4.0 MATERIALS AND METHODS

4.1 STUDY SITES

A brief description of the wetlands selected for ecological studies of the community structure of zooplankton population is given below. Four different types of wetlands located in four districts of south West Bengal were chosen, namely, East Kolkata Wetlands (Kolkata), Canning (South 24-Parganas), Dankuni (Hugli) and Bangaon (North 24-Parganans). A Bheri is the local name given to a semi-enclosed form of waterbody where pisciculture is carried out by drawing water from a nearby river or from other point source like the sewage water. A Baor or oxbow lake is the portion of the river that is left out by siltation during its later course through the plain land and it may or may not remain connected to the main river. A Jheel or lake is a large natural fresh waterbody that is larger in area and deeper than a pond and receives water from the rain, seepage and surface runoffs.

4.1.1 Sewage fed freshwater fishponds of East Kolkata wetlands ("Bheries"/Dykes)

Bheries are semienclosed waterbodies, which are used for intensive fish culture drawing water from sewage or waste released by the surrounding human settlement. EKW is a complex biological system and a natural waste management system, an integrated resource system, where 600 million litres of liquid sewage and 2500 tonnes of garbage are dumped everyday. 150 tonnes of fresh vegetables are produced daily, and paddy field produce goes upto 16000 tonnes in POM. Aquaculture receives increasing importance in the country, as it is a mean for augmenting food production, as enterprise for improving economy and an operation for productive utilization of land and water bodies.

GEOGRAPHICAL FEATURES

The wetlands lying in the eastern part of the city of Kolkata is situated between 22°25'-22°40'N latitude and 88°20'-88°35' E longitude and covering an area of...
East Kolkata Wetlands

Map 3
about 12,500 ha. The climate here in Kolkata is of tropical monsoon type, hot and humid but varies seasonally. Being located between the Equator and Tropic of Cancer, the area is predominantly hot with three main seasons, namely, summer (Premonsoon) or the hot dry season from March to June, Monsoon or wet rainy season from July to October and winter (Postmonsoon) or the cool, dry season from November to February. Heavy rainfall occurs during monsoon period with higher humidity ranging from 60-95%. Occasional rains occur almost throughout the year. More than 80% rain falls in the monsoon months, which are brought about by South-west monsoon winds. Premonsoon period is predominantly dry and warm accompanied by occasional violent thunderstorms or hail storms. Postmonsoon period is characterized by cold weather with negligible rainfall. The temperatures range between 10°C-22°C in winter and maximum temperature in summer varies between 30°C and 38°C. Average relative humidity is high between 70%-90% and average annual rainfall is about 1582mm.

HISTORY OF SEWAGE SYSTEM OF EAST CALCUTTA WETLANDS

The wetlands are located between the levée of the river Hugli to the west and that of the presently dead river Bidhyadhan to the east. Since 1850, the wetlands of Calcutta were reclaimed for brackishwater aquaculture. The source of water at that time was the tidal river Bidhyadhan that received water from river Hugli and its other tributaries, thus inundating large areas of North 24 Parganas including North and South Salt Lakes and areas east of Calcutta. But in course of time, the river water depleted due to heavy silting. The river stopped receiving water from the Hugli and its tributaries and depended on the rainwater. Gradually, the river completely lost connection with the main river resulting in its death. With the death of the river and the elimination of the tidal water, which fed fishponds, the entire area gradually became a vast derelict swamp. As the fishponds were deprived of a continuous supply of tidal water to run viably, one of the leading fish farmers experimented with sewage as a substrate for growing fish in 1929-30 (Ghosh and Sen, 1987). Then gradually, other fishermen adopted this method of fish culture and wastewater-fed
fishponds, locally called the bhenes, came into existence These wetlands
cover a large area of about 10-12 km

HYDROLOGY
The hydrologic regime of the wastewater –fed fishponds has unique
properties It is neither lotic nor lentic. Wastewater is introduced into the
fishponds in batches When these ponds are large (>40 ha) the wastewater
flow is almost continuous and the water regime becomes lotic Sewage is
largely organic and inorganic solids in dissolved and suspended forms The
photosynthetic activity within these ponds is the basis of natural biological
purification

CALENDAR OF ACTIVITIES
The wastewater-fed fishpond system follows a systematic calendar of activities
involving 5 major phases pond preparation, primary fertilization, fish stocking,
secondary fertilization and fish harvesting The waste recycling includes four
principal resource recovery practices garbage vegetable farms, wastewater-
fed fishponds, paddy fields using fishpond effluent and sewage-fed
aquaculture

The farmers utilize water hyacinth (Eichhornia crassipes), the floating aquatic
weed, around the periphery of the pond to protect the bank from erosion by
surface waves and prevent illegal netting of fishes Water hyacinth also
provides shade to the fish and absorbs heavy metal toxic ions present in
wastewater The weeds cover a large part of the water surface during early
summer but declines in winter Periodically, the weeds are removed

PATTERN OF OWNERSHIP
There are various forms of ownership of the sewage-fed fishponds Most of the
fishponds are privately managed, a small cluster is under the cooperative
society of farmers and a few are managed by the State Government Fisheries
Department
Aerial view of East Kolkata Wetlands

