2 and 3) it was observed that increase in the rotifer population was more pronounced just after the application of vermicompost than other zooplankton community.

Table-4. Zooplankton species observed from different study sites during the study period

Rotifera Species

Family ASPLANCHNIDAE

1. *Asplanchna priodonta* Gosse, 1850

Family BRACHIONIDAE

2. *Brachionus angularis* Gosse, 1851
 3. *B. bidentata bidentata* Anderson, 1889
 4. *B. calyciflorus f. anuraeiformis* (Brehm, 1909)
 5. *B. falcatus* Zacharias, 1893
 6. *B. patulus patulus* Muller, 1776
 7. *B. quadridentatus quadridentatus* Hermann, 1783
 8. *B. rubens* Ehrenberg, 1838
 9. *Keratella cochlearis* (Gosse, 1851)
 10. *Keratella tropica* Apstein, 1907
- Family LECANIDAE
11. *Lecane (L) luna luna* (Muller, 1773)
 12. *L. (L) papuana* (Murray, 1913)
 13. *Lecane (Monostyla) bulla* (Gosse, 1851)
- Family FILINIDAE
14. *Filinia longiseta* (Ehrenberg, 1834)
 15. *F. terminalis* (Plate, 1886)

Cladocera Species

Family ALONINAE

1. *Alona* sp.

Family BOSMINIDAE

2. *Bosmina* sp.

Family DAPHNIDAE

3. *Daphnia lumholtzi*

Family MACROTHRICIDAE

4. *Macrothrix* sp.

Family MOINIDAE

5. *Moina micrura*

Copepoda Species

Family DIAPTOMIDAE

1. *Heliodiaptomus viduus*

Family CYCLOPIDAE

2. *Eucyclops* sp.
3. *Mesocyclops* sp.
4. *Microcyclops varicans*
5. *Nauplius* larvae

Others

Zooplankton Includes –protozoa, ostracoda, nematodes and crustacean larvae

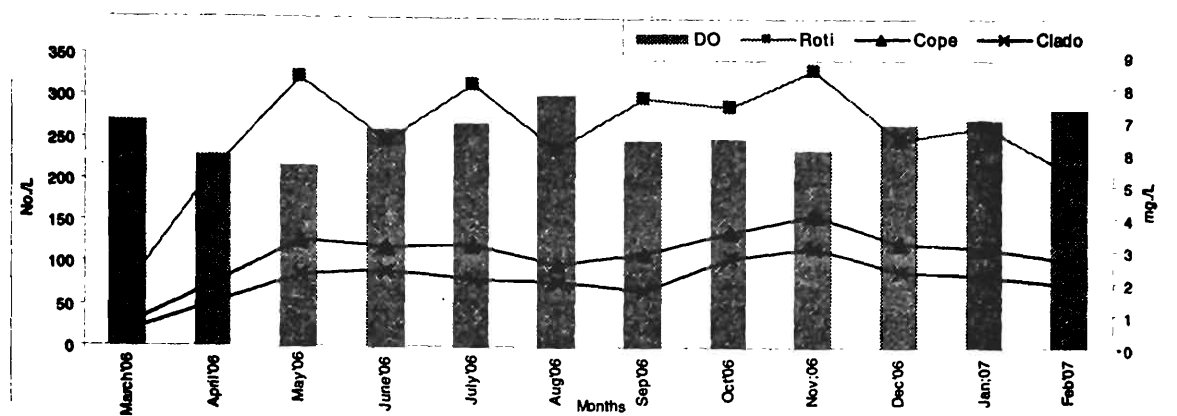


Fig. 2. Relationships between abundance of Rotifer, Copepod and Cladocera with dissolved oxygen of water.

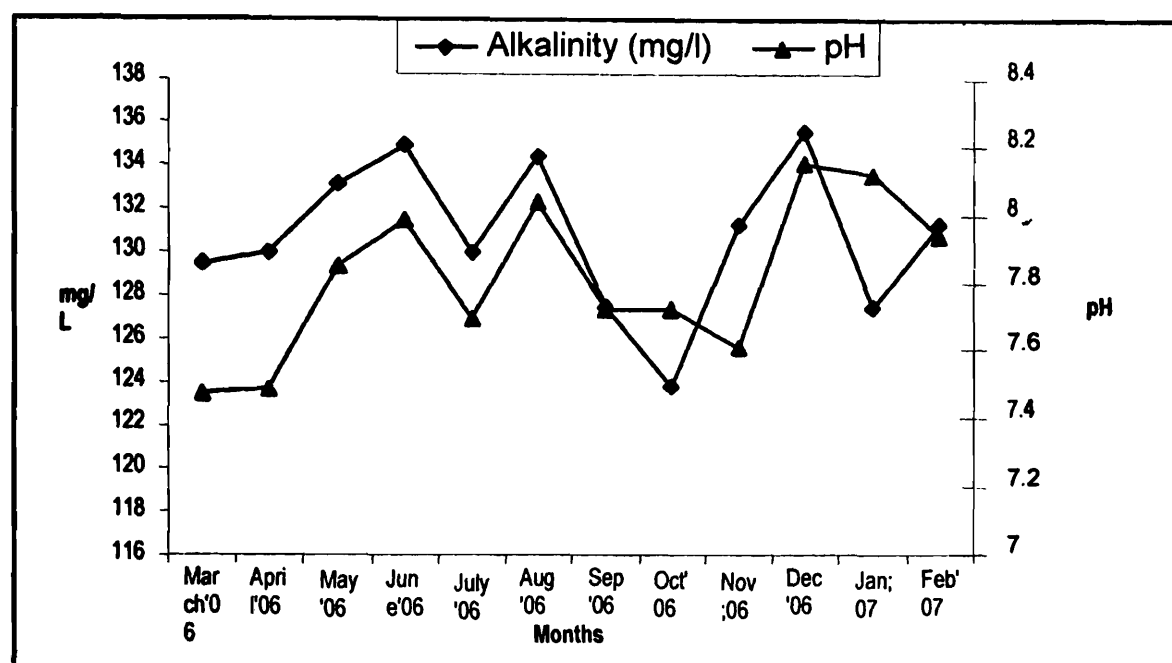


Fig. 3. Relationship between pH and Alkalinity of water

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LITERATURE CITED

- APHA. 2005. Standard methods for the examination of water and wastewater. *American Water Works Association and water environmental Federation*, 21th Edition .Washington DC. 2000. 1-3710.
- BATTISH, S. K. 1992. *Fresh water zooplankton of India*. Oxford and IBH publishing Co., New Delhi.
- BONEY, A.D. 1983. *Phytoplankton*. The Institute of Biology's Studies in Biology. Edward Arnold Publishers Limited, London, U.K. 52 : 15
- CHAUDHURY, H., CHAKRABORTY, R.D., SEN, P. R., RAO, N.G.S. and JENA, S. 1975. A new high in fish production with records yield by composite fish culture in freshwater pond. *Aquaculture*, 6 : 343-355.
- DAS, P.C., AYYAPPAN, S. and JENA, J. 2005. Comparative changes in water quality and role

- of pond soil after application of different levels of organic and inorganic inputs. *Aquaculture Research*, **36** : 785-798.
- DAVIES, O.A. ALFRED-OCKIYA, J.F. and ASELE, A. 2006. Induced growth of phytoplankton using two fertilizers (NPK and agrolyser) under laboratory conditions. *African Journal of Biotechnology*, **5**(4) : 373-377.
- DHANAPATHI, M.V.S.S.S. 2000. *Taxonomic notes on the rotifers from India* (from 1889-2000). Published by Indian Association of Aquatic Biologists. Hyderabad, A.P. India, 31-32
- DHAWN, A. and TOOR, H. S. 1989. Impact of organic manure and supplementary diet on plankton production and fish growth and fecundity of an Indian major carp, *Cirrhinus mrigala* (Ham) in fish pond. *Biol. Waste*, **29** : 289
- DHAWAN, A. and KAUR, S. 2002. Pig dung as pond manure: Effect of water quality, Pond productivity and growth of carps in polyculture system. *Naga, The ICLARM Quarterly*, **25**(1) : 11-13.
- DIWAN, A. D. and AYYAPPAN, S. 2004. Organic fish farming. *Fishing Chimes*, **6** : 11-13.
- EDMONDSON, W.T. 1959. Rotifera. In : Fresh Water Biology. Ed : W.T. Edmondson. John Wiley & Sons, Inc. New York, London. 420-494.
- FAO. 1976. Physical and Chemical Method of Soil and Water Analysis. Soil bulletin No. 10. Food and Agriculture Organization of the United Nation, 1-275.
- GARG, S.K. 1996. Brakish water carp culture in potentially water logged areas using animal wastes as pond fertilizer. *Aquaculture International*, **4** : 143-155.
- GARG, S. K. BHATNAGAR, A. 1996. Effect of varying doses of organic and inorganic fertilizers on plankton production and fish biomass in brackish water fish ponds. *Aquacult Res.*, **27** : 157-166.
- GARG, S. K. and BHATNAGAR, A. 1999. Effect of different dose of organic fertilizer (Cow dung) on pond productivity and fish biomass in still water ponds. *J. Applied. Ichthyology*, **15** : 10-18
- HENRY, R., TUNDISI, U. and GURI, P.R. 1984. Effect of enrichment on phytoplankton in Tropical Reservoir (Lobo reservoir, Brazil). *Hydrobiologia*, **118** : 177-185
- HOFMANN, W. 1977. The influence of abiotic factors on population dynamics in planktonic rotifers. *Arch. Hydrobiol. Beih., Ergebn. Limnol.*, **8** : 77-83.
- HOPKINS, K.D. and CRUZ, E.M. 1982. The ICLARM-CLSU integrated animal fish farming project : final report. *ICLARM Tech. Rep.*, **5** : 1-96.
- KANWAL, S. AHMED, I. AFZAL, M. SUGHRA, F. and ABBAS, K. 2003. Comparison of Fresh and Dry Cowdung Manuring on Growth performance of Major Carps. *International J. Agri. and Bio.*, **3** : 313-315.
- MICHAEL, R. G. and SHARMA, B.K. 1988. Indian Cladocera. (Crustacea : Branchiopoda : Cladocera). Fauna of Indian and adjacent countris Series, 262 pp Publ. *Zoological Survey of India*, India.
- MOSES, B. S. 1983. Introduction to tropical fisheries, studies in the biology of Africa Ibadan University Press. 117.
- NEEDHAM, J.G. and NEEDHAM, P R. 1962. A guide to the study of fresh water biology. Published by Holden-Day, Inc. San Francisco, 1-108.

- PAUL, C. P. CAROL, L.F. CELIA, B. K. and JOEL, D. BHUM. 2002. Algal blooms reduce the uptake of toxic methylemercury in freshwater food webs. *Proc. of the National Academy of Science of the United States of America*, **99**(7) : 4419-4423.
- PEARSON, T.R. TAKAHASHI, M. and HARGARE. 1984. *Biological Oceanography* 3rd edition. 380.
- REDDY, Y.R. 1994. Copepoda : Calanoida : Diaptomidae : Guide to the identification of the micro invertebrates of the continental waters of the world. Coordinating Ed: H.J.F. Dumont. SPB Academic Publishing. 1-221.
- SAHA, G.N., CHATTERJEE, D.K. SALVARAJ, C., 1990. Impact of fertilization on production enhancement in tropical still water fish culture. *Proc. FAO-EIFAC Symp. on production enhancement in still water pond culture*, 180-186.
- SCHRODER, G. L. 1980. Fish farming in manure loaded ponds. In : R.S. V. Pullin and Z. H. Shehadeh (eds) *Integrated agriculture aquaculture farming system*, ICLARM Conf. Proc. 4, International centre for graduate study and research in agriculture colleges, Los Banos Laguna, Philipines, 73-86.
- SHARMA, B. K. 1988. Fish culture integrated with various system of live stock farming I. Fish-cum-Pig. II. Fish-cum-Duck. III. Fish-cum-Poultry. IV. Fish-cum-Cattle. Compendium of lecture No. 2 of Training Programme on Integrated Fish Farming. 12-31 January, 1989. CIFA (ICAR), Bhubenaswar.
- SHARMA, B.K. 2001. Biomonitoring and role of Rotifera. In : *Water quality Assessment, Biomonitoring and Zooplankton Diversity* (Ed. B.K. Sharma, Department of Zoology, NEHU, Shillong) 83-95.
- SINHA, M. and SAHA, P.K. 1980. Efficacy of commercial fish feed for composite fish culture. *Journal of Inland Fisheries Society of India*, **12** : 51-55.
- TRIVEDY, R.K. and GOEL, P.K. 1984. *Chemical and Biological methods for water quality studies*. Published by Environmental Publication, Karad-415110. 1-215.
- WESTLY, R. R. 1984. *Fish Pond Management* : 27-41.
- WOLHFARTH, G. W. and HULATA, G. 1987. Use of manures in aquaculture. In : D.J.W. Moriarity and R.S.V. Pullin (eds) *Detritus and Microbial Ecology in Aquacultural*. ICLARM. Conf. Proc., **14** : ICLARM Manila : 353-367.
- YADAVA, N.K. and GARG, S.K. 1992. Relative efficacy of different doses of organic fertilizer and supplement feed utilization under intensive fish farming. *Bioresource Technology*, **42** : 61-65.

FIRST REPORT OF AN UNUSUAL AND UNIQUE ASSOCIATION OF INSECT-MITE-FUNGI WITHIN GALL-LIKE OUTGROWTHS ON AN IMPORTANT MEDICINAL AND TIMBER YIELDING PLANT, SAMANEA SAMAN (JACQ.) MERRILL. J. WASH. (FAM. MIMOSACEAE) IN SUNDARBANS REGION OF WEST BENGAL

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ABSTRACT

The present paper reports for the first time in the world the occurrence of an unusual and unique association of insect-mite and fungi with gall-like irregular outgrowths, on the twigs of an important medicinal and timber yielding plant, viz. *Samanea saman* (Jacq.) Merr. J. Wash. (Fam. Mimosaceae), at Kakdwip area under Sundarbans Biosphere Reserve during November 2006 to February 2007. Those outgrowths appeared to be whitish in the beginning but later turned reddish brown and got covered with cottony fuzz—like material. The infested twigs dried up and defoliated. The gall-like outgrowths when crushed between fingers yielded blood-red stain. Though the matured galls had no insect or any other organism within it, the dusty material, formed by crushing of gall—like outgrowths, when mounted (in Heinze's medium) and examined under microscope revealed the occurrence of one scale insect [*Dactylopius indicus* (?)], the role of which in causing formation of gall—like outgrowth is unknown. The infested twig also harboured 3 species of fungi, viz. *Erysiphe* sp., *Fusarium* sp. and *Bipolaris* sp., which might have grown on the twig due to secretion of honeydew by the insect. Further, the fungal growth invited 2 species of fungal feeding mites, viz. *Tyrophagus putrescentiae* (Schrank) and *Acarus siro* Linn. which in turn, invited one predatory mite, *Cheyletus malaccensis* Oudemans, which fed upon the former two mite species. From this preliminary investigation, it is rather difficult to throw any light as to the role of the individual species in causing gall-like outgrowths on the twigs and hence detailed in-depth study is needed for drawing further inference. Nevertheless, this sort of association appears to be indeed unique and interdependable and is reported here for the first time in the world.

Keywords : *Samanea saman*, Mimosaceae, Insect-mite-fungi, Fungal-feeding mite, Predator mite, Coccid, Gall, new report

INTRODUCTION

Samanea saman (Jacq.) Merr. J. Wash., belonging to the Family Mimosaceae is widely distributed in the Tropics and is used as a medicinal plant in Venezuela as root decoction in hot bath for stomach cancer. The other traditional uses of different parts of this plant

include its use in cold, headache, intestinal ailments, stomachache, diarrhoea, sore throat, etc. Besides, it is renowned for being a source of timber that can be further utilized to make furniture (Prain, 1903; Naskar, 1993). It also serves as a source of fodder, beverage, etc. In Thailand, this tree is used as food source of lac insect. Most of the uses of this plant are evident

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from outside India. However, within India, its uses are not that popular in spite of its abundance.

Recently, the first author, while surveying the medicinal plants in the Sundarbans region, observed in Bhubannagar village of Kakdwip (35 km south of Kolkata), 24 Pgs. (S), few trees of *Samanea saman* bearing heavy gall-like swellings and encrustations on its uppermost branches [Fig.1]. Those were whitish in the beginning and covered with white cottony fuzz-like material but later turned brown [Fig.2]. Unlike the fresh healthy twigs, the infested twigs were seen to be drying up slowly and eventually were defoliated. The leaflets on the infested twigs ultimately turned blackish and were covered with black powdery mass [Fig.3]. Besides the twigs and leaflets of *Samanea saman*, leaves of other shrubs and trees, viz. *Hibiscus rosa-sinensis* (China rose), *Tamarindus indica* L. (Tamarind), *Azadirachta indica* A.Juss. (Neem), *Cocos nucifera* L. (Coconut) and *Phoenix dactylifera* (Date palm) growing in its vicinity, showed such similar blackening. The gall-like outgrowths in *Samanea saman* when crushed between fingers yielded a blood red stain having long term retentivity. This type of infestation was seen during summer month when there was extreme humidity and it continued till monsoon, post monsoon and early winter. Enquiry with the local residents revealed that some outside agencies were looking for such infested twigs with the intention of selling those at a high price though the purpose for which those were used were not known to them.

So, in order to detect, identify the cause of the gall-like outgrowth formations and determine the reason for their exploitation, such infested twigs were collected and brought to the laboratory for further examination.

MATERIAL AND METHODS

The infected twigs, when examined under stereobinocular microscope revealed no insect or other organism within the matured galls.

But the dust-like substances accumulated in the polythene bags where the herbarium sheets of the infested twigs were kept, when examined after mounting in Heinze's medium revealed a complex association of insect, mite and fungi. The insects were light brownish but after mounting in the mounting medium turned bright scarlet brown. The black powdery substance on the leaflets of *Samanea saman* as well as on leaves of the other plants as mentioned above were cultured in a standard media to detect the presence of any fungus.

RESULT

The insect species which has been found abundantly belonged to the soft scale insect *Dactylopius indicus* (?) (Dactylopiidae : Coccoidea) [Fig. 4]. Besides the insect, there were 3 species of fungi which had grown on the infested twigs namely *Erysiphe* sp. (Erysiphaceae), *Fusarium* sp. (Hypocreaceae) and *Bipolaris* sp. (Pleosporaceae). It is known that *Erysiphe* sp. is the pathogen causing Powdery Mildew disease in many agricultural crops. In addition to insect and fungi, there were 3 species of mites namely, *Tyrophagus putrescentiae* (Schrank) [Fig.5] and *Acarus siro* Linn. (Acaridae: Astigmata: Acari) [Fig.6] and the predatory mite, *Cheyletus malaccensis* Oudemans (Acari: Prostigmata: Cheyletidae).

DISCUSSION

The role of the insect-*Dactylopius indicus* (?), if any, in causing the symptoms as described is not known with certainty. In the initial stage, the white color on twigs is due to the presence of a scale insect. The secretion of honey dew by the insect has invited some fungal growth. The mites associated with the insects include *Tyrophagus putrescentiae* (Shrank) and *Acarus siro* Linn. both of which are fungal feeders and probably feed on the fungi grown on the infected twigs and leaflets. The predatory mite, *Cheyletus malaccensis* Oudemans undoubtedly fed on the fungal feeding mites. The above observation therefore reveals that the gall-like formations on the twigs and the honey dew

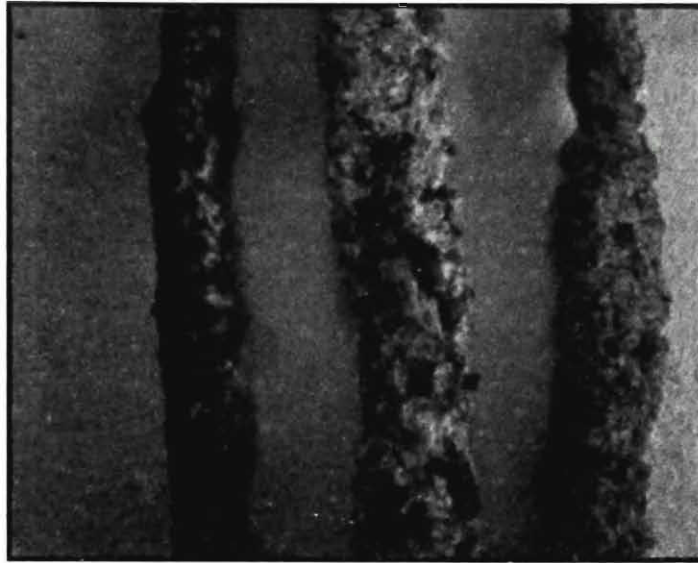


Fig. 1. Gall-like outgrowths on uppermost branches of *Samanea saman*

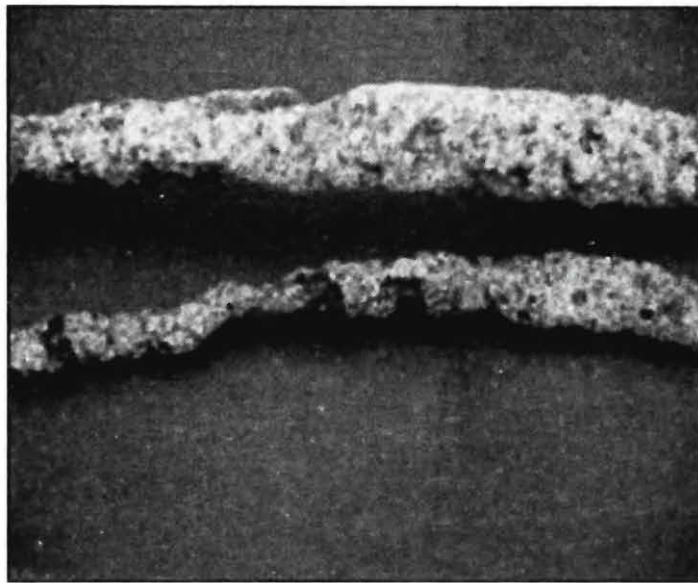


Fig. 2. Early and matured stages of gall-like outgrowths

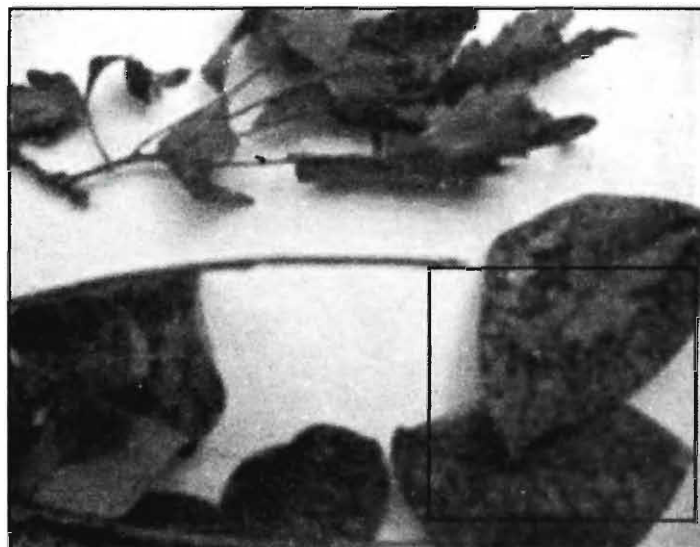


Fig. 3. Black powdery mass on leaflets of *Samanea saman*

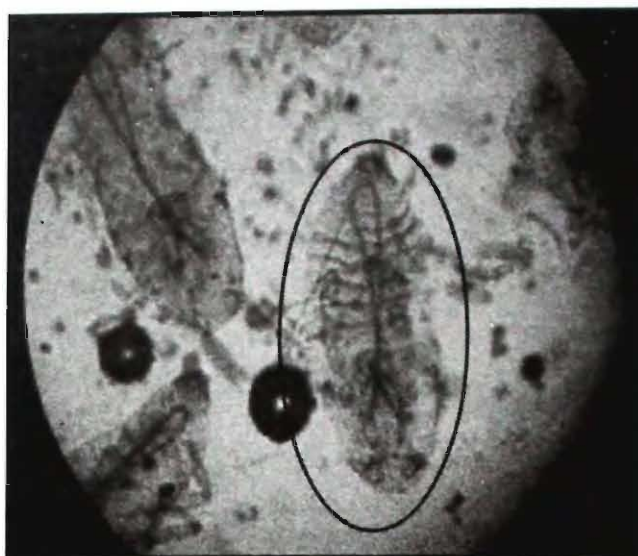


Fig. 4. *Dactylopius indicus* (?) as seen under Microscope

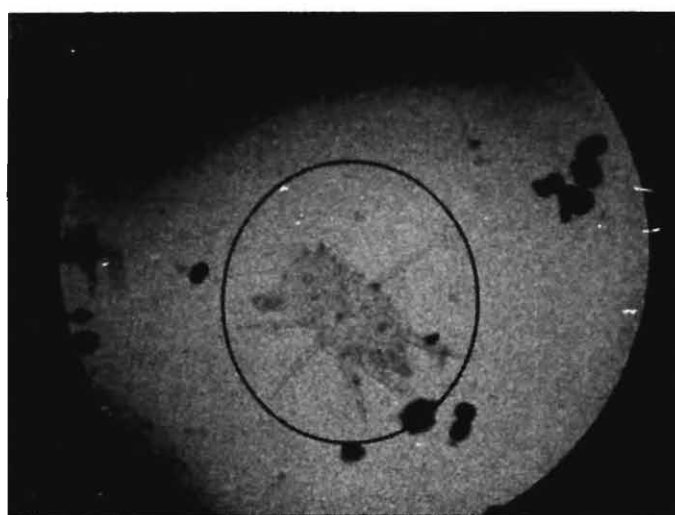


Fig. 5. *Tyrophagus putrescentiae* as seen under Microscope



Fig. 6. *Acarus siro* as seen under Microscope

secreted on those by the insect provided a unique microecological niche comprising of insects-mites-fungi showing interdependence among themselves.

On enquiry with the village folk of the area of collection, it was learnt that the outsiders scrapped out the gall-like structure from this tree and sold them at high prices at Purulia and other districts. However, the purpose for which those were used was not known to them. The gall-like outgrowths along with the insect, on pressing, yielded a blood red pigment. The insect has been known in different parts of the world for being a source of traditional dye used as a food colourant, in textiles and in cosmetics. So, study is under progress to find out its potentiality in yielding dyes.

As far as the authors are aware of, such types of association of insect-mite-fungi on *Samanea saman* has not been reported earlier from any

part of the world and nor the mentioned organisms have been reported on *Samanea saman* (Table.1). Hence this association is not only novel and unusual but also unique. However, from this preliminary observation the role of each of the organism is not very clear and therefore needs further in-depth investigation to draw any meaningful and acceptable conclusion as to the nature of association and its role in formation of galls/ encrustations on the twigs.

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Table 1. List of species of insects and fungi reported earlier on *Samanea saman*

Sl. No.	Category	Order	Scientific name
1.	INSECT	Coleoptera	<i>Anomala antiqua</i>
2.			<i>Apate monachus</i>
3.			<i>Lepropus chrysochlorus</i>
4.			<i>Onciderus tessellata</i>
5.		Hemiptera	<i>Ferrisia virgata</i>
6.			<i>Hemiberlesia lataniae</i>
7.			<i>Icerya aegyptiaca</i>
8.			<i>Icerya formicarum</i>
9.			<i>Kerria lacca</i>
10.			<i>Ptylus flavescens</i>
11.			<i>Rastrococcus iceroides</i>
12.	FUNGI	Isoptera	<i>Coptotermes amarii</i>
13.		Lepidoptera	<i>Attacus atlas</i>
14.			<i>Homona coffearia</i>
15.			<i>Indarbela quadrinotata</i>
16.			<i>Melisomimus metallicus</i>
17.		Poriales	<i>Fomes annularis</i>
18.		Ganodermatales	<i>Ganoderma australe</i>
19.		Ganodermatales	<i>Ganoderma lucidum</i>

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Head & Reader of Museology Department, Calcutta University, Shri Supreo Chanda, Lecturer, Museology Department, C.U. and Dr. K.M. Agrawal, Head, PSM, IISWBM for their constant inspiration and encouragement.

LITERATURE CITED

- NASKAR, K.R. 1993. *Plant Wealth of the Lower Ganga Delta*. Daya Publishing House, India., Vol-1 : 314.
- PRAIN, D. 1903. *Bengal Plants*. 2 vols. (Reprinted ed. 1963), BSI, Howrah.

STUDIES ON CROSS-INFECTION OF MICROSPORIDIAN SPORES OF MULBERRY, ERI AND TASAR SILKWORM TO MUGA SILKWORM, *ANTHERAEA ASSAMENSIS* Ww. AND A NEW APPROACH FOR MANAGEMENT OF PEBRINE DISEASE IN MUGA SILKWORM IN ASSAM AND WEST BENGAL, INDIA

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ABSTRACT

Assam is the principal and unique state of North-East region of India, where 98% muga or golden yellow silk is produced. Muga silkworm, *Antheraea assamensis* Ww., is an important silkworm in sericulture due to its endemism and economic value. However, the production of this silk is less and around 40% loss is due to its infection with various diseases. It is estimated that 20–30 % crop loss is attributed to outbreak of pebrine disease only and sometimes it leads to total crop failure. The prevalence of pebrine disease will be higher due to its pathogenic activity through cross-transmission, where *Nosema* spp. (Protozoa:Microsporida) harbouring in one type of silk worm infect to other type of silkworm. So, the pathogen has a role for further damage of sericulture industry due to its cumulative effect through cross-infectivity. Unlike domesticated mulberry and eri silkworm, eradication of pebrine disease in muga silkworm is very difficult, as it is reared outdoor.

Nosema assamensis Chakrabarti and Manna, 2006, caused pebrine disease in muga silkworm, *Antheraea assamensis* Ww. Besides *N.bombycis* Nageli of *Bombyx mori* L., *N.ricini* Chakrabarti and Manna, 2006 of *Philosamia ricini* Boisd., *Nosema mylitta* Chakrabarti and Manna, 2006 of *Antheraea mylitta* Druary all are virulent microsporidian parasite cross-infected and were able to produce pebrine disease in muga silkworm. In addition, these four pathogens were transovarially transmitted in muga silkworm. Average larval mortality % was recorded higher (81.67 – 99.17%) in all cross-infected batches than infected control (73.67%) in different seasons. However, multiplication of pathogen is higher in infected control (1.70×10^6 spore/ml.) than all cross-infected batches ($1.85 - 8.12 \times 10^5$ spore/ml.), when higher doses of above pathogens (1.52×10^8 spore/ml.) were inoculated in early stages.

On the basis of this study, risky zones are identified in Assam and West Bengal for muga culture to check the cumulative effect of cross-infectivity, which is becoming necessary now a days for any state as well as extinction of muga silkworms particularly, as it is reared primarily in Assam and extends in the Cochbehar district of West Bengal, India.

Keywords : Pebrine disease, Silkworm, *Nosema*, Cross-infection, pathogen

INTRODUCTION

Assam is the principal and unique state of North-East region of India with a geographical area of 78,523 sq. km, lies between 24°–25° N latitude and 89.52°–96°E longitude, of which 77 % in hills altitude varying 97-500 mt. Upper

Assam constitutes mostly hilly areas whereas lower Assam is mainly plains. The districts of Nowgaon, Shibsagar, Jorhat, Lakhimpur, Dibrugarh, Tinsukia, Golaghat, Digboi etc are included in upper Assam encircled by Arunachal Pradesh and Nagaland whereas the districts Dhubri, Goalpara, Kamrup, Darang,

Kakhar and Mikir hills, Kokrajhar etc are included in lower Assam encircled by Bhutan, West Bengal, Meghalaya, Tripura, Mizoram and Manipur. Average rainfall is very high (1800–2200 mm) in this state spreading from February–October. Rainfall in upper Assam, 395 mm in rainy season than in lower Assam (200 mm). Due to these ideal geographical, ecological, meteorological advantages, this state is rich in natural floral and faunal wealth including four varieties of sericigenous insects viz, muga, eri, tasar and mulberry silkworm and their food plants (Fig. 1).

Assam is the primary epicentre for origin and global spread of muga culture (Sharma, 2002). About 90% muga is cultivated in this state (Chandrasekhar *et al.*, 1989). The districts of Goalpara, Kamrup, Darang etc. are the main seed zones in lower Assam and Sibsagar, Lakhimpur, Jorhat, Dibrugarh, Tinsukia etc. are the main commercial zones of this state. Muga silkworm is a polyvoltine, heterogenous and semi-domesticated in nature. 98.50 MT muga silk was produced in 7852 He. plantation area with the engagement of 1,96,417 families in this state during 2005-06 (Anonymous, 2006). The

production of muga silk was 86.6 MT during 1995-96. Thus, the production of muga silk is not increasing at the desired level. Production of muga silk has some problems like depletion of food plants, dearth of quality seed, poor yield, low fecundity, lower multiplication rate, mismanagement, pollution from oil refineries, lack of skill manpower, environmental constrains, improper marketing, post cocoon technologies and various silkworm diseases (Sharma, 2002).

Muga silkworm is an important silkworm in sericulture point of view as well as strategically and evolutionary point of view due to its endemism and economic importance. In small population the combined effect of natural selection, genetic drift and greater likelihood of inbreeding is to raise the level of homozygosity and thus lower the amount of variability in population. For that reason, the small population may loose their ability to adopt for changing conditions and therefore, this may be extinct. As muga silkworm confined only in Assam, there is no chance of development of old races and new races or species formation in natural habitat, thereby, the old races/species may be extinct by the way

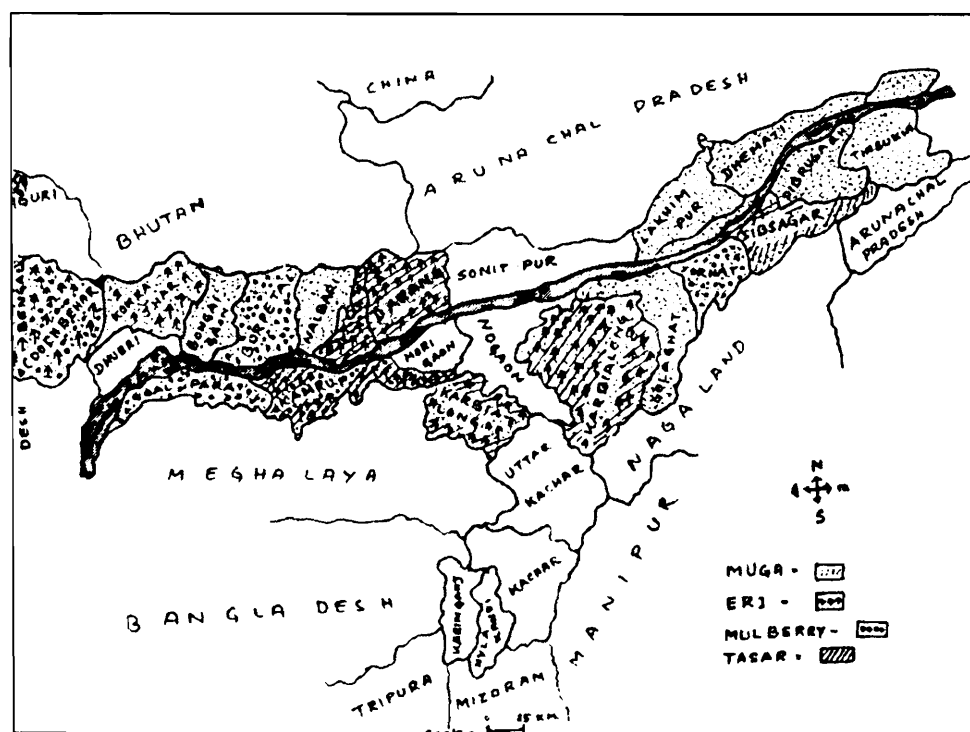


Fig. 1. Sericulture map of Assam and Coochbehar district of West Bengal

of inbreeding depression (Dodson, 1964, Thangavelu, 1986, Gogoi and Goswami, 1998).