Part of Sukantonagar Bheri
Plate 1
BIODIVERSITY IN EAST KOLKATA WETLANDS

Wetland ecosystems are rich sites of biodiversity. There are about 100 plant species recorded in and around this region, a few include *Sagittana montividensis*, *Cryptocoryene ciliata*, *Cyperus* spp, *Crostichum aureum* and *Ipomoea aquatica*. About 160 species of birds, both aquatic and terrestrial, some migratory fowls have been recorded from this region. Some of the common birds observed here are Black cormorants, Lesser goldenbacked woodpecker, whitebreasted Kingfisher, Rose ringed parakeet, Rock Pigeon, Little cormorant, Little Egret, House crow, Jungle crow, Black drongo, Common myna and House sparrow.

Amongst the rare mammals in the area are the Marsh Mongoose, Small Indian Mongoose, Palm Civet, and Small Indian Civet and the common ones include bats, *Bandicoota bengalensis*, squirrel and mouse, which are found in large numbers. About 20 mammals are reported from this region. Different types of reptiles recorded from the wetlands are water snakes, monitor lizard, common lizards (*Hemidactylus flaviviridis*), *Calotes versicolor*, freshwater tortoises and *Mabuia caranata*. Snakes common to the wetland include the checkered keel back (*Xenochrophis piscator*), Smooth water snake (*Enhydris enhydrids*), Buff striped keel back (*Amphiesma stolata*), Bronze back tree snake (*Tendrelaphis pristis*), *Naja naja*, *Naja kaonthia*, *Vipera russelli*. The amphibians common to this place are *Rana tigrina*, *Rana hexadactyla* and *Bufo melanostictus*.

**EKW – A Ramsar site**

East Kolkata Wetlands (EKW) was declared a Ramsar site (Ramsar site No 1208) by the Ramsar Convention Bureau on August 2002 under the article 8 as per Ramsar guidelines and recognized as “Wetland of International importance.” The justification for declaring EKW as Ramsar site were –

1) It is an example of wise use and sustainable development of a wetland ecosystem where usage of city sewage for traditional practices of fisheries and aquaculture is practiced.
2) It is a rare example of combination of environmental protection and development where the local farmers have adopted a complex ecological process by mastering resource recovery activity.

3) It is the largest sewage-fed aquaculture in the world.

One among these bheres or sewage-fed fishponds namely, Sukantonagar bhen, was selected for study keeping in view their importance and paucity of literature. The geographic position of this bhen is 22°33'42.7"-22°33'71.6"N and 88°25'09.9"-88°25'26.0"E and at an altitude of 34 ft from the sea level. It is a rectangular shaped pond covering an area of 25 acres approximately with a mean depth of 4 ft (1.2192m) the bhen is managed by the Sukantonagar Fishermen Cooperative Society (whose office known as “Aala” in local dialect) located near the bhen. The general features of the bhen are:

a) It has an inlet on the eastern side and an outlet on the northwestern side.

b) A stilt house made of bamboo called the “Machha” or watchtower to guard the bhen is constructed. There are 3 such “Machha” in this bhen.

c) The sewage is let in periodically through sieve made of bamboo called “Patta”.

Most of the major Indian carps (Labeo rohita, Catla catla, Cirrhinus mrigala), wild fishes (Channa punctatus, Chanda sp, Clarias batrachus, Anabas testudineus and Puntius sp) and exotic carps (Ctenopharyngodon idella, Hypophthalmichthys molitrix, Cyprinus carpio, Oreochromis mossambica) are cultured. Yield is variable with a mean of 105 kg per acre and about 1000 kgs per month.

Though extensive work has been done on the general diversity of avifauna, mammals, reptiles and aquaculture practices, not much study has been carried out on the aquatic faunal biodiversity (excluding fishes). Keeping this in view, a bhen was selected for intensive limnological studies including physico-chemical and biological characteristics.
During the study period covering two annual cycles minimum and maximum atmospheric temperature was recorded in January (25°C in first annual cycle and 21°C in second annual cycle) and in June (34.7°C for the first annual cycle) and April (35°C for the second annual cycle) respectively. Rainfall was very heavy during the monsoon season ranging from 213 to 351mm. The maximum relative humidity varied from 90-98% and minimum from 32-93% during this period.

4.1.2 Brackishwater shrimp culture ponds of Canning ("Bheries"/Dykes)

The brackish water areas have been recognized as the most productive ecosystem on our planet since these areas are rich in nutrients, especially nitrogen and phosphate, needed for plant and animal growth. The supply of these nutrients is continuously replenished by flow from rivers, seas, and the adjacent lands. These are complex and dynamic habitats since these are connected to sea and there is fluctuation in salinity due to tidal effects, rainfall, and floods. These areas are also famous for their quantitatively rich faunal resources though smaller in qualitative nature.

Numerous studies have been carried out on the various aspects of brackishwater aquaculture, fish-cum-paddy culture, and sociobiological investigations of the estuarine complex of the Sundarban region. But little knowledge is available on the biological and physico-chemical characteristics of the "nona-bheries" (saline dykes) present along the river Matla, near Canning.