Nevertheless, the production of silk is comparatively low due to various reasons of which diseases and predation are noteworthy in this region. Further, silkworm races are reared in India since decades without any major change. As a result they loose their tolerance against diseases (Veeranna, 1999).

Muga silkworm, *Antheraea assamensis* Ww., is highly susceptible to many diseases viz., protozoal, viral, fungal and bacterial, resulting in heavy crop loss. Around 40% crop loss is attributed to infection with various diseases (Veeranna, 1999). The several reports are available of loss due to specific diseases in silkworm in India. The loss may vary from a range 15-20% (Chitra *et al.*, 1975) to 30-40% (Janakiraman, 1961 and Hanumappa, 1968). It is estimated that 20-30% crop loss is attributed to outbreak of pebrine disease only and sometimes it leads to total crop failure (Manual of Sericulture, Central Silk Board, Bangalore, 1990). The prevalence of pebrine disease will increase due to its pathogenic activity through cross-transmission when *Nosema* spp harbouring in one type of silk worm infect to other type of silkworm. So, the pathogen has a role for further damage of sericulture industry due to its cumulative effect through cross-infectivity.

The existence of more than one species in the same habitat and presence of diseases in any one of them may lead to the chances of cross-infection. But as a matter of fact this does not occur. Normally, a general lack of susceptibility is exhibited by the members of the other groups. In a few instance, cross-infection does occur in nature but they are relatively few in case of closely related groups. However, the parasites are very specific about their host (Sengupta and Griyaghey, 1981a). Infection of *Nosema* sp. to tasar silkworm, *Antheraea mylitta* D. (Lepidoptera: Saturniidae) is reported by Jolly and Sen (1972).

Fujiwara (1980) and Sato *et al.* (1981) isolated besides *Nosema bombycis* Nagaeli, 4-6 other

microsporidian belonging to *Nosema*, *Pleistophora* and *Thelohania* genera from mulberry silkworm, *Bombyx mori* L. Infection of *Nosema bombycis* N. to 20 different lepidopteran insects is shown by Machay (1957). Similarly, Kashkarova (1981) reported the infection of *N. bombycis* N. to other 8 insects. The *Nosema* spores of tasar silkworm also infect and cause disease in mulberry silkworm (Patil, 1993) though Sengupta and Griyaghey (1981a) reported non-pathogenicity of *Nosema* spores of *Antheraea mylitta* to mulberry silkworm, *B. mori* L., *Nosema* sp. affecting *A. perneyi* do not infect mulberry silkworm (Jolly, 1986).

However, the studies are seldom (Rao *et al.*, 1976) on the cross-infection of *Nosema* spore of mulberry, tasar, eri and muga silkworm to muga silkworm. Therefore, to understand the possibility of cross-infection of microsporidia causing pebrine of mulberry, eri and tasar silkworm to muga silkworm is necessary, as it is almost a regular practice in Assam and Coochbehar district of West Bengal to rear mulberry, tasar, eri and muga silkworm without knowing the adverse effect of cross-infection.

Moreover, eradication of pebrine disease in muga silkworm is difficult as it is reared in outdoor, unlike domesticated mulberry and eri silkworm. It is observed during survey, muga culture are practiced in the villages or areas in the districts of Sibsagar, Lakhimpur, Jorhat, Dibrugarh, Tinsukia, Dhemaji, Karbialong and Golaghat of upper Assam and Goalpara, Kokrajhar, Kamrup, Bongaigaon, Borpheta and Nalbari of lower Assam. Eri silkworm is cultivated in the district of Kamrup, Darang, Kokrajhar and Karbialong district of Assam. Mulberry sericulture is practiced in the districts of Goalpara, Kamrup, Borpheta and Jorhat of Assam. Tasar culture is practiced in the districts of Kamrup, Darang, Shibsagar and Karbialong of Assam (Fig. 1).

On the basis of cross-infection risky zones may be identified in Assam for overlapping culture of mulberry, tasar, eri and muga, which may be an approach for management of pebrine disease in Assam and West Bengal.

MATERIALS AND METHODS

Collection of muga silkworm eggs and rearing of host insects

Fifteen disease free eggs of muga silkworm (*A. assamensis* Ww., Multivoltine, Semidomesticated) were collected from Regional Muga Research Station, Central Silk Board, Boko, Dist- Kamrup, Assam, India on 19.08.2002. Rearing was conducted during 25.08.2002 to 25.09.2002 (Season-1). Few eggs were crushed with mortar and pestle in sterilized water and examined under microscope to confirm further that the eggs were free from any disease. 100 selected larvae were reared as healthy control.

Collection of microsporidia from mulberry, tasar, eri and muga silkworm

Nosema spp., microsporidia of mulberry, tasar, eri and muga silkworm were propagated in their respective primary hosts and purified from moths using percoll cushions (PVP coated silica particles, Sigma chemicals Co., USA). The technique involves collection of spores from pebrine-infected moths by centrifugation in endotoxin free water (E.F. water). As microsporidian spores are dense, a series of washes and centrifugations remove the dissolved substances but small particulate contaminants remain. Spores are, in fact, denser than most of other particulates from the host and centrifugations concentrate them near the bottom of the residue. 20–30 infected moths were crushed together with mortar and pestle in sterilized water in 0.5% potassium carbonate solution for easy separation of spores from different tissues. Then the suspension was filtered twice through cotton and washed 2–3 times in E.F. water. The suspension was centrifuged at 2,600 rpm for three minutes. The sediment was resubmitted in 2% potassium hydroxide solution, which dissolved fat globules making observation easy (Bhattacharya *et al.*, 1994). Finally the suspension of spore was layered over percoll cushions and centrifuged at 10,000 rpm for 30 minutes in an RC5C high speed refrigerated centrifuge (Sorvall) with

swing-out-rotor (SH-MT12) to obtain purified *Nosema* spp. (Bhattacharya *et al.*, 1993).

A new improved haemocytometer with Thoma-zaiss counting slide (German Fine Optik) was used to count the spore under microscope for determining the inoculum concentration (Cantwell, 1970 and Undeen, 1997).

Inoculation of microsporidia of mulberry, tasar, eri and muga to muga silkworm

Multivoltine muga silkworm, *A. assamensis* Ww. were reared indoor under laboratory condition on a diet of fresh Som and Soalu twigs (*Machilus bombycina* King. and *Litsaea polyantha* Pers.) dipped into water in mud pitcher at 26–33°C and 93.5–71.0% R.H. and 12L+12D photoperiodic condition. Freshly collected first instars larvae at '0' hour (1st day 1st instars) were considered for experiment and fed on fresh Som and Soalu leaves smeared with microsporidia of mulberry, tasar, eri and muga silkworm. Briefly, the procedure involves dipping leaf dishes (28.27 sq.cm.) in 1 ml. of spore suspension, drying and then allowing the larvae to feed on the dish for a period of 6 hours following the procedure of Sengupta and Griyaghey (1981a) and Patil (1989). The Som and Soalu leaves smeared with distill water was fed to the tasar silkworm of healthy control group.

Recording of mortality

Mortality and life span were recorded and dead larvae were examined under microscope to confirm mortality due to pebrine disease. Spores were extracted from pooled sample and purified as described and were counted by haemocytometer. All the data are statistically analyzed.

Second Season Rearing

For the next season, fifteen disease free eggs of muga silkworm (*A. assamensis* Ww., Multivoltine) were collected from Regional Muga Research Station, Central Silk Board, Boko, Dist-Kamrup, Assam, India on 09.09.2002. Rearing was conducted during 15.09.2002 to

18.10.2002(Season-2). Procedure involved as in case of previous rearing, inoculation, purification etc. Eggs were hatched during and rearing conducted in between 19 -33°C and 62-94% R.H.

RESULT

Nosema bombycis, *N. mylitta* and *N. ricini* were highly cross infected to muga silkworm and larvae survived 10-21 days of post inoculation, even if inoculated at a very lower dose (1.52×10^5 spore/ml.).

Rate of infection was very high and disease symptoms appeared in 2nd stage infected larva. The black spots over the surface of the larval integument appeared after 1st moulting i.e., 2nd stage onwards. Most of the cross-infected larvae died in the 2nd stage itself and just after reaching 3rd stage (Fig. 2 and 3) and smaller in size that did not carry black spots. The very few larvae could reach 4th stage.

Larval mortality started 4 to 5 days post inoculation (Fig. 2 and 3). *Nosema bombycis* was highly cross-infective to muga silkworm and infection was very rapid in comparison to infected control, when *N. assamensis* infected

to muga silkworm (Fig. 4). Mortality % was recorded always higher (73.67-99.17%) in all cross-infected batches. However, muga silkworm that cross-infected with *Nosema bombycis* was recorded highest mortality % (98.00) than infected control (95.00%) during August-September (Season-1) when inoculum concentration was higher (1.52×10^8 spore/ml.). But, *N. ricini* effected less mortality (67.00%) during September-October (Season-2) when inoculum concentration was lower (1.52×10^7 spore/ml.). Mortality % was recorded lowest (52.00%) during Season-2, but it was very high in Season-1 (95%) in infected control batches. Average mortality % of all cross-infected and infected control batches were recorded less (71.96%) during Season-2 than Season-1 (84.00%). *Nosema bombycis*, *N. mylitta*, *N. ricini* and *N. assamensis* were highly virulent and multiplied very rapidly in muga silkworm irrespective of inoculum concentrations and seasons.

The development and multiplication of microsporidia was continued with the advancement of larval stages and it was increased maximum (1.70×10^6 spore/ml.) in infected control batches during September-

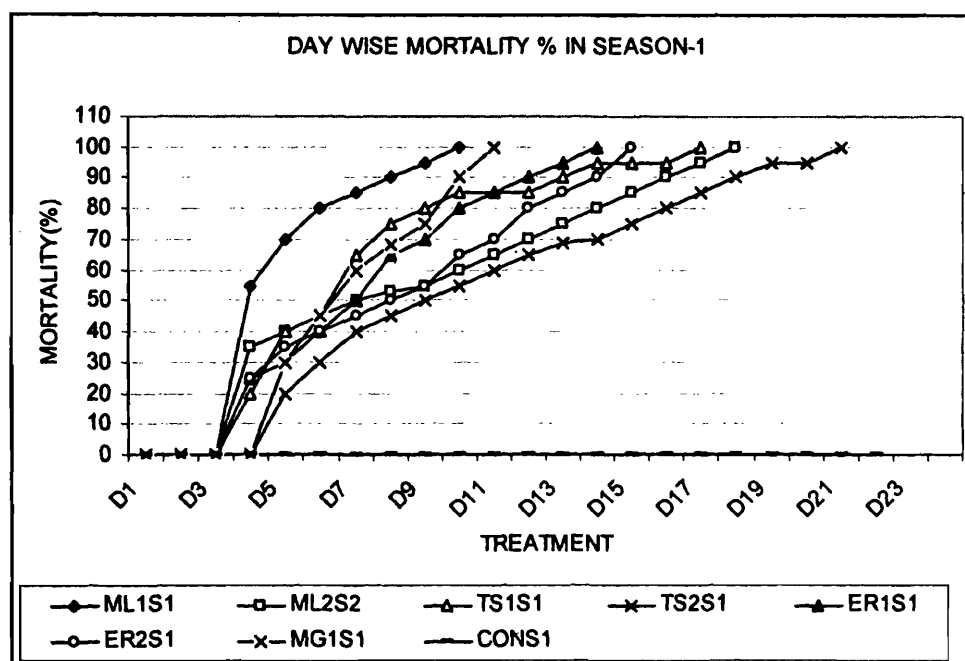


Fig. 2. Daywise mortality due to cross-infection in Season-1. (ML = *Nosema bombycis* N., TS = *N. mylitta* Chakrabarti and Manna, ER = *N. ricini* Chakrabarti and Manna, MG = *N. assamensis* Chakrabarti and Manna, Dose 1 and 2 = 1.52×10^8 and 1.52×10^7 spore/ml. CON = Healthy control)

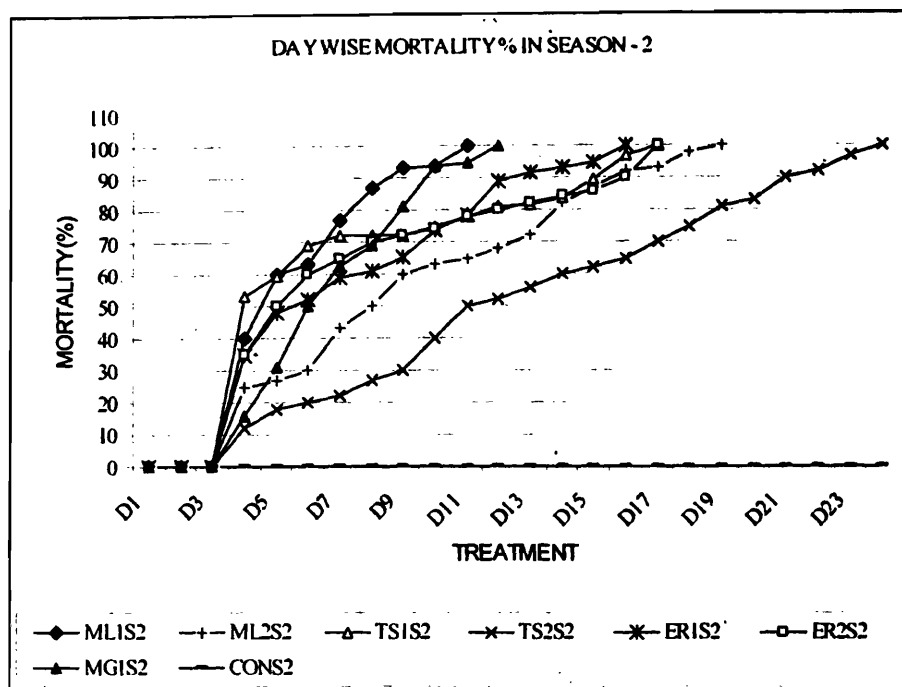


Fig. 3. Day-wise mortality due to cross-infection in Season-2. (ML = *Nosema bombycis* N., TS = *N. mylitta* Chakrabarti and Manna, ER = *N. ricini* Chakrabarti and Manna, MG = *N. assamensis* Chakrabarti and Manna, Dose 1 and 2 = 1.52×10^8 and 1.52×10^7 spore/ml. CON = Healthy control)

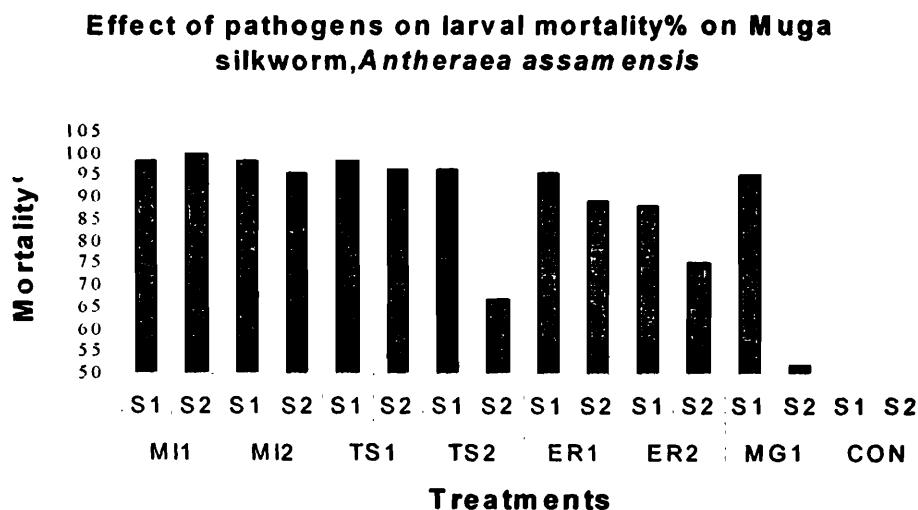


Fig. 4. Mortality % in muga silkworm due to cross-infection. (ML = *Nosema bombycis* N., TS = *N. mylitta* Chakrabarti and Manna, ER = *N. ricini* Chakrabarti and Manna, MG = *N. assamensis* Chakrabarti and Manna, S1 and S2 = Season 1 and 2., Dose 1 and 2 = 1.52×10^8 and 1.52×10^7 spore/ml., CON = Healthy control)

October (Season-2) when inoculated with higher concentration (1.52×10^8 spore/ml.) and minimum (1.85×10^5 spore/ml.) when cross-infected by *N. mylitta* during August-September (Season-1) with lower inoculum concentration (1.52×10^7 spore ml.). Surprisingly, it was observed that the average multiplication of microsporidian were less (3.11

$\times 10^5$ spore ml.) in Season-1 than in Season-2 (5.60×10^5 spore/ml.) in all infected and cross-infected batches, but, average mortality % was higher (83.79%) in Season-1 than Season-2 (71.96%) (Fig. 5). Moreover, mature spores were found in the gut content of larvae till survived.

Influence of microsporidia on muga silkworm treated with *Nosema bombycis* N.,

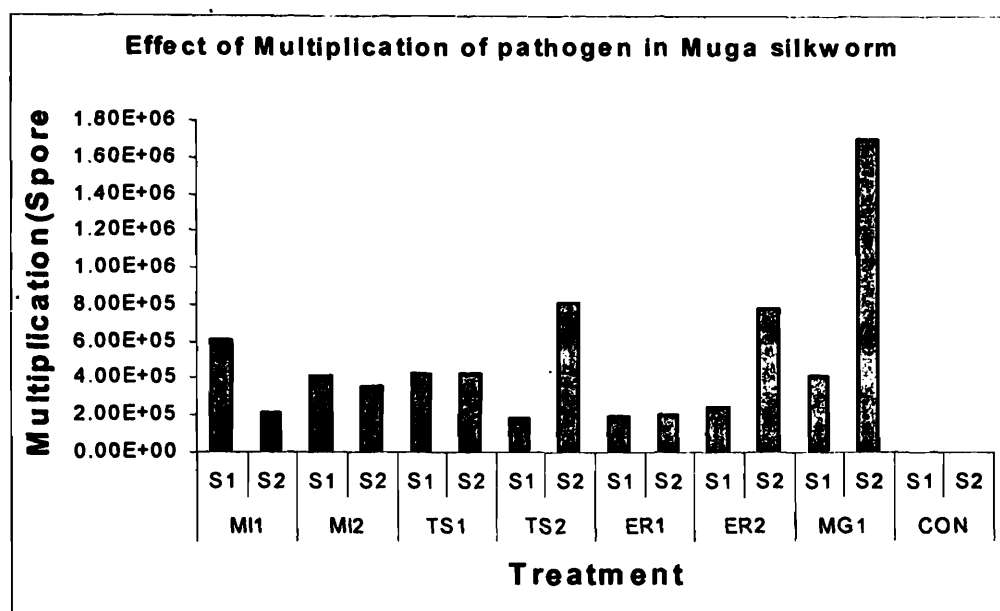


Fig. 5. Multiplication of pathogen in muga silkworm due to cross-infection. (ML = *Nosema bombycis* N., TS = *N. mylitta* Chakrabarti and Manna, ER = *N. ricini* Chakrabarti and Manna, MG = *N. assamensis* Chakrabarti and Manna, S1 and S2 = Season 1 and 2., Dose 1 and 2 = 1.52×10^8 and 1.52×10^7 spore/ml., CON = Healthy control)

N. mylitta Chakrabarty and Manna, *N. ricini* Chakrabarti and Manna and *N. assamensis* Chakrabarti and Manna on qualitative parameters were also noticed and all the above infection were effected to maximum and worms died before reaching the cocoon stage. The average life span was slightly increased during Season-2 (16.14 days) than Season-1 (15.2 days) in cross-infected batches. Lower concentration of spores (1.52×10^7 spore/ml.) effected more to increase life span (15–23 days) than higher concentration (1.52×10^8 spore/ml.) (Fig. 6). *Nosema bombycis* N. and *N. assamensis* Chakrabarti and Manna mostly effected to decrease the life span (10–12 days) in comparison to infection by *N. mylitta* Chakrabarty and Manna (17–23 days) and *N. ricini* Chakrabarti and Manna (14–16 days) where life span of control batches was recorded as 30–32 days in healthy control batches of muga silkworm.

IV. DISCUSSION

In nature the pebrine disease occurred in mulberry, tasar, eri and muga silkworm (Rao *et al.*, 1976). In the present study, *Nosema bombycis* N., *N. mylitta* Chakrabarti and Manna and *N. ricini* Chakrabarti and Manna, are cross

infected to muga silkworm and showed highly positive response causing development of severe pebrine disease. The previous study in this aspect is not available, except Patil (1989) got higher incidence of pebrine disease, when spores isolated from eri silkworm cross-infected to muga silkworm and Mistry (1979) cross-infected pebrine spore from eri to muga silkworm in natural condition and got 22.6% mortality. He suggested such cross infection may be possible as the rearing of muga and eri silkworm are conducted side by side in villages in Assam.

The temperature and humidity are moderate during Season-1 regime and coincides with the highest mortality in the present finding, which might have acted as stimulatory factors for parasite (Dash and Nayak, 1998). Dasgupta (1950) made similar observation in *B. mori* L. But the findings of Deviah and Krishnaswamy (1975) in *B. mori* L. records minimum incidence of pebrine at high temperature and humidity. Nomani *et al.* (1971) made contradictory statement and stated that temperature and humidity has no role with incidence of pebrine but certainly temperature and humidity has a role for better larval growth and good ERR as in the present findings.

The mortality % is higher in Season-1 than Season-2 in different inoculum concentration. So, slight variation of season and treatment is responsible for difference of mortality % (Fig. 1). This finding gets support from Johnson (1989). The infection rate that resulted from early application of *Nosema locustae* bait (treatment) to grasshopper (Orthoptera:Acrididae) was initially higher than caused by late application. The prevailing temperature range 19–33°C in Season-2 is less favourable to the experimental diseases (Nosemiasis at 25° C) resulting lower mortality in Season-2 also gets support from the view of Aizawa (1962).

Higher dose of pathogen is responsible for higher mortality due to inactiveness of spores in the alimentary tract before it comes into the susceptible tissues (blood, epidermis, silk gland) of accidental or secondary host. The digestive fluids of the gut may be responsible for some activation (Aizawa, 1962).

Temperature range 26–28° C is optimum for pathogen multiplication. Therefore, pathogens multiply maximum and mortality % is higher in Season-1 than Season-2. It supports the views of Steinhaus (1954) that **optimum range of temperature** for the lepidopteran host corresponds to the most favourable

microorganism. This fact counterbalances the greater resistance of the host associated with temperatures most favourable for its development (Hurpin, 1959).

Ghosh and Saha (1995a) observed a close relationship of temperature (31.7–33.8°C) together with Relative Humidity % (97–100%) while infecting *Lophocaters pusillus*, coleopteran stored grain pest. This also gets support from the present findings, where all the pathogens infecting tasar silkworm reared during season-1 at the temperature range 26–33°C together with R.H. 71–93.5%. Patil *et al.* (1983), Ghosh *et al.* (1986) and Ghosh and Halder (1989) pointed out that a specific range of temperature and humidity is required for maximum sporulation of gregarine parasites, which supports present findings.

The time taken for establishment of the parasite for completion of its life cycle and production of spores varies considerably, depending on the age of host, species of the parasite, size of the inoculum and other environmental factors (Weiser, 1976). In general the mortality of insects is directly related to the inoculum size of parasite received (Ghosh and Saha, 1995b). This also gets support from the present findings, where a lower dose, $1.52 \times$

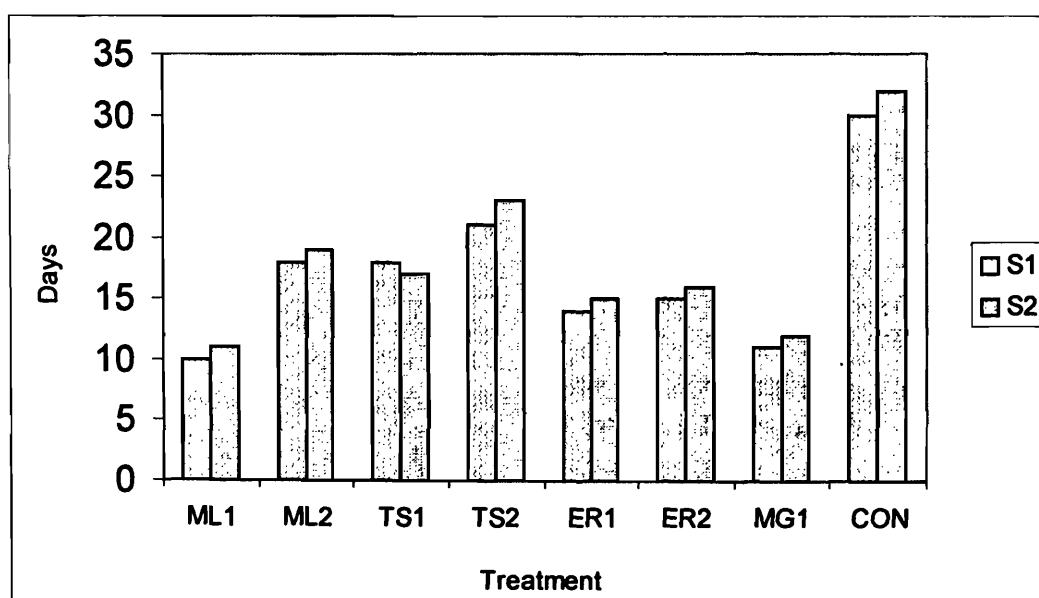


Fig. 6. Life span of muga silkworm affected due to cross-infection (ML = *Nosema bombycis* N., TS = *N. mylitta* Chakrabarti and Manna, ER = *N. ricini* Chakrabarti and Manna, MG = *N. assamensis* Chakrabarti and Manna, S1 and S2 = Season 1 and 2., Dose 1 and 2 = 1.52×10^8 and 1.52×10^7 spore/ml., CON = Healthy control)

10^6 spore/ml. is responsible for lower mortality and higher dose, 1.52×10^8 spore/ml. responsible for higher mortality.

The number of spores (intensity of infection) that a host can harbour and still function normally is important in determining the role of a microsporidia as parasite in nature (Ghosh and Saha, 1992). A particular dose is effective for multiplication of spore and mortality (Windels *et al.*, 1976) and below that level of dose cause no mortality but reduce the fecundity of infected moths (Malone and Wigley, 1981). This is contradictory to the present findings, where lower spore dose (1.52×10^5 spores/ml.) has effected huge mortality in all batches. Thus muga silkworm is found to be highly susceptible to the infection.

However, higher doses of pathogens (1.52×10^7 – 1.52×10^8 spores/ml.) are virulent and get maximum gut area to infect tissue of muga silkworm. Season-1 is suitable for pathogen multiplication, where all the meteorological factors are stimulatory for pathogen multiplication (Dash and Nayak, 1998). Here the parasitic effect on larval mortality is related with the season and nature of parasite viz., virulence, wild/domestic etc, but not related with the dose. Teetor and Kramer (1976) informed that there was no discernible relationship between spore dose and subsequent infection of host which also supports the present findings. All stages of muga larvae are more susceptible for microsporidian infection (Wilson, 1984 and Patil, 1993) without gradual development of immunity in the surviving larvae (Dash and Nayak, 1998).

Maddox (1968) found in his **quantitative study** that **generation time** of *Nosema necatrix* varied with the spore dose administered to the caterpillar *Pseudolatia unipuncta*. Similarly in the present observation all the pathogens are effective during August–September (Season-1), when both temperature and spore doses were higher for effective high mortality in muga silkworm.

The maximum number of spores are required to initiate a disease in mulberry

silkworm vary with the age of the host. 1-10 spores and 100 spores are sufficient to cause disease in 2nd and 5th instar larvae respectively (Patil, 1993). The longevity of the instars and the amount of spore feeding are some of the factors, which influence the disease manifestation (Ishihara and Fujiwara, 1965). This observation gets support from our present findings, when minimum dose, 1.52×10^5 spore/ml. cause heavy mortality to muga larvae which is undergoing changes from 1st to 2nd stage (4-6 days) and infected to '0' hour 1st stage silkworm.

In *P. brassicae*, there was a sharp increase in spore production on 19th and 20th days when insects were undergoing changes from pupa to imago stage. The physiological changes in the insect could possibly have caused the development cycle of the parasite to switch on from a predominantly vegetative phase to sporogony, resulting in an increasing spore production (Lai and Canning, 1983). Maximum spore is harvested, when larva undergoing changes from 3rd to 4th stage (1.70×10^6 spore/ml) on 11-13 days in infected control batches in the present findings, which supports the view of Lai and Canning (1983).

The age and condition of insects affect the action of phagocytes and low temperature (15-18°C) retards the beginning of phagocytosis (Steinhaus, 1947). Older larvae might have a greater capacity for phagocytosis (more phagocytosis) than younger larvae and would be able to destroy a greater population of the inoculum before fat cell division. Henry *et al.* (1973) obtained similar spore numbers of *Nosema acridiophagus* and *N. cuneatum* in *Melanoplus sanguinipes* at 20 days using 10^4 and 10^6 spore doses but with a low dose of 10^2 the spore production was lower. The spore numbers resulting from the two higher doses had reached the stationary phase but spore multiplication was still in progress at the time of harvest, when 10^2 spore doses were used. Therefore, the insect must be harvested before the stationary phase of spore production is reached to test the dose effect (Lai and Canning, 1983). If development is allowed to proceed to the stationary phase, multiplication of the

parasite is greater with low doses than with high doses. Phagocytes or inactivation of spore is happening by the host to destroy a higher proportion of the dose, when small number of spore is given than the large numbers. Thus during an exponential phase, there is an apparent increase in replication with increased dose. The difference between the replication of a high spore dose and the replication of a low spore dose will narrow and reverse during the exponential phase, so that at the stationary phase the high dose results in high replication. Any factor affecting spore production and spore replication needs to be determined in relation to the logistic pattern of development of the microsporidium (Lai and Canning, 1983). The closely related microsporidia might occur in the same locality, but occurrence of high microsporidiosis infection in one host and lower infections in another may be due to host behavioural differences (Maddox, 1968). In the present findings, it is observed that higher dose (1.52×10^8 spore/ml.) of all the pathogens are more effective in mortality to muga silkworm. Further, the spore harvest is almost at the same level at 4th stage ($4.10 \times 10^5 - 1.7 \times 10^6$ spore/ml.) in both the 1st and 2nd seasons, when the spore production reaches the stationary phase. The magnitude of **spore production** is strongly age specific and thus, time dependent under certain environmental conditions (24°C) (Sloter *et al.*, 1989).

Interaction of different microsporidians with host or different hosts with one microsporidia involves as assessment of variations. Sometimes, the infection in one host is acute and chronic in another. Acute infection, as in the case of *N. bombycis* N., results in the death of host within 10-14 days, whereas chronic infection results in mortality during pupation or adult moth. In an apparent infection, spores and vegetative spores will be present but the rate of multiplication is slow that regeneration replaces all the infected cells and there is no visible alteration in the host (Kishore *et al.*, 1994). This observation also gets supports from present findings. The effect of pathogen, *N. ricini* Chakrabarty and Manna and *N. mylitta* Chakrabarty and Manna on mortality % and multiplication of pathogen is more on

muga silkworm, where the cases are acute in comparison to effect of *N. assamensis* Chakrabarty and Manna to muga silkworm, where the cases are chronic (Figs. 1 & 2).

Silkworm larvae become **resistant to** spores of *N. bombycis* N. as they grow. Therefore, the incidence of pebrine may become lower as their age progress. On the other hand, the chance of eating *Nosema* spore increases as they grow, since the amount of feeding becomes greater with development; 88.00 % of the total amount of food is ingested during the 5th instar, only 0.5% during the 1st to 2nd and less than 2% during 3rd, respectively (Matsumura and Takeuchi, 1950). These observations get support from the present findings. The mortality % was higher during 2nd and 3rd stage and larval mortality % increases suddenly from 11th to 14th day i.e., 3rd to 4th stage. Larval mortality % moves slowly to a steady state after 15th day in Season-2, the maturing 4th stage to 5th stage.

Nosema assamensis Chakrabarty and Manna multiplies maximum in its primary host muga silkworm (infected control) with parasitic load, 1.70×10^6 spore/ml. with mortality % is less (52.00%). Alternately, *Nosema bombycis* N., *Nosema mylitta* Chakrabarty and Manna and *N. ricini* Chakrabarty and Manna multiplies less ($1.99 - 5.12 \times 10^5$ spore/ml.) in its secondary or accidental host, muga silkworm, but mortality % is more (81.66 – 99.167%) than the infected control.

The magnitude of **spore production** is strongly age specific and thus, time dependent. In addition, under certain environmental conditions (24°C) infected larvae developed more slowly than healthy ones. These two effects of the disease lead to less synchrony between healthy and diseased corn borers and even greater asynchrony between the production of spores and the presence of healthy larvae. In addition to these direct effects of the pathogen and host-parasite indirect effects may occur (Sloter *et al.*, 1989). Due to presence of adjustment, the pathogen multiplies very rapidly become enormous in number within a short time in its primary host. However, pathogen multiplies slowly in its

secondary host or accidental host to cope up with the new environment. The pathogen multiplies maximally to ensure certain percentage of pathogen gets entry in the next generation through transovarial transmission. It is reasonable to assume that higher rate of infection of the adult would increase the rate of transmission of the pathogen to the next generation (Henry *et al.*, 1973) thus ensure survival in nature.

The larval and pupal mortality was higher and adult life span shorter when, *N. pyrausta* infected European Corn Borer (Kramer, 1959). Zimmack *et al.* (1954) found infected moths of field collected European corn borer larvae had a shorter life span and the percentage of infected larvae that survived to emerge as adults were lower (Zimmack and Brindley, 1957). The present observation also supports this view.

From the present observation, it is apparent that wherever, rearing of tasar, mulberry and ericulture are conducted simultaneously that zones are risky for muga culture as muga silkworm are highly cross-infective by *Nosema bombycis* N., *N. mylitta* Chakrabarty and Manna and *N. ricini* Chakrabarti and Manna. Therefore, Kamrup, Darang, Kokrajhar, Karbialong, Goalpara, Borpeta, Jorhat and Sibsagar are risky zones for muga culture as these zones are overlapping by mulberry, tasar and eri culture and have a chance of cross-infection. As, muga is suitable for cultivation in Assam and it is the

most susceptible silkworm, therefore, the zone covered by other than muga culture is required to be free for only muga culture to protect the muga silkworm from extinction. Moreover, tasar, eri and mulberry can be reared in other places of the country, but muga culture can only be reared in Assam and bordering of West Bengal. Besides, the area, where the muga culture are going on in decades viz., the districts of Dibrugarh, Tinsukia, Golaghat, Dhemaji, North Lakhimpur and more or less whole of the Assam, may be kept free for muga culture to overcome the risk of extinction. The few districts where the tasar, eri and mulberry are reared in less quantity may also be free for muga culture by shifting tasar, eri and mulberry culture to elsewhere to protect the muga silkworm, an endemic species, from its extinction.