GEOGRAPHICAL FEATURES

Canning town is located at about 25 kms from the city of Kolkata and there are a large number of brackish water fish farms called "nona bheries" along the Matla riverbank, which draw saline water from the Hugli-Matla riverine system. In such fish culture ponds, brackishwater finfish and shellfish are cultured.

The maximum and minimum atmospheric temperatures generally varies from 26°C-38°C and 12°C-27°C respectively in Canning. The annual precipitation varied from 0.9 to 554.5 mm during the study period. Maximum rainfall occurred from July to October during both annual cycles. The relative humidity (R.H.) is...
An aerial view of Matla river and the bheries located near it

A part of Nikarighata bheri near river Matla

Plate 2
generally high with the range of maximum R H being 83-96% and that of minimum being 33-85%

A study was undertaken on the general ecology of the fishponds situated near the river Matla. For this purpose, a privately owned bhen, Nikarighata bhen (geographical position 21°54'N 88°24'E, 21°9N 88°4E) situated near the Canning town was chosen. It is rectangular in shape and covers a large area of about 60 acres with depth ranging between 4-5 feet (1.2192-1.524m).

HISTORICAL REVIEW

Old records refer to lower Bengal as a land of hundreds of rivers and rivulets. Most of the rivers, which generally flow from the north to the south, are influenced by tides from the Bay of Bengal. The channels connecting these rivers flow from East or West. The main estuaries from West to East are the Hugli, Saptamukhi, Thakuran, Matla, Bidya, Ajmalmani, Bidyadharin, Gosaba, Kalindi, and Raimangal. The western estuarine complex as a whole is known as the Hugli-Matla estuary where the process of delta formation is active. The Matla River was once considered the largest and deepest river of the area and was navigable throughout the year by ocean-going vessels. The town of Canning was located on its banks and formed an important port connected with the Calcutta canal through the rivers Piali, Bidyadharin, and Rampura Khal. As these rivers dried up in course of time, the freshwater flow to the Matla River was lost and the river also became narrower with the reclamation of its beds for aquaculture activities and human settlement.

HYDROLOGY

The bhenes or semienclosed ponds are either extensive type, where the water is drawn along with the juveniles of fishes during high tides or intensive type where ponds are stocked with fish seeds at certain intervals. Each pond has one main sluice gate to let in water, which is provided with shutters to regulate the water level. There are bamboo-gratings in front of sluice gates to prevent the fishes in the ponds from escaping when the gates are opened. Most of the bhenes are privately owned by local fishermen.
**BHERI MANAGEMENT**

The culture of fishes commences in January –February when ponds are stocked with fry and filled with river water. From February to April, only tidal water is let in occasionally, embankments are repaired if required and the bhen is guarded to prevent theft. Several twigs are stuck into the bottom of the canals to prevent easy fishing by the poachers. Fishing occurs on a small scale during May-June. Large-scale fishing operations are carried out between September and November. As no tidal water is required in the ponds during this period, excess of water is released back taking care that the spawn and fry do not escape.

**BIODIVERSITY**

This estuarine wetland covers some of the faunal resources of Sunderbans. The common birds sighted here include herons, cormorants, egrets, kingfishers and spotted dove. The estuarine crocodile has been reported to occur in the river Matla and attacking humans. Frogs and toads such as the common toad, skipper frog, pond green frog are common residents. The fish species cultivated include *Catla catla*, *Cirrhinus mrigala*, *Labeo* spp. Commercially important fish and prawn species bred are *Lates calcarifer*, *Macrobrachium rosenbergii*, *Penaeus* spp., *Tilapia mossambica* which require high saline conditions (20-35 μmhos/cm). There is complete absence of aquatic macrophytic vegetation and the flora constituted of mainly phytoplankton, some algae and fungi in the littoral zone and the terrestrial plants.

**4.1.3 Freshwater Marshy natural wetlands of Dunkuni**

**GEOGRAPHICAL FEATURES**

The Hugli district is bounded by Hugli River on the East, Rupnarayan River on South –West and intersected by Damodar River. There are a large number of marshy wetlands located in the Hugli district of West Bengal. These constitute about 17.87% of the total wetland area. These natural freshwater marshes are known as ‘jolas’, which vary in shape, size, origin, vegetation type and hold surface run-off or flood waters during monsoon.

The Dunkuni Railway jheel is located along the railway tracks near the Dunkuni station. Its exact geographical position constitutes 22°40’178”-22°40’368”N and
Hugli district

Map 5
It is an elongated type of wetland about 48 acres in area and 6-7 feet (1.8288-2.1336 m) deep. The source of water for this jheel is rainwater, surface runoffs constituting of agricultural waste water and drainage water.

The maximum temperature varies from 23°C to 38°C and the minimum temperature from 13°C to 27°C. The annual precipitation generally ranges from 16-310 mm with maximum rainfall during June-October. During the postmonsoon months very little precipitation occurs.