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LITERATURE CITED

- AIZAWA, K. 1962. Antiviral substances in the juice of the silkworm, *Bombyx mori* L. *Journal of Insect Pathology*, 4 : 72-76.
- ANONYMOUS 2006. *Annual Report of Regional Development Office, Central Silk Board, Guwahati, Assam, India for 2005-06*.
- BHATTACHARYA, J., KRISHNAN, N., PRAKASH, O. and SENGUPTA, U. 1993. Use of simple slide agglutination test for the detection of nuclear polyhydrosis virus of silkworm, *Bombyx mori* L. *Current Science*, 65(8) : 638-639.
- BHATTACHARYA, J., KRISHNAN, N., KUMAR, P. and CHANDRA, A. K. 1994. 125 years of mother moth examination technique of Sir Louis Pasteur. *Indian Silk*, December : 15-18.
- CANTWELL, G. E. 1970. Standard methods for counting of *Nosema* spores. *American Bee Journal*, 110(6) : 222-223.

- CHANDRASEKHAR, M., MD, ISA. and SAMSON, M. V. 1989. Muga culture in waste lands of North- East, India. *Indian Silk*, 28(2) : 14-15.
- CHAKRABARTI, S. and MANNA, B. 2006. Three new species from *Nosema*-like isolates of three non-mulberry silkworms in Assam : light, scanning and transmission electron microscopy, *Journal of Parasitic Diseases*, 30(2) : 125-133.
- CHITRA, C., KARANTH, N.G.K. and VASANTHARAJAY, V.N. 1975. Diseases of mulberry silkworm, *Bombyx mori*, L. *Journal of Science and Indiana Reserch*, 34 : 386-401.
- DASGUPTA, M. R. 1950. In : *Monographs of cottage industries No. 1. Diseases of silkworm*. Government of India press, Kolkata, p-9.
- DASH, A. K., and NAYAK, B. K. 1998. Studies on mortality of larvae of Indian wild Tasar insect *A.paphia* L. due to pebrine (*Nosema* sp.) infection. *Bulletin of Indian Academic Sericulture*, 2(1) : 61-64.
- DEVIAH, M. C. and KRISHNASWAMY, S. 1975. Observation on the seasonal incidence of pebrine disease on silkworm *B.mori*, L, *Indian Journal of Sericulture*, 14 : 27-30.
- DODSON, E.O. 1964. In : *Evolution : Process and products*. Affiliated East-West Press Pvt. Ltd., New Delhi (5th Edition) : 253-262.
- FUJIWARA, T. 1980. Three microsporidians (*Nosema* sp.) from the silkworm, *Bombyx mori*. *Journal of Sericulture Science, Japan*, 49 : 229-236.
- GHOSH, S., SENGUPTA, T. and HALDAR, D.P. 1986. Bioecological studies of three species of separate gregarines (Apicomplexa : Sporozoa) from insects. *Environment and Ecology*, 4 : 281-285.
- GHOSH, S. and HALDAR, D. P. 1989. Role of environmental factors in the incidence of two new species of apicomplexan parasites, *Hirmocystis lophocateri* n. sp. and *H.triboli* n. sp. from coleopteran insects. *Acta Protozoologica*, 28 : 49-60.
- GHOSH, S. and SAHA, K. 1992. Experimental application of *Nosema* sp. on *Lophocaters pusillus*, K. (Coleoptera : Curculionidae). *Acta Protozoologica*, 31 : 181-184.
- GHOSH, S. and SAHA, K. 1995a. Impact of temperature and relative humidity on the incidence of a microsporidia parasite, *Nosema* sp. I, infecting coleoptera stored grain pest, *Lophocaters pusillus*. *Journal of Entomological Research*, 19(3) : 207-214.
- GHOSH, S. and SAHA, K. 1995b. Effect of infection of *Nosema* sp. on moulting and mortality of a stored grain pest *Lesioderma sericerne* (Coleoptera : Curculionidae). *Environment and Ecology*, 13(3) : 618-625.
- GOGOI, B. and GOSWAMI, B. C. 1998. Morphometric studies on muga silkworm, *Antheraea assama* Westwood. *International Journal of wild silkmoth and silk*, 5 : 213-215.
- HANUMAPPA, H. G. 1968. In : *Sericulture for rural development*. Himalaya Publishing House, Bombay, India, : 147-157.
- HENRY, J. E., TIAHRT, K. and OMA, E. A. 1973. Importance of timing, spore concentration and levels of spore carrier in applications of *Nosema locustae* (Microsporida : Nosematidae) for control of grasshoppers. *Journal of Invertebrate Pathology*, 21 : 263-272.
- HURPIN, B. 1959. Etude de diverses souches of maladie laitense sur les larves de *Melolontha melolontha* et sur cells de quelques especes voisies, *Entomophaga*, 4 : 233-248.
- ISHIWARA, R. and FUJIWARA, T. 1965. The spread of pebrine with a colony of the silkworm, *Bombyx mori* L. *Journal of Invertebrate Pathology*, 14 : 316-320.

- JANAKIRAMAN, A.T. 1961. Disease affecting the Indian silkworm races. *Journal of Silkworm*, **13** : 91-101.
- JOHNSON, D. L. 1989. The effects of timing and frequency of application of *Nosema locustae* (Microspora : Microsporida) on the infection rate and activity of grasshoppers (Orthoptera : Acrididae). *Journal of Invertebrate Pathology*, **54** : 353-362.
- JOLLY, M. S. and SEN, S. K. 1972. Infection of *Antheraea mylitta* Druary (Lepidoptera : Saturniidae) by a microsporidian *Nosema* sp. *Indian Journal of Sericulture*, **11**(1) : 52-58.
- JOLLY, M. S. 1986. Pebrine and its control. Central Sericultural Research and Training Institute, Central Silk Board. Manandavadi, Mysore, India.
- KASKAROVA, L.F. 1981. Nosematosis of the silkworm. *Zashchita Rastenil*, **9** : 28-29.
- KISHORE, S., BAIG, M., NATARAJU, B.M., SHIVAPRASAD, N., IYENGER, M.N.S. and DUTTA, R.K. 1994. Cross infectivity of microsporidians isolated from wild Lepidoperan insects to silkworm, *Bombyx mori* L. *Indian Journal of Sericulture*, **33**(2) : 126-130.
- KRAMER, J. P. 1959. Observations on the seasonal incidence of microsporidiosis in European corn borer population in Illinois. *Entomophaga*, **4** : 37-42.
- LAI, P.F. AND CANNING, E. U. 1983. Some factors affecting spore replications of *Nosema algerae* (Microspora, Nosematidae) in *Pieris brassica* (Lepidoptera). *Journal of Invertebrate Pathology*, **41** : 20-26.
- MACHAY, M.L. 1957. Occurrence of *Nosema bombycis* Nageli among wild lepidopterans. *Folia Entomologia Hungarica*, **10** : 359-363.
- MADDOX, J. V. 1968. Generation time of the microsporidia *Nosema necatrix* in the larvae of the armyworm, *Pseudaletia unipuncta*. *Journal of Invertebrate Pathology*, **11** : 90-96.
- MALONE, L. A. and WIGLEY, P. J. 1981. Quantitative study on the pathogenecity of *Nosema carpocapsae* in Newzeland,. *Journal of Invertebrate Pathology*, **38** : 330-334.
- MANUAL OF SERICULTURE, Edited by the Member Secretary, Central Silk Board, Bangalore 560068, India, 1990
- MATSUMARA, S. and TAKEUCHI, K. 1950. Studies on the silkworm, *Bombyx mori* L. Nutrition of silkworm F1 hybrid recently approved. *Journal of Sericulture Science*, **19** : 192-200 (In Japanese).
- MISTRY, P. K. 1979. Cross infection studies on *Nosema* spp. of *Antheraea mylitta* and *Philosamia ricini*. *Annual Report of Central Tasar Research Station, Ranchi for 1978-79* : 49.
- NOMANI, K.R., KRISHNASWAMI, S. and SAHA KUNDU, A. K. 1971. Observation on the seasonal incidence and intencity of pebrine disease of the silkworm (*B.mori*) under West Bengal climatic conditions. *Indian Journal of Sericulture*, **10** : 101-104.
- PATIL, C. S, AMOGI, S. D. and NEELGUND, Y. F. 1983. Effect of temperature on the formation of sporocyst and their viability. *Archiv Fuer Protistenkunde*, **127** : 181-187.
- PATIL, C. S. 1989. Preliminary investigations on cross infections of microsporidian spores from tasar silkworm, *Antheraea mylitta* Druary to mulberry silkworm, *Bombyx mori* L. *Entomon*, **14**(3&4) : 207-210.
- PATIL, C.S. 1993. Review of pebrine, a microsporidian disease in the silkworm, *Bombyx mori* L. *Sericologia*, **33**(2) : 201-210.
- RAO, G. S., KAKOTY, P. K. & SAIKIA, H. C. 1976. Studies on cross infection on eri, muga, mulberry and tasar. *Annual Report, Central Muga and Eri Research Station, Titabar, Assam, India, for 1975-76* : 26-27.

- SATO, R., KOBAYASHI, M., WATANABE, H. and FUZIWARA, T. 1981 Serological discrimination of several kinds of microsporidia spore isolated from the silkworm, *Bombyx mori*, by an indirect fluorescent technique. *Journal of Sericulture Science, Japan*, 50 : 180-184.
- SENGUPTA, K. and GRIYAGHEY, U.P. 1981a. Cross infection studies of *Nosema* sp. of *Antheraea mylitta* to *Bombyx mori*. *Annual Report of Central Tasar Research Station, Ranchi* for 1980-81 : 65-66.
- SENGUPTA, K. and GRIYAGHEY, U.P. 1981b. Cross-infection studies on *Nosema* spores of *A. mylitta* to *Philosamia ricini*. *Annual Report of Central Tasar Research Station, Ranchi*, 1980-81 : 69-70.
- SHARMA, V.P., 2002. Introspection of muga silk production protection and improvement : Must in changing global silk scenario. *Textile Industry of India, Feature-2002* : 19-46.
- SLOTTER, L.F., ONSTAD, D.W. and MADDOX, J.V. 1989. Timing of disease influenced process in the life cycle of *Ostrinia nubilalis* infected with *Nosema pyrausta*. *Journal of Invertebrate Pathology*, 55 : 337-341.
- STEINHAUS, E.A. 1947. *Insect microbiology*, Comstock, Ithaca, New York : 763
- STEINHAUS, E.A. 1954. The effect of disease in insect population, *Hilgardia*, 23 : 193-216.
- TEETOR, G.E. and KRAMER, J.P. 1976. Dosage effect study of the Microsporidian *Octospora muscadomesticae* in the adult Black Blowfly *Phormia regina* with reference to the reproductive cycle of the pathogen. *Journal of Invertebrate Pathology*, 28 : 37-41.
- THANGAVELU, K. 1986. Inbreeding depression of heterosis in muga silkworm, *A. assama*. *Insect Science Application*, 8(1) : 61-63.
- UNDEEN, H.A. 1997. In : *Microsporidia (Protozoa) : A handbook of biology and research techniques*, Southern Cooperative Series, Bulletin No., 387.
- VEERANNA, G. 1999. Integrated silkworm disease management: China vs India. *Indian Silk*. July : 27-29.
- WILSON, G.G. 1984. Pathogenicity of *N. distriae*, *Pleistophora schubergi* and *Varimorpha necatrix* (Microsporidia) to larvae of the forest tent caterpillar *Malacosoma distriae*. *Zhurnal Parasitenkunde*, 70 : 763-767.
- WEISER, J. 1976. Microsporidia in invertebrates : host parasite relations at organismal level. In : *Comparative Pathobiology* (Eds. L. A. Bulla and T. C. Cheng), Plenum Press, New York, London, 1 : 164 -201.
- WINDELS, M. B., CHIANG, H. C. and FURGALA, B. 1976. Effect of *Nosema pyrausta* on pupa and adult stages of the European corn borer *Ostrinia nubilalis*. *Journal of Invertebrate Pathology*. 27 : 239-242.
- ZIMMACK, H. L., ARBUTHNOT, K.D. and BRINDLEY, T.A. 1954. Distribution of the European corn borer parasite, *Perezia pyraustae* and its effect on the host. *Journal of Economic Entomology*, 47 : 641-645.
- ZIMMACK, H.L. and BRINDLEY, T.A. 1957. The effect on protozoan parasite *Perezia pyrausta* Paillot on the European corn borer, *Journal of Economic Entomology*, 50 : 637-640.

THREAT TO NATURAL RESOURCE OF MARINE BIOTIC COMPONENTS AROUND SANKARPUR FISHING HARBOUR OF WEST BENGAL

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ABSTRACT

Sankarpur is one of the six minor fishing harbours of India, situated at the East Midnapore district of West Bengal (latitude 21°36' N and longitude 87°38' E). The natural bioresources in the coast around this harbour are heavily exploited owing to over crowding of motorized fishing vessels within a limited area leading to reduction of fish stock including juveniles. Other natural factors and pollution, etc. are also responsible for reduction of the resources in this coastal belt. The paper discusses the possible reasons of depletion of stock, and suggests a strategy for the conservation of the resources.

Key words : Fishery harbour; Sankarpur, bioresources, depletion, conservation

INTRODUCTION

In India, there are 6 major fishing harbours and 36 minor harbours. One of such harbours is Sankarpur harbour. Sankarpur (latitudes 21°39' N and longitudes 87°38' E) is situated at East Midnapore district of West Bengal under North East coast. Marine fishery potential of West Bengal is relatively less compared to that of other marine states of the country, as the coastline is short in this state.

It is a well known fact that a great threat to a quality environment is unsustainable pattern of consumption of natural resources. In recent years, demand of fish increases, consequently in the country develops a lucrative export business. There had been a tremendous development of fisheries along Digba-Rasulpur coast in West Bengal like other coastal areas of the country during the last decade. In this coastal belt, Sankarpur Fishing Harbour plays a vital role in fishing. Motorized fishing vessels fish major part within 50 m depth for this Harbour This type of fishing is based on

exploitation of multispecies stocks of mostly small size fish. Appreciable quantities of juveniles of fish are captured which could have grown to a considerable size, many roe bearing fish are also caught. This way breeding population is also disturbed and the coast is already under the threat of over exploitation. The main reasons for threat to the marine biotic components in this coastal belt are critically analyzed and the strategies for overcoming the problem are discussed.

MATERIALS AND METHODS

The data of marine bio-resources in the form of fishes and other invertebrates, fishing gears, fishing nets, etc. were collected from Shankarpur fishing harbour during the years 1990-1998. This landing station was periodically visited to collect catch data and other information. The technical details about fishing gears were collected from Hameed and Boopendranath (2000). At present more than 1500 motorized fishing vessels (locally known as 'trawler') operate from this harbour.

RESULTS AND DISCUSSION

Fisheries in Asia have shown a robust performance compared to the rest of the world. Asia contributes over 50% of the global production of capture fisheries (FAO, 2006). Available information indicates that out of 600 marine fisheries studied, 50% are fully exploited, which indicates that they have reached their maximum sustainable yield and there is no room for further increase in production (Mukherjee, 2007). Sea fishing in the coast around Shankarpur as well as in entire West Bengal coast is strictly speaking mainly concentrated in the foreshore areas, while in a few cases in the offshore region, equipped mainly with indigenous fishing requisites (*viz.* 'Sarni' and 'Vasani' nets) Hence, at present, the fishing operations are mainly concentrated within 50 m depth (Ramakrishna and Chatterjee, 1997). An analysis of the observations points to the possible causes of depletion in stock which are discussed in the foregoing paragraphs.

Reduction in mesh size : Reduced mesh size in fishing gear has led to reduction in the size at first capture of different species, capturing young fish in large quantities even before they spawn. This has disastrous consequences, resulting in the elimination of a fish species from the fishing ground. This has been particularly observed in the case of shrimp. Presently very large quantities of juveniles of commercial varieties are caught all along the coasts and sold as by-catch which forms the raw material for the poultry feed industry. This is a great wastage of resource. Valuable protein resources are fed to the poultry, which ultimately reaches the rich man's table.

Selective fishing : Certain selective fishing methods using specific gears are adopted to exploit some species like tuna, snappers, pomfrets, shrimps, squids, etc. Use of certain gears like purse seine and trawls in inshore waters has resulted in conflicts of interests between the traditional and the mechanized sectors.

Poaching by foreign vessels : The Exclusive Economic Zone is rich in resources like

groupers and snappers beside pelagic resources like tuna, bill fishes, clupeids, etc. A number of foreign vessels poach the foreign waters taking advantage of insufficient patrolling. If not checked, this can have serious implication. Coast guards and the Indian Navy have so far apprehended about 160 such foreign vessels fishing illegally within the 80 m depth contour. The Government of India has issued a few permits to foreign vessels and this has resulted in confusion at the time of patrolling.

Oil spills and other forms of pollution : Oil spills threaten the very existence of the coastal ecosystem. These can have serious short term as well as long-term effects on the marine fish stock.

To prevent over fishing and other reasons responsible for destruction of bioresources in future, a well-planned study should be executed before the introduction of new gears, which can have adverse effects on traditional fishery. Recommendation of experts point out that only artisanal fishery may be allowed to fish in the inshore waters from the view point of conservation as the inshore waters are presently over fished. Saldanha (1996) rightly pointed out that we had to learn a lot from our traditional fisher people who were totally guided by the forces of nature for conducting their fishing activity to protect the oceans' well being.

Although it is said that mesh size regulation is not a very effective management strategy, under the present multispecies fisheries an increase in the mesh size will be effective to some extent to overcome the problem of under utilized fishing to and help in successful recruitment of several species. The principal objective of mesh size regulation is to allow smaller size fish to escape and grow to a marketable size thereby preventing overfishing at the same time allowing individual fishes to reach maturity so that it would reproduce at least once in its life time.

Selection of suitable mesh size for the particular gear needs to be made after intensive experimental trials, and implemented strictly for various gears, localities as well as species

exploited. In addition, a legislation banning the capture and marketing of undersized fish, shrimp and other bottom fauna require to be formulated and implemented.