**Biodiversity**

Wetlands are inhabited by aquatic species as well as wetland dependent and wetland associated species of fauna. Some terrestrial and arboreal species are also found as ‘occasional visitors’. Some of the vertebrate fauna recorded during the study period are given here.

Mammalian species found here include Bandicoot Rat and Mabuya, which are dependent on the wetlands. Though there are earlier reports of jackal, Indian fox, Small Indian Mongoose, small Indian civet to have been found around the wetlands, they are no longer visible due to human settlement, landscape changes due to reclamation for agricultural activities, and industrial development. The avian species, either resident or migratory, depending on wetlands are comprised of swimmers, divers, waders, kingfishers and kites. Among the wetland dependent resident birds, 9 species were recorded namely Little Grebe, Little Cormorant, Darter, Pond Heron, Cattle Egret, Little Egret, Cotton teal, Brahminy Kite, Common Kingfisher, and the migratory birds were represented by Pintail, Gadwal, garganey whereas reed inhabiting wetland associated birds comprised of long-tailed tailor bird and red-vented bulbul. Both water fowls and waders are in great pressure of hunting particularly during winter months, hence their population is dwindling.

The wetlands are inhabited by a number of water snakes such as checkered keelback and Indian cobra is very common especially during monsoon. There are quite a few species of amphibians like skipper frog, Indian Bull frog, Green frog.
An aerial view of Dunkuni Railway Jheel

A part of Dunkuni Railway jheel

Plate 3
and common Indian Toad which are found to be active after heavy rains and dependent on the wetlands for completing the larval stages of their life-cycle. The fishes cultured in the wetlands include Catla sp, Labeo sp, Mrgala sp, Common carp, Channa sp, Chanda sp, Anabas sp, and these are either marketed or consumed by the people who manage the wetland. It can be said that all categories of fishes—major and minor Indian carps, exotic carps and siluroid species are cultured here.

Various types of floating, fixed and amphibious macrophytes occur in abundance. Some of the commercially important emergent plants include Shola (Aeschynomene indica), Madurkathi and Mutha grass (Cyperus spp), Kalmi shak (Ipomoea aquatica) and Hogla (Typha elephantona), rooted forms include Sushmi shak (Marsilea quadrifoliata) and Paniphal (Trapa bispinosa) and free floating forms are commonly occurring water hyacinth, water lettuce and duckweeds.

Thus the marshy wetlands of Dankuni are home to wild varieties of flora and fauna. Though there are reports on the aquatic flora, avifauna and general features of these types of wetlands, but not much literature is available on the wetland ecology, limnology and aquatic fauna of these wetlands. Hence, an intensive study was carried out on the occurrence and abundance of microinvertebrates, primary productivity and biotic and abiotic interactions in a selected wetland.

ANTHROPOGENIC ACTIVITIES

The wetland is a source of water for various domestic purposes of the local people living around the ‘jolas’, such as for bathing, washing, and cattle bathing. Fishing and paddy culture is also carried out. The drainage from the nearby human dwellings falls onto one side of the wetland where the powerhouse for electric supply is located. Fishing is carried out occasionally and the profit made by marketing is distributed among the people managing the wetland. Enterprising individuals and local bodies take interest in the management of the jheel. The jheel is cleaned of weeds and wastes and desilted at regular intervals. The soil is enriched with fertilizers.
MANAGEMENT

There is no proper managing body or cooperative society to look after this water body and undertake organized fishing activities. This wetland is divided into many small areas by putting up wires aerally without any physical intervention into the wetland. Each specific area is allotted to a small group of local people who carry out fishing in those specific zones. On the whole, the wetland is not very productive one but if managed properly it can be a source of livelihood to people living around it.

4.1.4 Floodplain wetland or ox-bow lake in Icchamati river basin at Bangaon

GEOGRAPHICAL FEATURES

Located at about 8 km west of the Bangaon subdivision (23°07'N 88°82'E) of North 24 Parganas district (23°4' N, 88°49' E) is a small town, Gopalnagar, on the Sealdah-Bangaon section of Eastern Railway, about 77 km from Sealdah Station, where the river Icchamati has formed a number of floodplain wetlands. This is an open type (having connection with the source at one side) of oxbow lake (locally known as “Baor”) 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. It has an average elevation of 7 meters.

The temperature in this region generally varies between 12°C and 38°C. The relative humidity during this period was found to vary from 67% to 88%. The total annual precipitation was 1262mm with the maximum rainfall occurring during July-October (110 mm-338mm).

HISTORICAL REVIEW

The meandering nature of the Icchamati River resulted in the formation of this floodplain wetland in the lower Gangetic plain of West Bengal. It is a gateway to the neighbouring country of Bangladesh as the two countries share the river water. It is used for navigation, fishing activities and also for religious purposes during festivals (people of both countries use it for immersion of the idols after the festival of Durga puja during the months of September-October).
An aerial view of Gopalnagar baor of river Icchamati

A view of Gopalnagar baor, Bangaon

Plate 4
HYDROLOGY
This open type of Ox-bow Lake is connected to the river Icchamati at one side, which is the source of water throughout the year thus forming a unique type of lotic system. During the monsoon season when the river gets flooded the excess water enters the baor through the inlet. In postmonsoon and premonsoon the level of water decreases as the river water also reduces and the source of water is occasional precipitation and surface run-off. The source of nutrient inputs is both autochthonous, mainly through the rapid decay of macrophytes, as well as allochthonous.

BAOR MANAGEMENT AND CALENDAR OF ACTIVITIES
This baor is managed by the Barrackpore Fishermen’s Cooperative Society whose headquarters is situated at Beledanga in North 24 Parganas. Organized fishing is carried out by the cooperative of fishermen on a regular basis. Fingerlings of Indian Major Carps, common carp, silver carp and grass carp are released periodically. The yield varies between 700-2300kg/ha in a year and these are properly recorded and marketed. The income obtained from these catches is distributed among the members of the society. Sometimes the fishermen have to incur heavy losses due to mass mortality of the fishes especially when there is overgrowth of macrophytic vegetation. The ox-bow lake is cleaned regularly of weeds leaving only at the sides and bottom.

ANTHROPOGENIC ACTIVITIES
The ox-bow lake has a large number of human settlement, agricultural fields and jute fields on its banks and the people depend on the lake water for their daily activities like bathing, washing, agricultural purposes and transport. This poses a heavy pressure on the natural resources of the lake.

BIODIVERSITY
The ox-bow lake possesses a high biodiversity of both vertebrate and invertebrate forms. The vertebrates include wetlands dependent mammals, viz, *Bandicoota indica* (Bandicoot rat), birds including resident species and migratory species of waders, eagles and kingfishers, reptiles like water snakes, monitors, amphibians namely, *Rana* spp, *Microhyla* sp and fishes like *Cyprinus carpio*, *Puntius* spp,
A view of Dunkuni Railway jheel

Inlet for the sewage water at Sukantonagar Bheri

Plate 5
Labeo spp, Catla catla, Cirrhinus mrigala, Ctenopharyngodon idella, Lepidocephalus guntea, Clarias batrachus, Channa spp, Chanda sp, Lates calcalifer, etc.

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. Altogether 16 taxa of macrophytes were recorded throughout the oxbow lake during the study period. 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 submerged group like Ceratophyllum sp, Hydrilla sp, Potamogeton sp and Vallisneria sp were the major contributors throughout the year in the baor. Rooted floating macrophytes were represented by Limnophila sp. and Nymphaea sp. The marginal areas were infested with mainly Eichhombia sp followed by Pistia sp, Lemna sp and Typha sp.

4.2 METHODOLOGY

4.2.1. Plan of work
The entire project work involved different phases of study. The first phase included fieldwork wherein collection of samples of water and zooplankton was done. Primary productivity studies were carried out by in situ incubation technique and analysis was done later in the laboratory. Water was collected for measuring the BOD and COD of the wetland at the particular time period. The second phase consisted of analysis of water samples collected as also the preliminary sorting and identification of zooplankton specimens in the laboratory. Primary productivity, BOD and COD were analyzed following the standard methods. The life cycle of three important freshwater crustacean species were followed in the field samples as well as in the cultured laboratory conditions. The occurrence pattern of the zooplankton population in general in the natural waters was observed. The third phase required further analysis of the primary data collected in order to compute the relative abundance and load of the population. The secondary data acquired was then used to interpret the diversity of the zooplankton population in a.
particular wetland both qualitatively and quantitatively using various recorded indices. This data was again used for statistical interpretation following various techniques like correlation, regression and cluster analysis.

An overview of the phases of work is given below

FIELD WORK
Sampling and Sample Processing
a) Collection of Water samples
b) Collection of Zooplankton specimens
c) Primary Productivity studies
d) Collection of water for BOD and COD

LABORATORY WORK AND EXPERIMENTS
a) Analysis of water parameters
b) Analysis (sorting and identification) of Zooplankton Specimens
c) Analysis of primary productivity
d) Analysis of water for BOD and COD
e) Life-cycle studies of three crustacean species

DATA ANALYSIS
a) Measuring the abundance (relative composition in percentage) and load (density of individual species in no/l)
b) Application of diversity indices – Shannon-Weiner diversity index, Simpson’s species richness index, Margalef’s and Menhinick’s diversity indices and Community similarity and Dissimilarity indices

STATISTICAL ANALYSIS OF DATA
a) Correlation between biotic and abiotic factors
b) Regression of biotic and abiotic factors
c) Cluster analysis of biotic factors

4.2.1.a. Field Work
4.2.1.a.i. Collection and analysis of water samples
The wetlands were sampled once in a month for two years during early hours of the day between 11 00 AM and 1 00 PM. Subsurface water samples were
collected using acid washed polyethylene bottle of 500 ml capacity (TARSON) for analyzing the various physico-chemical parameters of water. The climatological parameters viz., air temperature, rainfall, and humidity during the study period were obtained from the five-year report of Meteorological Department, Kolkata, and from the Central Soil Salinity Research Institute, Canning. Physical parameters measured include water temperature, transparency, total dissolved solids, and electrical conductivity. The chemical parameters include pH, salinity, dissolved oxygen content, total alkalinity, and total hardness. The anionic radicals estimated were nitrite, nitrate, chloride, phosphate, and sulphate.