It is necessary to strictly implement the fishing legislation. The Indian fisheries act of 1897 calls for protection of juveniles and spawners. Special attention is needed to those causes which call for the ban of destructive methods such as dynamiting and use of fish toxins. Besides these certain other causes concerned with the conservation, protection of juveniles, spawners and their habitat may also be included under the act. Violation of the act is punishable under the court of law. The marine Fishing Regulation Acts stipulate that the mechanized fishing vessels should operate beyond 3-5 nautical miles from the coast to protect rights of traditional fishermen. In some states the extent of territorial water is earmarked for fishing by boats. This also acts as a management tool in the sense that the already over exploited stocks in inshore waters is given sufficient time and chance to replenish themselves under the low fishing pressures of artisan sector.

The Maritime Zones of India Act of 1981 specifies certain specific fishing zone beyond the territorial waters and also checks poaching by foreign vessels in our water. The guardians of law can bring about effective implementation of these acts by educating the fishermen and industrial fisheries operators about the legislation and also by intensifying patrolling. If there are legislations and mechanisms that could effectively stop this abuse of resource, commercial fisheries in India are bound to recover from the present stagnation within a few years time.

The majorities of fishermen in India are illiterate and have incomes much bellow the poverty line. Awareness can result in developing a better insight on the concept of conservation of resources and optimization of catch among the fishers. Government departments and NGOs can train fishermen on aspects pertaining to operation of deep sea fishing fleets, handling of electronics and other

deck equipments, their maintenance, beside marketing strategies, hygiene and proper handling, preservation and transportation of catch.

Fishing in the inshore waters has been a point of conflict between the powerful mechanized sector and the artisan sector over since the introduction of mechanization in the early 1960s. As cited earlier, numerous traditional fishing operations have been adversely affected owing to the relentless exploitation of inshore water by the mechanized fleets. Even though the near shore waters are earmarked for the artisan sector, encroachment goes on in the absence of effective patrolling by relevant governmental agencies. This has not only deprived our traditional fisher folk of their catch but has adversely effected the resource dynamics. The need of the hour is to clearly demarcate the fishing zones and increase patrolling from the viewpoint of conservation, equitable resource sharing and prevention of conflicts of interests.

The picture of deep sea fishing in India is not bright. The country has about 196 deep-sea vessels operating along both coasts. Considering the immense potential of about 3.9 million tonnes this industry is not doing well. The reasons have been attributed to insufficient database on resource mapping, delay in the issue of permits, licenses and hurdles in obtaining clearance from various government agencies, marketing problems, and lack of deep sea fishing policy, difficulties in obtaining financial assistance and several others. The recent statistics are quite alarming, pointing toward the failure of this industry. A planned development of the Indian deep sea fishing fleet is necessary to step up fish production. Since the return from this industry has been far from encouraging extensive resource surveys and resource mapping are needed to make the industry profitable.

Attention is also needed to the endangered marine fishes. International Action Plan for sharks initiated by CITES and FAO has established that more than 100 out of 400 shark species of the world are being continuously

exploited. The whale shark (*Rhincodon typus*), has been exploited since time immemorial. It has now reached a stage where its survival has become uncertain. The species is included in the list of 20 endangered shark species of the world (source : (<http://www.shark.ch/Database/EndangeredSharks/index.html>). The sawfishes belonging to genus *Pristis* are also threatened. Indonesia enacted legislation to protect saw fishes, following severe depletion of their population in the gill net fishery (Compagno and Cook, 2005). It is necessary to conserve them by adopting a few stringent conservation techniques. Mukherjee *et al.* (2003) recommended conservation of endangered marine and brackish water fish stocks through artificial propagation and larval rearing. Vessels found possessing any of the endangered animals or engaged in the activity of their capture should be confiscated and the people involved should be punished under the court of law. Enforcing the Indian Fisheries Act of 1897 and intensifying coastal patrols to book the offenders can easily achieve this.

Following the closed areas, closed seasons and banning monsoon trawling will expectedly help in conservation. Closed areas are those areas, declared closed for fishing during a particular period of time or round the year. Closed seasons are time periods declared closed for fishing in a given area or region. These two very effective tools for management of depleting stocks are adopted particularly during the critical times to facilitate recruitment of the species. The areas where the species spawn or the areas where the critical life history stages of the species congregate may be declared closed for fishing e.g. estuaries in the case of prawns. On smaller lines that part of the year coinciding with the breeding or migration may be declared closed for fishing. Trawls during monsoon can prove to be highly destructive as brooders, the young fin fish and shell fish may get caught. A ban on trawling during monsoon is called for on the west coast and east coast as numerous species breed and migrate at this time of the year. Violations of the ban order are quite common owing to the inefficient patrolling and surveillance

mechanisms. To make it effective patrolling should be intensified and those found guilty is booked.

Other issues where attention is needed are encouraging mariculture project and ocean ranching. As per the recent estimates; the total area available for sea farming is around 2 million ha. With such an immense potential, the activity can augment marine production. Similarly ocean ranching too is an important measure from the viewpoint of conservation of the marine resources. The country's research institutes should make the potential farmers aware about such activities and pass on the technical know-how.

Post harvest handling and preservation are also much needed. The seafood exporting industry is one of the largest foreign exchange earners in India. Freshness of the raw material is a prerequisite for a quality end product since sea food is a highly perishable commodity. Quality end products ensure better market and therefore better returns. Great care is needed to be exercised at the time of capture, handling, transportation and preservation. Fishermen should be made aware of the importance of maintaining hygiene and adopting proper handling techniques during capture and subsequent preservation, in order to minimize wastage at all levels of handling

CONCLUSION

As already discussed, Sankarpur is one of the minor fishing harbours of India. A large quantity of multispecies fishes is landed here. More than 90% of the marine catch comes from inshore water of less than 50 m depth. In our country total marine fishing resources available is estimated to be around 3.9 million tonnes of which the exploited quantity is only 2.69 million tonnes. There is an immense scope for increasing the fish landing. But at Sankarpur, there is no infrastructure for operation of deep sea fishing vessel. Thus a planned development of the deep sea fishing fleet is necessary to step up fish production. It is also necessary to induce advance technology for fishing in this region

to improve fish catch. Introduction of echo sounder, sonar, net recorder, etc. in the fishing vessels will undoubtedly improve the fishing activities. Extensive type of preservation like icing, drying and salting have only been done here. Processing center is very much necessary in this region, so that freezing, canning or other suitable methods of preservation could be done here. Thus increase the quality of the preserved fish and improve the foreign exchange value. There is also no marketing place. It is necessary to establish a market at Sankarpur.

For implementation of fishery regulation, it is essential to properly explore the marine living resources and accurately assess the catch composition on a regular basis. Apparently it appears that present day catch from Sankarpur region has reached the optimum level of consumption, hence any attempt to expand fishery activities within 50 m depth in this coast will be detrimental. We need to consider development and management and commissioning of implementing mechanisms in order to reduce conflicts of interests and to insure equitable and responsible resource sharing. A large number of fishermen are engaged in this harbour. Most of them are poor. More active participation of the Government is needed to improve the socio-economic status of the fishermen.

Therefore, the strategy involved in conservation of marine biotic resources include :

- ★ Need for a clear unbiased understanding for the present and future management issue in this sector.

- ★ Sharing of information and experience from the tropical multispecies fisheries management programmes in developing countries of the region.
- ★ Setting of end objectives for fulfillment of the three basic management functions viz. information acquisition, management options and enforcement within the EEZ.
- ★ Setting a participatory resource-sharing pattern acceptable to all end users within the framework of revised management regulations.
- ★ Dissemination of information with a view to creating awareness among end users on the needs and benefits accruing from informed and responsible resource sharing.
- ★ Creating an efficient monitoring and surveillance mechanism to strictly implement all regulations pertaining to Fisheries Act and Coastal Zone Regulation.
- ★ Setting up of a national agenda for fisheries planing and management, creation of the separate central ministry for fisheries and bringing marine fisheries under the central list and national consultative bodies with representation to all user sectors in order to effectively implement all regulations affecting common property resource management.

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LITERATURE CITED

- COMPAGNO, L. J. V. and COOK, S. F. 2005. Order Pristiformes, Saw fishes. In : *Sharks, rays and Chimaeras : the status of the Chondrichthyan fishes*. IUCN SSC Cambridge.
- FAO, 2006. *The state of world fisheries and aquaculture*. FAO.
- HAMEED, S. and BOOPENDRANATH, R. 2000. *Modern Fishing Gear Technology*. Daya Publishing House, New Delhi.
- MUKHERJEE, M. 2007. Dreaming Aqua Industry Cluster across the coastal West Bengal. *Natn. Workshop Sustainability Indian Aqu. Industry*, 2007, IIT Kgp. : 46-69.

- MUKHERJEE, M., PRAHARAJ, A and DAS, S. 2003. Conservation of endangered fish stocks through artificial propagation and larval rearing technique in West Bengal, India. <http://govdoes.aquake.org>.
- RAMAKRISHNA and CHATTERJEE, T.K. 1997. Need to conserve marine biotic resources for sustainable development of coastal fisheries at Digha-Rasulpur coast (West Bengal). *Proc. zool. Soc. Calcutta*, 50(1) : 63-68.
- SALDANHA, M. 1996. Living marine resources. In : *A report to the independent World Commission on the oceans*. The international Ocean Institute, Madras.

A SIMPLE DEVICE FOR SAMPLING OF BENTHIC FAUNA IN SHALLOW WATER BODY

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ABSTRACT

A simple, low cost easily operative instrument is designed for sampling of benthic organisms in shallow ponds. Studies had been conducted at six sewage fed and fresh water fishery ponds by using the devised equipment and the pertaining data are presented. The equipment is considered to be a substitute of the high cost conventional dredge. The instrument is about 84 cm in total length, of which the main working area or sampler part is a prism (dimension $24 \times 24 \times 24$ cm along length; $10 \times 10 \times 10$ cm along breadth; 9 cm in height). Qualitative estimation of benthic macrofauna has been done and quantitative determination is on progress.

Keywords : Sampler; Benthic macrofauna; Standardization

INTRODUCTION

Benthic fauna, specially, invertebrates are recognized as important component in determining water quality, as some benthic macro invertebrates are sensitive to pollution (Mason, 1981). They can be collected and handled easily, followed by identification (Ragothaman and Trivedy, 2002). There are a number of devices to study the benthic fauna of lentic ecosystem. Eckman dredge, Peterson & Poner dredges, Substrate corer etc. are popular sampler for study of benthic fauna. Hessler *et al.* (1974), Coggan (2006), Sulak *et al.* (2006) have described several samplers for collecting benthic macrofauna. A bibliography of samplers for benthic invertebrates (Elliot and Tullet, 1978, 1983) is available too. But, there are some practical difficulties in most of them, beside higher cost and problems of regular availabilities. Dredges are difficult to be operated in sandy bottom or macrophyte-

infested areas; moreover they work best at the surface level of the substratum. It is also not suitable for shallower ponds for all the times. Corer works better in shallow ponds with soft sediments, but it causes more leaning and bending to the user, which may not be convenient for all the times. To overcome the difficulty, a simple, low cost easily operative instrument is prepared which is a combination of both the two and can be suitable for both qualitative and quantitative estimation for benthic organisms in shallow fishery ponds. The equipment is considered to be a substitute of the high cost conventional dredge. Moreover, by slight modification, the same sampler can be used for quantitative sampling of macrofauna from floating and submerged macrophytes also. Although a good sampler for this purpose has been described already (Pal and Nandi, 1998), still it can be considered as a dual-purpose sampler for both littoral

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macrophyte associated as well as benthic macrofaunal study.

MATERIALS AND METHODS

The sampler is a metallic prism shaped structure with opening at both ends. The dimension is $24 \times 24 \times 24$ cm along length; $10 \times 10 \times 10$ cm along breadth; 9 cm in height. There is a small pointed projection at the lower end for easy penetration through pond bottom. The sampler part is supported by a handle (about 60 cm i.e. total length of the instrument becomes 84 cm) that helps it to penetrate the bottom from a considerable height, without much bending or leaning. The lower end can be closed by drawing a movable lid attached to the sampler with the help of a string connected to the handle or, may be kept open (Fig. 1). The volume of the sampler can be obtained by the mathematical formula of mensuration for a prism that is $\frac{1}{2} \times 10 \times 9 \times 24$ cubic cm. or, 1080 cubic cm.

OPERATION OF THE SAMPLER

The instrument is kept in vertical position at first, keeping the lower end open. Then it is carefully lowered in water and is allowed to penetrate through the substratum. When the sampler is filled with material the lid is closed and carefully lifted up. This ensures retention of definite volume of samples. The collected

samples are then sieved and transferred to a plastic bucket, or enamel tray containing water for washing and sorting of macrofauna.

The sampler can be used to study the macrofauna associated with littoral macrophytes also. For this purpose, the sampler can be lowered into the water over macrophytes and after introduction of the macrophyte, the lower end of the sampler is closed. The upper free end must be covered by nylon net for draining of excess water. The collected samples are ready for further studies.

STUDY AREA, FIELD TRIAL AND STANDARDIZATION OF THE SIZE OF SAMPLER

The sampler has been tested in a rearing pond of a sewage fed fishery pond (bheri) at Jhagrashisa under East Kolkata wetland, about 6km away from Salt Lake. A total of five samplers (dimension for pyramid is 6×20 , 8×22 , 10×24 , 12×26 , 14×28 cm respectively) were tested at five different points (named as I, II, III, IV, V) of the pond (at a depth about 30 cm) using each sampler for five times. The efficiency is measured by Dominance index (Berger and Parker 1970), Species diversity index and Simpson's index (Simpson, 1949). The results are tabulated and the suitable size of sampler is determined.

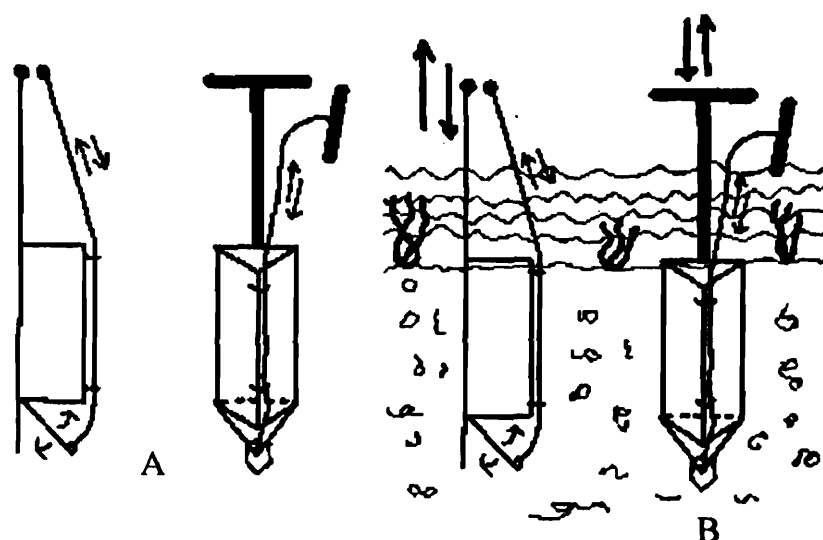


Fig. 1. Diagrammatic representation of the sampler ($10 \times 10 \times 10$ cm; $24 \times 24 \times 24$ cm) A. Sampler's side view; B. Sampler in use

RESULT

The observation data is depicted in Table-1. From the observation, four important ecological indices have been worked out (Figs. 2,3). The maximum numbers of species were obtained by sampler 10×24 cm, the highest value of dominance index (Berger and Parker, 1970), species diversity index are also shown by this size. The highest value of Simpson's index and Shanon index is shown by sampler size 12×26 cm, but richness value is minimum for this

sampler as minimum taxa are observed. Since, the species diversity is a suitable measure of function of species number and relative abundance (Odum, 1971), the sampler 10×24 cm is chosen for work.

DISCUSSION

From the result, it appears that, the samples contain a few representatives of class Oligochaeta and Hirudenia under the phylum Annelida; very few arachnid and crustacean

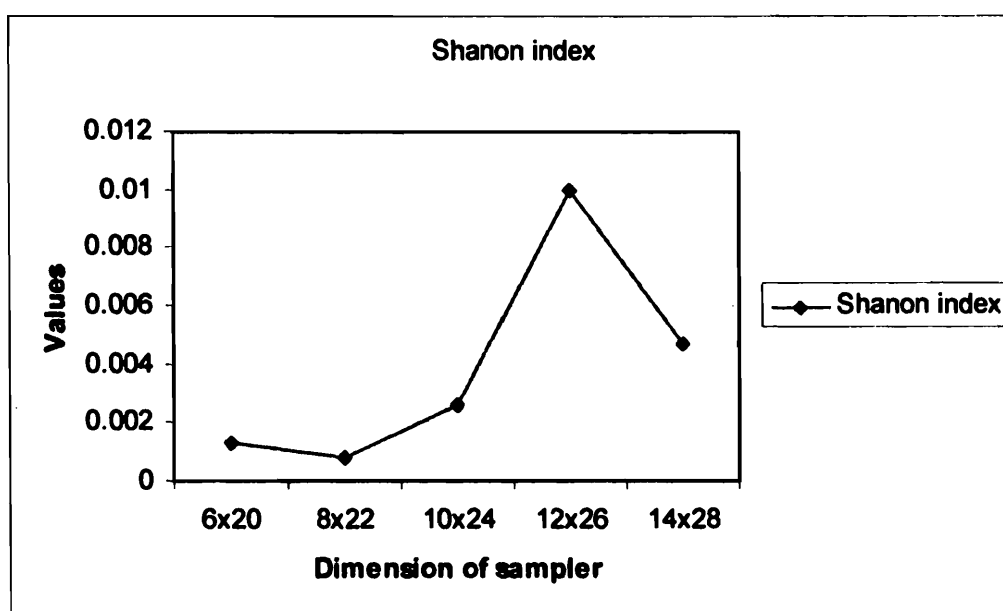


Fig. 2. Comparison of the values of Shanon index between different samplers.