Dissolved oxygen was determined using Bruhn's Azide Modification of Winkler's iodometric method. Air and water temperature were recorded with a mercury thermometer, pH was measured with the help of a pH meter (Eutech Instruments Water Proof pH Scan 1 Tester) and pH paper (Qualigens). Total alkalinity was determined with the Methyl Orange – Phenolphthalein indicator following the procedure in APHA (1995). Secchi Disc (a black and white disc of 18 cm diameter) was used to obtain the transparency values. These parameters were analysed in the field itself immediately. The water samples were carried to the laboratory for further analysis, in dark boxes to maintain its in situ quality.

4.2.1.a.ii. Collection of zooplankton specimens

Zooplankton samples were collected from littoral zones of the habitats. Qualitative samples for relative abundance and taxonomic studies were obtained using hand-held plankton net (mesh size 65 μm, nylon bolting cloth no 25) by sweeping through the macrophytic vegetation in the littoral zone and/or towing from a boat. Quantitative collection was done by sieving 50 litres of water samples through the plankton net. The samples collected in the bottle of the net were transferred in a small enamel tray with little water. The inside of the net near the mouth of the bottle was also washed in the tray so as to collect any attached plankter. The collected specimens were first narcotized with 5% formalin and as the animals died / were narcotized, the supernatant water was separated slowly and concentrated zooplankton samples were then
Light and Dark bottles for measuring productivity

Hand Net for plankton collection

Plate 6
Plankton Collection tube
Clamp
Plankton Net

Plate 7
preserved in small tubes containing 4% formalin – glycerol mixture. These were taken to the laboratory for identification and enumeration.

4.2.1.a.iii Collection and observation of macrophytic vegetation

A general study of the occurrence, abundance and coverage of macrophytic vegetation was done in the field. Those aquatic plants, which could not be identified, were collected and brought to the laboratory for identification. This was done once during all the seasons.

4.2.1.a.iv. Primary Productivity studies

The primary productivity was determined by using Light and Dark bottle method of Gaarder and Grans (1927) that was later modified by Vollenweider (1970) and came to be known as Light and Dark Bottles _insitu_ incubation technique. A set of 2 light and 1 dark bottles (each of 250 ml with ground glass stopper) was taken. Water from the wetland was filled in the bottles at the same time. One light bottle and the dark bottle were suspended in the water body at littoral region and incubated for 4 hrs. The other light bottle was fixed immediately to determine the initial oxygen content. After the incubation period the suspended bottles were taken out and fixed for oxygen. These bottles were carried to the laboratory in a black box to avoid contact with light.

4.2.1.a.v. Biological oxygen Demand (BOD)

It is the amount of oxygen (mg) required by microorganisms in a liter of water sample to decompose the organic material present when the sample is stored in darkness at 20°C for five days. Water samples were collected in 250 ml ground glass stopper BOD bottles from the subsurface waterbody. One bottle was fixed to get the measure of initial oxygen content (modified Winkler's method). The other bottle of water sample was incubated at 20°C for five days in a BOD incubator after which the oxygen content was measured. The samples were taken in dark boxes to the laboratory to prevent contact with light. The measure of BOD was obtained by subtracting the value of the final oxygen content of the bottle incubated from the value of the initial oxygen content measured.
Collection of zooplankton specimens by hand net

Zooplankton specimens preserved in vials and other laboratory wares

Plate 8
4.2.1. a.vi. Chemical Oxygen Demand (COD)

It is the amount of oxygen required for chemical oxidation (using potassium dichromate) of the organic matter present in the water samples. Water was collected in a 250ml ground glass stopper polyethylene bottle and taken in dark boxes to the laboratory to prevent contact with light. The estimation of COD was done by reflexing the sample with potassium dichromate and sulphuric acid and then titrating the residual potassium dichromate against ammonium ferrous sulphate using ferroin as indicator. Oxidation of water sample takes two hours.

4.2.1. b. DURATION AND SAMPLING PERIODICITY

The duration of field studies and laboratory analysis together was 4 years from May 2004 to April 2008. Water sampling and analysis and collection of zooplankton specimens were done once monthly for two consecutive years from May 2004 to April 2006 in the sewage-fed pond of East Kolkata Wetlands and brackishwater bheri of Canning, from January 2005 to December 2007 in the freshwater marshy wetland of Dankuni and from January 2005 to November 2005 in Gopalnagar baor. For seasonal analysis, the annual cycles were divided into 3 main seasons. These were Premonsoon (PRM), from March to June; Monsoon (MON), from July to October and Post Monsoon (POM), from November to February.