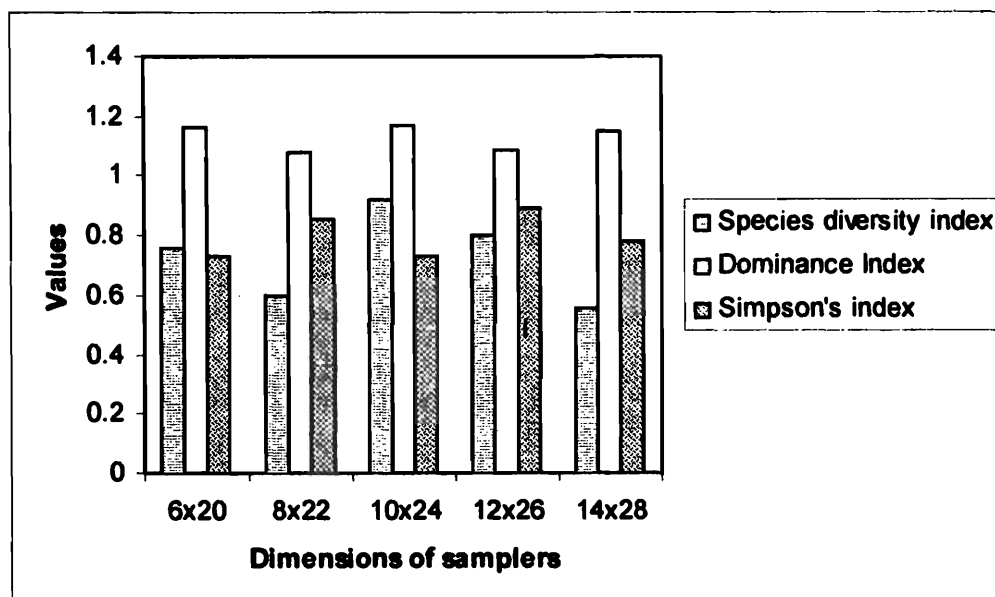


Fig. 3. Comparison of the values of Species diversity index, Dominance index and Simpson's index between different samplers.

Result for standardisation								
Sampler size	No. of Observation	Taxa with number of animals						Total
		Oligochaeta	Crustacea	Arachnida	Hirudenia	Hemiptera	Gastropoda	
6 × 20	I	1			1		12	
	II	1		1			10	
	III	1				1	11	
	IV	1			1		10	
	V				1		11	
	total	4		1	3	1	54	63
8 × 22	I		1				11	
	II			1			13	
	III						15	
	IV				1		16	
	V	1			1		10	
	total	2		1	2		65	70
10 × 24	I	2		1			12	
	II	1			1	1	11	
	III	1			1		15	
	IV	1					13	
	V	1			1		14	
	total	6		1	3	1	65	76
12 × 26	I						14	
	II	1			1		15	
	III	1					16	
	IV		1				14	
	V						12	
	total	3			1		71	75
14 × 28	I	1					12	
	II	2					18	
	III	1			1		15	
	IV				1		15	
	V	1	1		1		11	
	total	5	1		4		71	81

[Table 1 Results for standardization of the observation]

arthropods whereas abundance of molluscs, belonging to the class Gastropoda. A proper identification of the collected specimen upto species level is required for ascertaining the efficiency of the sampler and also for better understanding of the biodiversity of the respective ecosystem. Since the present workers are engaged in study of faunal community of

some selected ponds as mentioned earlier, there was an absolute requirement for a simple device specially for study of benthic fauna. The principal objective of designing the device was to collect and study the benthic fauna of shallow water bodies in a convenient way avoiding high cost and operational hazards. Thus, for standardization, specimens are identified upto

subclass level for separation as discrete groups, although study at further lower level taxa obviously would reflect more accurate results. Moreover, it is not possible to recommend single index as superior to other (Stiling, 2002), so the sample size is chosen after comparing different indices for community study. The value of degree of similarity $[S(x,y)]$ for two samples of totally dissimilar species composition would be zero, and for two identical samples $S(x,y)$ would be 100% (Minto, 1977). The values obtained for this function with the selected sampler (10×24) are in between 0.57 to 0.86 of which three samples give result more than 0.8. This indicates a high degree of similarity among five test sample units (Fig. 4). Thus chi square or Berdlett's M test may be computed after complete study in all the study areas and identification upto species level, will

also ensure uniform sampling, as well as the efficiency of the sampler to indicate the difference of ecological condition in the ponds.

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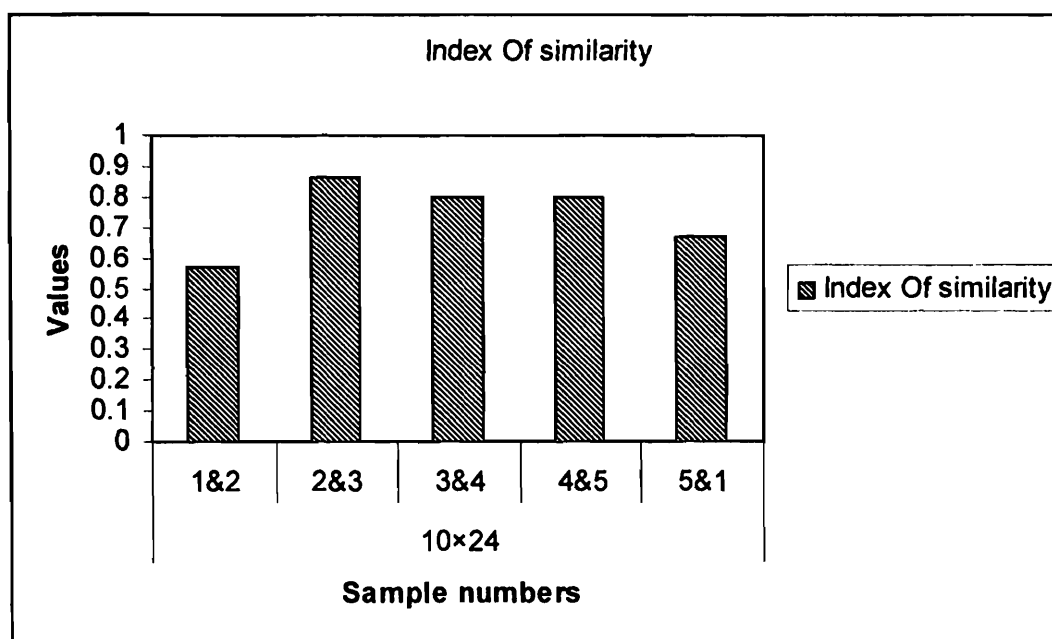


Fig. 4. Comparison of the Index of Similarity of different samples of the selected sampler

LITERATURE CITED

- BERGER, W. H. and PARKER, F. L, 1970. Diversity of planktonic foraminifera in deep sea sediments. *Science*, 168 : 1345-47.
- COGGAN, R, 2006. SOP for the collection of macrofaunal samples using a 0.1 m² Hamon grab *CEFAS SOP 1380 1 1.0 Hamon grabbing (PDF)*
- ELLIOT, J. M. and TULLET, P. A. 1978. A bibliography of samplers for benthic invertebrates. *Freshwat. boil. Ass. Occ. Publ*, 4, 61 pp
- ELLIOT, J. M, and TULLET, P.A.1983. A supplement to a bibliography of samplers for benthic invertebrates. *Freshwat. boil. Ass., Occ. Publ.* 20, 25 pp.

- FISHER, R.A. and YATES, F. 1974. Statistical tables for Biological, Agricultural and Medical Research, Longman.
- GERKING, S.D. 1957. A method of sampling the littoral macrofauna and its application. *Ecology*, **38** : 219-226.
- HESSLER, R. R. and JUMARS, P.A. 1974. Abyssal community analysis from replicate box cores in the central North Pacific. *Deep-Sea Research*, 1974, Vol. **21** : 185-209. Pergamon Press.
- MASON, C.F. 1981. Biology of freshwater pollution. Longman group Ltd.
- MICHAEL, P. 1984. Ecological method for field and laboratory Investigation. Tata McGraw Hill Publ. Co., New Delhi.
- MINTO, M.L. 1977. A sampling device for the invertebrate fauna of aquatic vegetation. *J. Freshwater Biology*, **7** : 425-430.
- NUTTAL, P.M., and PURVES J. B. 1974. Numerical indices applied to the results of a survey of the macro-invertebrate fauna of the Tamar catchment (southwest England). *J. Freshwater Biology* **4**(3), 213-222. Odum, E. P. 1971. Fundamentals of Ecology. Saunders, London.
- PAL, S. and NANDI, N. C. 1997. A simple device for Quantitative sampling of Macrofauna from Littoral Macrophytes. *J. Freshwater Biol.*, **9**(3-4) : 114-117.
- PROBERT, P. K. and ANDERSON, P. W. 1984. Quantitative distribution of benthic macrofauna of New Zealand, with particular reference to the west coast of the South Island *New Zealand Journal of Marine and Freshwater Research*, 1986, Vol. **20** : 281-290
- RAGOTHAMAN, G. and TRIVEDI, R. K. 2002. Aquatic Ecology. Agrobios (India).
- RICKLEFS, R. E. and MILLER, G. L. 1999. Ecology. 4th. Ed., W.H. Freeman & co., New York.
- SIMPSON, G. C. 1964. Species density of North American recent mammals. *Systematic Zoology*, **13** : 57-73.
- SOUTHWOOD, T.R.E. 1966. Ecological methods. Methuen, London.
- STILING, P. 2002. Ecology theory and applications. 4th. Ed., Prentice-Hall of India, New Delhi
- SULAK, K. J., LUKE, K. E., NOREM A. D. & RANDELL M. 2006. Sequential frame analysis of fishes associated with *Lophelia* reefs in the Gulf of Mexico. *11th International Deep-Sea Biology Symposium*, National Oceanography Centre, Southampton, Southampton Solent University Conference Centre, Southampton UK.
- TRIVEDI, P.R. and RAJ, G. 1992. Environmental water and soil analysis. Akashdeep publ, New Delhi
- WELCH, P. S. 1952. Limnological methods, The Blakistone Co. Philadelphia.

THREATENED FAUNAL DIVERSITY OF INDIAN SUNDARBANS MANGAL WITH REFERENCE TO THEIR HABITAT IDENTIFICATION AND NEED FOR ITS PRESERVATION

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ABSTRACT

The mangrove forests and the overall ecosystem in Indian Sundarbans are the ideal habitats for large group of terrestrial, avian and aquatic fauna. It contains the richest biodiversity among the inter-tidal forest in the world. The reason for high faunal diversity is the fact that here the ocean and land come in contact of each other. During the last two centuries, these highly productive mangrove ecosystems had been suffering from rapid destruction and degradation. If this negligence or ignorance continues in future there will be random exploitation of this natural resource and lost of diverse biota will be unavoidable. Recently, it has been established that natural factors along with direct and indirect human interferences have largely changed the biological composition, ecosystem function, productivity, regeneration and succession patterns within the mangrove ecosystem. The present paper attempts to highlight the major threats to the richest biodiversity of Indian Sundarbans mangrove ecosystem along with their status and habitat destruction.

Keywords : Biodiversity, Threats, Sundarbans, Faunal Habitat, Preservation.

INTRODUCTION

The Sundarbans is the largest Gangetic delta of the world. It is a land of majestic beauty for its tropical humid forest, luxuriant mangroves, wide rivers, sea facing islands and extensive estuaries. It covers an area of 9,630 sq. km, out of which 4,096 sq. km. is under Indian administration (Naskar & Guha Bakshi, 1987). The major land use patterns of the mangrove regions involve areas meant for agriculture, wildlife, forestry and recreation. The people have reclaimed the mangrove areas of the Sundarbans for many years for their settlement and agriculture (Chakrabarty, 1984). Most of the mangrove areas in the Indian Sundarbans have been degraded and converted to busy areas for the construction of harbours, industries, agricultural fields, human habitation,

grazing grounds or for regular exploitation of the forest products and also for the enhancement of tourism. This rapid rate of degradation affects the other living organisms and leads to occurrence of natural calamities like floods, hostile climates, and soil erosion considerably (Chaudhury & Chowdhury, 1994).

METHODOLOGY

The present study was undertaken at Indian Sundarbans area of West Bengal, which extends from 88°10' E to 89°51' E longitude and 21°31' N to 22°30' N latitude. For the last two years, during the establishment of Sundarban Biosphere Resource Information Centre, field survey was conducted in different parts of Sundarbans in West Bengal covering all seasons. The required data were collected during the

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course of such field trips, analyzed and presented in the following paper.

UNIQUENESS OF INDIAN SUNDARBANS MANGAL

In terms of zoogeography the situation of Sundarbans is better than that of any other regions of India. The strategic advantages are due to its unique physical factors, which no other districts in the sub-continent (except the adjoining delta regions of Bangladesh) enjoy. Three great biocycles of ocean, freshwater and land come into contact around the margins of this largest delta of the world. The succession from ocean to land and to the freshwater through estuaries is the most outstanding field for the huge amount of biodiversity. The gradient from saltwater to brackish-water to entirely freshwater fluctuates back and forth with the tides. Since freshwater is less dense and warmer, it flows over the top of the saltwater, with the result that strata with different physical characteristics are formed, which are inhabited by different kinds of fauna (Naskar, 2004).

The various species thriving in this vibrating ecosystem exhibit high degree of adaptive modifications as protection against the fluctuating environmental conditions. Topography of Sundarbans is also useful for all kinds of animals. Muddy and sticky substratum is the adobe of many groups of animals whereas deep, dense, mangrove forest is useful for the others who could also very well choose alternative suitable habitat. Burrowing animals easily withstand the cyclone, tidal inundation, weather hazards, etc. by simply retreating themselves completely within the holes. The diversity of animal life in Sundarbans is very vast, which cannot be restricted to their distribution.

The animal fauna can be subdivided on their range of salinity tolerance, which is a deciding factor for the zone closely associated with its mangrove forest, its salinity, its muddy and subsoil chemistry, tidal fluctuation, temperature and humidity. So due to the full adaptation of

all the animals with the surrounding environment of Sundarbans, this region contains the richest biodiversity among the inter-tidal forest in the world.

EXISTING STATUS OF FAUNAL DIVERSITY IN INDIAN PART OF SUNDARBANS

The mangrove ecosystem sustains a wide range of faunal diversity. Although, the faunal exploration of Sundarbans can be traced back to mid-eighteenth century and extensive studies have been carried out by the workers of Zoological Survey of India, but the recent works of Nandi *et al* (1984) and Das & Nandi (1999) provide an excellent data base of faunal diversity of the ecosystem from Protozoa to Mammals (Table I).

Sundarbans ecosystem is still one of the most biologically productive and taxonomically diverse ecosystems of the Indian sub-continent, but about 6 vertebrates have wiped out from this ecosystem, which were once common in this area (Naskar & Mandal, 1999) (Table II) and about 20 species are in the endangered / threatened species list (Chaudhury & Chowdhuri, 1994) (Table III).

GLIMPSE OF FAUNAL RESOURCES IN INDIAN SUNDARBANS

Sundarbans environment supports excellent wildlife resources in the mangrove swamps and is a host to important economic species in its aquatic ecosystem. The faunal resources can be utilized for industrial development and exports. Scientific utilization of these faunal resources through fishery, froggery and faunal farming may provide a base for employment and ancillary industries (Das & Nandi, 1999). This will help in the upliftment of the rural economy in addition to agri-maricultural prosperity of the country.

• Invertebrate Faunal Resources

Invertebrates are important faunal components of the Indian Sundarbans. In the mangrove ecosystem of deltaic Sundarbans,

Table-I. Distribution of animals in relation to habitats in Indian Sundarbans

INVERTEBRATE FAUNA (989 species)							
Kingdom	Sub kingdom	Phylum	Class	Total No. of species	Number of species in representing zone		
					Supra littoral	Inter-tidal	Estuarine
PROTISTA	Protozoa	Sarcomastigophora		46	26	6	14
		Apicomplexa		24	19	1	4
		Myxozoa		4		3	1
		Ciliophora		31	2	19	10
		Porifera		1		1	
				33	20	13	-
		Cnidaria	Hydrozoa	13		13	
			Anthozoa	20		-	20
		Ctenophora		2			2
				41	-	3	38
	Platyhelminthes		Turbellaria	1		1	-
			Monogenea	21	-	2	19
			Trematoda	13	-	-	13
			Cestoda	6	-	-	6
		Nemathelminthes		68	-	68	-
		Acanthocephala		3	-	-	3
		Nemertinea		2	-	2	-
		Rotifera		4	-	-	4
		Mollusca		142	12	116	14
		Sipuncula		2	-	2	-
ANIMALIA		Echiura		3	-	3	-
				78	9	69	-
		Annelida	Polychaeta	69	-	69	-
			Oligochaeta	6	6	-	-
			Hirudinea	3	3	-	-
				476	234	90	152
			Crustacea	240	-	90	150
		Arthropoda	Insecta	201	201	-	-
			Arachnida		33	33	-
			Merostomata	2	-	-	2
		Entoprocta	1			1	
		Bryozoa	3			3	
		Brachiopoda	1		1		
		Chaetognatha	4			4	
		Echinodermata	20		14	6	

Source : Sundarbans Mangal, ed. by K. Naskar, D. N. Guha Bakshi, Naya Prakash. 1999.

[Table-I]
VERTEBRATE FAUNA (445 species)

Phylum	Class	Total No. of species
CHORDATA	Condricthyes	22
	Osteichthyes	154
	Amphibia	8
	Reptilia	58
	Aves	163
	Mammalia	40

Source : Sundarbans Mangal, ed.by K. Naskar, D. N. Guha Bakshi, Naya Prakash.1999.

Table-II. Extinct Species from Indian Sundarbans Mangals

Scientific Name	Common Name
<i>Cairina scutulata</i> (S. Muller)	White-winged wood duck
<i>Muntiacus muntjac vaginalis</i> (Boddaert)	Barking deer
<i>Cervus duvauceli duvauceli</i> Cuvier	Swamp deer
<i>Bulbalus bulbalus bulbalus</i> (Linnaeus)	Wild buffalo
<i>Rhinoceros sondaicus</i>	Javan rhinoceros
<i>Rhinoceros unicornis</i> Linnaeus	Great one-horned rhinoceros

Source : Indian Sundarbans-An Overview by A.K. Raha, Sundarban Biosphere Reserve. West Bengal, 2004.

almost all the major invertebrate phyla are found with considerable species richness and a good number of them are commercially important.

- i. The rock bees (*Apis dorsata*), a conspicuous insect fauna of Sundarbans are intimately associated with the socio-economy of Sundarbans. A large number of honey collectors are engaged in this trade. (Fig. I – P.4.1.)
- ii. The crustacean prawns and crabs are the chief dominating fauna. Depending on the varieties of edible prawns and shrimps and crabs, prawn culture, shrimp culture and crab culture have been developed in this region, which help in rural economy.
- iii. The mangrove wetland of Indian Sundarbans also forms the habitat of two species of horseshoe crabs in this ecosystem namely *Carcinoscorpius rotundicauda* and *Tachypleus gigas*. They

have excellent biomedical values and have recently been established as potential source of biotic substances, like *Carcinoscorpius* Amoebocyte Lysate (CAL) and *Tachypleus* Amoebocyte Lysate (TAL) (Mitra & Banerjee, 2006). (Fig. II – P.4.2.)

- iv. Among molluscs, various gastropod and bivalve shells can be utilize in the lime industry. Many are edible and may profitably be involved in the shell fishery.
- v. The benthic invertebrate community encompasses several untapped marine living resources like edible oysters (*Saccostrea cucullata* and *Crassostrea cuttackensis*), calms, mussels, etc., which can bring possible important commercial culture to provide alternative source of livelihood. (Mitra & Banerjee, 2002) (Fig. III – P.4.3.)
- vi. Innumerable planktons and protozoans

Status of Different Faunal Habitats in Indian Sundarbans

Different Faunal Habitat	Dominant Animal Species	Existing Habitats
Estuarine and River Water	Crocodile, Dolphin, Water monitor, Shell-fish, Fin-fish, Tortoise, Turtle, Terrapins, numbers of Aquatic Fauna threatened.	Dolphin and some of the shellfish and finfish species are becoming rare and
Naked River Flats/River Slopes	Different species of Molluscs, Crabs, Annelids and Insects.	Status of different species is not explored in Sundarbans.
Vegetated River Flats and River Slopes	Spotted Deer, Monkey, Wild Boar, Snakes, Frogs, Insect, Annelids, Molluscs, Crustaceans.	Status of micro and smaller animals are not assessed in India Sundarbans, but population decreasing.
Dense Mangrove Forest Floor	Tiger, Fishing Cat, Leopard Cat, Jackal, Fox, Toddy Cat, Civet, Wild Boar, Spotted Deer and few others Reserve.	Tiger population is said to be increasing after conservation measure by Sundarban Tiger
Naked Mangrove Forest Floor	Snakes, Frogs, Rodents, Lesser Cat, Molluscs, Crustaceans, Insects, Annelids, etc.	Status of different species is not explored in Sundarbans.
Tree Canopy	Monkey, Bat, Birds, Snakes, Insects, Molluscs and others.	Migratory and other birds species gradually decreasing.
Amphibian Habitat	Most macro fauna, i.e., Tiger, Crocodile, Snakes, water monitor, good number of other fauna.	Heavy pressure threatened most of these fauna and their habitats in Indian Sundarbans.

contribute themselves as food for fishes and other aquatic animals.

• Vertebrate Faunal Resources

The Sundarbans mangrove ecosystem is also a unique reservoir of vertebrate fauna. This ecosystem is rich in terrestrial, aquatic and avian faunal community. Many of these well-represented vertebrates in the Sundarbans are endangered in other parts of the world and have maintained a unique status as a Heritage Site.

- Variety of commercially important fish species has been recorded in coastal areas

of Sundarbans, which is a main source of income of Sundarbans rural people. Non-edible and other low rated fishes are used for making fish-meal, poultry feed and manures.

- The creeks of Sundarbans form the home of estuarine crocodile (*Crocodylus porosus*). It is the nesting ground of Olive Ridley turtle (*Lepidochelys olivacea*) and River Terrapin (*Batagur baska*). The largest lizard of the world – Water Monitor (*Varanus salvator*) and Monitor Lizard (*Varanus flavescens*) are common in marshy places.

Table-III, Endangered/Threatened Species of Indian Sundarbans Mangrove Ecosystem

Scientific Name	Common Name
MAMMALS	
<i>Felis viverrina</i> (Bennett)	Fishing cat
<i>Panthera tigris tigris</i> (Linnaeus)	Tiger
<i>Platanista gangetica</i> (Ledeck)	Gangetic dolphin
<i>Orcella brevirostris</i> (Owen)	Irrawady dolphin
<i>Neophocaena phocaenoides</i> (Cuiver)	Little porpoise
BIRDS	
<i>Ardea goliath</i> Cretzschmar	Giant heron
<i>Leptoptilos dubius</i> (Horsfield)	Adjutant stork
<i>Haliacetus leucogastar</i> (Gmelin)	White bellied sea eagle
<i>Pandion haliaetus</i> (Linnaeus)	Osprey
Reptiles	
<i>Crocodylus porosus</i> Schneider	Estuarine Crocodile
<i>Lepidochelys olivacea</i> (Eschscholtz)	Olive Ridley turtle
<i>Batagur baska</i> (Gray)	River Terrapin
<i>Kachuga tecta</i> (Grey)	Indian tent turtle
<i>Lissemys punctata andersoni</i> (Webb)	Indian flap shelled turtle
<i>Trionyx gangeticus</i> (Cuvier)	Indian soft shelled turtle
<i>Trionyx hurum</i> Gray	Peacock marked soft shelled turtle
<i>Varanus bengalensis</i> (Daudin)	Common Indian monitor
<i>Varanus flavescens</i> (Gray)	Yellow monitor
<i>Varanus salvator</i> (Laurenti)	Water monitor
<i>Python molurus</i> Linnaeus	Indian rock python

Source : Mangroves of the Sundarbans, Volume I : India, by A. B. Chaudhury and A. Choudhury, IUCN, 1994.

Different species of poisonous and non-poisonous snakes are seen in abundance in this region.

- iii. Unlimited varieties of crops for food and mangrove forest and trees for shelter provide most lucrative natural abode for many species of birds. Sundarbans also attracts large number of the migratory birds, which enjoy roosting in this place.
- iv. The mangrove forest of Sundarbans is the

excellent habitat for the largest tiger population in the globe. Apart from Bengal Tiger, this forest has different types of wild mammals, like, Spotted Deer, Wild Pig, Fishing Cat, Civet Cat, Mongoose, Jackal, Fox, Monkey are found in plenty. The Fruit Bats and Flying Foxes are common in the garden. The Bandicoot rats, House rats and Shrews are frequently met with in the huts and houses. Among aquatic mammals Irrawaddy Dolphins



A



B

Fig. 1. Rock bee–*Apis dorsata* Source of Honey

Fig. 2. Horse shoe crabs-Source of Biotic Substances like CAL & TAL

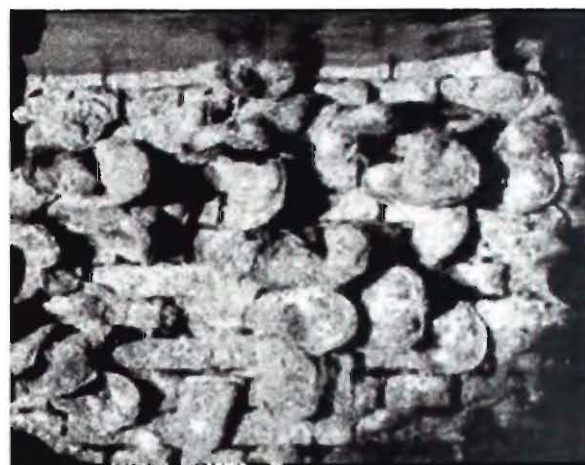


Fig. 3. Oyster-Source of possible Commercial Culture

and Porpoises are common in the estuarine rivers. (Chaudhury & Chowdhuri, 1994). (Fig. IV - P.5.1., P.5.2., P.5.3, P.5.4., P.5.5., P.5.6.)

MAJOR THREATS TO INDIAN SUNDARBANS BIODIVERSITY

The deltaic Sundarbans has been facing various kinds of threats. These threats are often direct functions of the people's need for the natural resources, but sometimes industrial and anthropogenic wastes from the nearby cities. Some of the major threats posing negative impacts on the richest biodiversity of this deltaic zone are as follows:

- **Uncontrolled collection of prawn seedlings** : Collection of shrimp/prawn seeds by the local villagers, for supplying to the commercial prawn culture firms has become an extremely attractive economic activity of common livelihood of Indian Sundarbans people, due to which a large variety of fin-fish and shell-fish juveniles are wasted (Mukherjee, 1984). (Fig. V – P. 5.7.)
- **Irregular fishing** : Unscientific fishing practices by the trawlers causes great damage to fishery stock and sea turtle population. (Kar, 2005) (Fig. VI – P.5.8.)



Fig. 4(1). *Boleophthalmus boddarti*



Fig. 4(2). Creeks of Sundarbans – Home of Estuarine Crocodile (*Crocodylus porosus*)



Fig. 4(3). Largest Lizard of Sundarbans Water Monitor (*Varanus salvator*)



Fig. 4(4). Nesting ground of Olive Ridley turtle (*Lepidochelys olivacea*)



Fig. 4(5). Civet Cat



Fig. 4(6). Royal Bengal Tiger–*Panthera tigris tigris* Only Mangrove-Tiger land of the World



Fig. 5. Catching of Tiger Prawns



Fig. 6. Uncontrolled & Irregular Fishing

- **Lime generation** : Exploitation of molluscan shells for lime manufacture prevents calcium recycling into the system and affects the ecological balance (Mitra & Banerjee, 2006).
- **Extension of non-forestry land** : The increased pressure on land for expansion of activities like aquaculture, prawn farming, drying of sea-fish, etc. are posing direct threat to the existing Indian Sundarbans mangroves (Naskar & Mandal, 1999).
- **Demand for small timber and fuel wood for local consumption** : Illegal cutting of timber and fuel wood from the fringe areas is common. Timber procurement has also caused considerable destruction of mangrove forest. (Fig. VII – P.5.9.)
- **Erosion** : The process of erosion is a common phenomenon in Indian Sundarbans due to current pattern and building of structures like guide walls, groins, etc. in the upstream region. Absence of protective vegetation cover in many areas of Indian Sundarbans has accelerated the process of erosion. (Fig. VIII – P.5.10.)
- **Construction of embankment** : It affects the drainage systems and cuts off the sweet water flow into adjoining areas, resulting in increased salinity in these areas. Due to the embankments the silt deposition along the inner banks and river beds from the tidal waves have raised the river beds to a higher level than of human settlements.
- **Loss of endangered species** : Many species like the tiger, fishing cat, gangetic dolphin, porpoise, adjutant stork, estuarine crocodile and olive ridley turtle have been marked as endangered species due to habitat destruction, increased salinity and illegal trade (Das & Nandy, 1999).
- **Man-animal conflict** : Straying of tigers into villages causes acute man-animal conflict, which poses direct threat to conservation efforts.
- **Deterioration of water quality** : Release of untreated wastes from the nearby city has caused deterioration of water quality in the western sector of Indian Sundarbans.
- **Dredging of riverbeds** : It is done to improve navigability of large vessels and oil tankers. Such operation directly affects the flora and fauna and also the fishery indirectly.
- **Unplanned tourism development** : In some regions of the mangrove island tourism have been developed in an unplanned way and so indiscriminate disturbance and environmental pollution are increasing day by day which seem to be an effective cause for destruction of Sundarbans mangrove ecosystem.

RESULT

Conservation Approaches needed for yielding Sustainable Benefits of Sundarbans Mangal.



Fig. 7. Exploitation of Mangrove Woods



Fig. 8. Erosion on the River Bank

The threats to Indian Sundarbans are mostly site specific in nature and indirectly related to the nature of resource, their exploitation pattern and socio-economic profile of the area. So there is a need of proper conservation approaches for protecting the richest biodiversity of this region. The greatest enemy of the Sundarbans is the poverty of its people. Deprived of any other means of sustenance, the inhabitants earn their livelihood by felling wood, catching fish-spawn in rivers and hunting, all of which destroy the natural resources and threaten the biodiversity of this area. Public awareness campaigns are urgently needed to inculcate environmental consciousness among people. Alternative means of income should be encouraged, replacing traditional methods that harm the ecosystem.

The Forest Departments and Fisheries Departments of Government of West Bengal and various NGOs have already adopted several strategies to conserve the vibrating mangrove ecosystem of Indian Sundarbans (Raha, 2004). Some of the important approaches are :

- Eco-Development and Joint Forest Management support activities
- Afforestation
- Vocational Training for prawn seed collectors
- Encouragement towards alternative livelihood
- Canal excavation
- Oyster culture
- Crab fattening
- Apiculture
- Pisciculture
- Development of Eco-tourism
- Establishment of Interpretation Centres

DISCUSSION

For keeping the nature in balance and for getting maximum benefit from these mangrove

wetlands, more and more planned conservation approaches are required to develop the sustainable awareness in such estuarine lands on an urgent basis, besides the above mentioned protective measures. In this estuarine wetland ecosystem of the Sundarbans, human influence would cause changes raising alarming conditions (Mandal, 2003). So, the main objective should be to convince the local people that they are the proud inhabitants of this World Heritage Site.

Proper scaling up of selective conservation related experiments and approaches, which generated positive result, are of utmost importance to maintain the pristine form of Indian Sundarbans. Community participation and alternative livelihood scheme implementations are mere experimental tools of conservation, which may have both positive and negative outputs (Mukherjee, 1984). Hence such experiments need to be conducted in selective pockets of this deltaic lobe.

□ Training Activities

In collaboration with the Forest Department other organizations should come forward to train the local people in alternative means of livelihood like –

- a) Potential agriculture techniques and procedures; such as – fodder and forage grass cultivation, medicinal plant gardening and the plantation of the selected fruit trees and timber producing plants, fibre yielding trees which may also help to improve the rural economy. By this artificial afforestation programme and by developing the social forestry, the pressure on the mangrove forest trees may be minimized.
- b) Economic and sustainable uses of the natural resources of the Sundarbans and other socio-economic implications may be considered.

□ Educational Activities

To generate mass education about this threatened environment some awareness programmes should be arranged in different

localities. By arranging such type of programme, people may be made aware about the—

- a) causes of degradation of the mangrove environment with special reference to anthropogenic activities.
- a) means and methods of preservation of the endangered or threatened mangrove biota and mangrove ecosystem of Sundarbans.
- b) effect of tourism development in the mangroves and recreation should be planned in such manner that the ecology is not destroyed.
- c) needs for wildlife development and conservation.

❑ Other Activities

- a) Survey and analysis of eco parameters of this threatened mangrove ecosystem may be done in collaboration with Government departments and various NGOs.
- b) Documentation of the significant faunal diversity followed by statistical data analysis of the scientific investigations is essential for keeping in mind the present status of the environment.

The proper activities for conserving the threatened environment of the Sundarbans are perhaps one of the sources to create any sustainable development. It is urgent to educate the rural people about the role of the mangrove ecosystem and ensuring alternative sources of livelihood for them (Mandal, 2003). It is expected that only by developing a sense of local awareness that this threatened environment of Indian Sundarbans Mangals be properly preserved.

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LITERATURE CITED

- CHAKRABARTI, K. 1984. Dynamics of Flora-Fauna Diversity in the Mangroves of Sundarbans and Laterite Tracts of West Bengal, India—A Bio-Ecological Study. *Environment & Ecology*, 7(3) : 220-232.
- CHAUDHURY, A. B. and CHOWDHURI, A. 1994. *Mangroves of Sundarbans*. Vol. I. IUCN. : 130-150.
- DAS, A. K. and NANDI, N. C. 1999. Fauna of Indian Sundarbans Mangal and their Role in Ecosystem in *Sundarbans Mangal* (ed. by Naskar, K., Guha Bakshi, D. N.) : 417-426.
- KAR, SAMIT ed. 2005. *Sundarbans—Problems and Prospects*. acb publication, Kolkata : 86-93, 78-81.
- MITRA, A. and PAL, S. 2002. *The Oscillating Mangrove Ecosystem and the Indian Sundarbans*. (Banerjee, Shakti Ranjan eds.) World Wide Fund for Nature—India : Kolkata : 19-25.
- MANDAL, A. K. 2003. *The Sundarbans of India—A Development Analysis*. INDUS : New Delhi : 78-91.
- MITRA, A. and BANERJEE, K. 2006. *Living Resources of the Sea : Focus Indian Sundarbans*. (Banerjee, Shakti Ranjan ed.) World Wide Fund for Nature—India: Kolkata. pp. 83-89, 91-105.
- MUKHERJEE, A. K. 1975. The Sundarban of India and its Biota. *J. Bombay Nat. Hist. Soc.*, 72(1) : 1-20.

- MUKHERJEE, A. K. 1984. Mangrove Wealth of Indian Sundarbans—Utilisation and Conservation, *J. Econ. Tax. Bot.*, 5(1) : 227-231
- NANDI, N.C. 1984. Faunal Resources of Sunderbans—its Prespective and Predicaments. *Environment & Ecology*, 2 : 99-102.
- NASKAR, K. 2004. *Manual of Indian Mangroves*, Daya Publishing House, Delhi. : 38-40, 172-177.
- NASKAR, K. & GUHA BAKSHI, D.N. 1987. *Mangroves Swamps of the Sundarbans—An Ecological Perspective*, Naya Prakash, Kolkata : 4-10.
- NASKAR, K. and MANDAL, R. 1999. *Ecology and Biodiversity of Indian Mangroves*, Daya Publishing House, Delhi : 188-195.
- RAHA, A.K. 2004. *Indian Sundarbans – An Overview*, Sundarban Biosphere Reserve. West Bengal. : 20 -25.