4.2.2. Laboratory Work and Experiments

4.2.2.i) Physico-Chemical analysis

The water quality parameters analyzed in the laboratory include total hardness, chloride, nitrate, nitrite, phosphate, sulphate, conductivity, total dissolved solids and salinity. Total hardness was determined by EDTA titrimetric method with 0.01M EDTA titrant using Eriochrome black T dye and sodium chloride as a dry power indicator. Chloride content was estimated according to the Argentometric method (APHA, 1998) by titrating the water sample with 0.0141N silver nitrate using potassium chromate as indicator. Sulphate was measured by the barium sulphate turbidimetric method, nitrate was obtained by the Phenol disulphonic acid method, and nitrite was estimated colorimetrically by developing a colour with EDTA, sulphanilic acid, and
naphthalamine hydrochloride and sodium acetate Total phosphorous was measured by the Ascorbic acid Method in which phosphate reacts with ammonium molybdate to form molybdophosphonic acid This is transformed by reductants to form a blue complex, which was measured spectrophotometrically (APHA, 1998) Salinity was measured with the help of a hand held salinity refractometer (RHS –10, Model range 0-100 PPT and accuracy of 1 000 – 1 070, SG) and also by Mohr's titrimetric method Conductivity and TDS values were recorded with the help of a direct reading Conductivity meter and a probe (Model WTW LF 320, Merck, Germany) and all values were corrected to 25°C (Goltermann et al 1978)

4.2.2.ii) Primary Productivity

Calculation of primary productivity was done using the formula (Vollenweider, 1970)

\[
\text{NPP in } O_2 \text{ mg/l/hr} = \frac{D_i - D_t}{h} \\
\text{GPP in } O_2 \text{ mg/l/hr} = \frac{D_i - D_d}{h} \\
\text{CR in } O_2 \text{ mg/l/hr} = \frac{D_i - D_d}{h}
\]

where , \( D_i \) = dissolved oxygen in the initial bottle in mg/l
\( D_l \) = dissolved oxygen in the light bottle in mg/l
\( D_d \) = dissolved oxygen in the dark bottle in mg/l
\( h \) = duration of exposure , that is three hours

The value of oxygen mg/l/hr was multiplied by 1000 and with a factor 0 315 to get carbon values in terms of mg C/m³/hr

Community respiration can be expressed as the percentage of the gross productivity by the given formula
\[
\text{value of CR} \\
\text{\% of GPP} = \frac{\text{value of GPP}}{\text{value of GPP}} \times 100
\]

4.2.2.iii) Zooplankton analysis
Preserved zooplankton samples were sorted into different major groups viz. Rotifera, Cladocera, Copepoda and Ostracoda using dissecting microscope (Olympus, SMXX). These were then identified under a stereoscopic binocular microscope (Leitz Wetzlar Aristoplan) with different magnifications. For quantitative analysis the filtered water samples of 50 litre were taken. Subsamples of 1 ml were used in triplicate and counting was done in a Sedgwick – Rafter chamber. Detailed taxonomic identification was done following the literature of Sewell (1934,35), Edmondson (1959), Kasturirangan (1972), Pennak (1978), Sharma (1979a,b, 1999a) Michael and Sharma (1988), Sehgal (1983), Battish (1992), Roy (1999), Venkataraman (999) and Khan (2003). The number of each zooplankton species and groups was counted per ml and the count was raised to get the abundance values for the total volume of 50 litre. The Sedgwick Rafter counting chamber has 1000 squares with 1ml capacity. The number of plankton counted in 100 squares was converted into units of plankton present per liter.

Key characteristics take into consideration for the identification of Rotifera, Copepoda and Cladocera were as follows:

a) Rotifera - body wall, foot, trophy, antenna, corona and reproductive system.
b) Cladocera – carapace, ocellus, Antenna and Postabdomen.
c) Copepoda – body shape, fifth leg, first antennae.
d) Ostracoda – size and shape of the shell, 2\textsuperscript{nd} antennae, spines of maxillary process, third thoracic leg, caudal furca.
The quantity of each species was then calculated in no/lt of pond water using the formula given by Welch, 1952

\[ n = \frac{(a \times 1000) \times c}{L} \]

Where, \( n \) = number of zooplankton /L of water  
\( a \) = average number of zooplankton in 1 ml of subsample  
\( L \) = volume of original water sample in litre  
\( c \) = the volume of original concentrate in ml

Relative distribution of different species was analysed by examining 100 animals randomly and making record species-wise. The size was measured with the help of ocular micrometer.

4.2.2. iv) Population dynamics

Studies on the annual population cycle, lifespan, instar duration, of two species of Cladocera (Moina micrura and Ceriodaphnia cornuta) and one species of Copepoda (Mesocyclops leuckarti) has been undertaken by following their cycle in a particular wetland and also in the laboratory culture. Specimens were collected and the three species were identified and one individual of each of these species were cultured separately in small petridishes having the pond water. Everyday the species was observed for changes and development.

4.2.2. iv.a) Population dynamics of Mesocyclops leuckarti

*Mesocyclops leuckarti* is a cosmopolitan species found in the Indian waters and distributed throughout the world because of its adaptability to a wide range of temperature, salinity conditions and other physical and biological factors of the aquatic system. It is a cyclopid copepod not known to produce resting eggs but they produce cysts containing copepodites and it is very likely that passive dispersal is brought about in this stage.

Field Studies

The sampling was carried out for a period of one year from January to December 2006. During this period sampling was done on alternate days in...
January and February and thereafter in order to trace the development of various instars fortnightly samples were collected following the method of Ghers and Robertson (1975). Zooplankton were collected by filtering 100 litres of water through a standard plankton net made of NO 21 cloth from two different points of the pond. Samples of the two points were mixed together so as to obtain only one sample for particular sampling day and preserved in 4% formalin. In laboratory, samples were diluted and several 1-ml subsamples were examined under a stereoscopic binocular microscope with varying magnifications. Identification and enumeration of total zooplankton and separation of each of the *Mesocyclops leuckarti* were done simultaneously. The entire population of the species was divided into 5 major classes: egg, nauplii, copepodite I – III, copepodite IV-V, copepodite VI (adult). Stages were recognized by the appearance and state of development.

**Lab Culture Studies:**
In laboratory, pairs of male and female species were taken and each couple was placed in separate petri dishes containing 10ml filtered pond water. These were examined daily and records of duration of development of eggs and various instars, total life span and fecundity were made. The room temperature varied between 25-30° C. As soon as the first nauplii appeared they were separated and kept in separate petri dishes which were examined daily. The size of the breeding population was recorded by establishing the ratio of ovigerous females to the total female population, clutch size was established by counting the number of eggs per sac for about 25 animals, egg stock of the population was counted by multiplying the mean clutch size to mean number of ovigerous females and the number of eggs in each clutch was recorded in laboratory. Number of clutches produced by females in the lake was recorded indirectly by dividing the number of ovigerous females to egg development time (Chapman, 1969).

**4.2.2.iv.b) Population dynamics of *Ceriodaphnia cornuta***

*Ceriodaphnia cornuta* belonging to the family Daphniidae (Edmondson, 1959) is a typical freshwater cladoceran inhabiting the lakes and ponds of the tropical region and contributing significantly to the density of the total zooplankton population. It is an important fish food for fishfries and adults but very little
information is available on the seasonal abundance and life cycle of the species. Hence the present study was undertaken to gain knowledge about the biology of the species. Both laboratory and field studies were undertaken. The method followed here is that adopted by Michael (1962) and Khan (1983).

Field Studies

The sampling was carried out for a period of one year from January to December 2006. During this period sampling was done on alternate days in January and February and thereafter in order to trace the development of various instars fortnightly samples were collected. Zooplankton were collected by filtering 100 litres of water through a standard plankton net made of NO 21 (65µ) cloth from two different points of the pond. Samples of the two points were mixed together so as to obtain only one sample for particular sampling day and preserved in 4% formalin. In laboratory, samples were diluted and several 1-ml subsamples were examined under a stereoscopic binocular microscope with varying magnifications. Identification and enumeration of total zooplankton and separation of each of the *Cerodaphnia cornuta* were done simultaneously. Their life cycle and seasonal occurrence was studied.

Observations on the number of young ones produced, moulting and size increase was recorded daily.

Laboratory culture

All experiments were carried out under laboratory conditions (temperature 25±3° C). Stock culture was maintained in large jars. Individual females were cultured separately in small petri-dishes. Culture was maintained in water collected from Dankuni Railway jheel and filtered through No 25 bolting cloth net so as to remove all zooplankton but all algae, protozoa, and detritus pass through. Water was changed on regular basis on every alternate day. When the number of individuals seemed to be more in a petri-dish, they were removed and put in separate petri-dishes, thus avoiding overcrowding and subsequent depletion of nutrients and mortality.

4.2.2.iv.c) Population dynamics of *Moina micrura*

The species belonging to the family Moinidae are very important source of cheap food for fishes and other aquatic animals. Laboratory studies on the
lifespan, instar duration, egg production and growth of micro crustaceans forms an important basis for understanding the population dynamics of any species of zooplankton. *Moina micrura* is a cosmopolitan, cyclic, parthenogenetic cladoceran, which inhabits the tropical and subtropical regions of the world. The methodology followed here is that of Murugan (1975b).

**Field studies**

Plankton samples were collected from the Dankuni railway jheel at fortnightly intervals during the period January to December 2006. Similar methods of collection, separation and identification as described for the earlier cladoceran species were applied for this species also. Their seasonal occurrence was studied in detail.

**Laboratory studies**

20 adult parthenogenetic females of *M micrura* were isolated and reared in small petridishes at a room temperature (28 ± 3°C). Stock culture was maintained in a large beaker filled with pond water. Those were left for 24 hrs for them to give birth to young ones. The neonates were kept individually in 50ml beaker and were examined daily. Data regarding the length increment, number of moult, duration of instar, number of youngs released, number of eggs per brood, growth rate and total life span were recorded. The water of the beaker was changed daily to avoid food and oxygen shortage and accumulation of excretory wastes.

**4.2.3 Data Analysis**

**4.2.3.1. Measurement of diversity and Community analysis**

To understand a particular biotic community or assemblage it is very important to work out some indices of species structure. The data obtained was used to compute the species richness and diversity applying the various diversity indices like the Shannon–Wiener Diversity Index, Margalef's species richness index, Simpson's dominance index, Pielou's evenness index and Sorensen's Community Similarity index.
A measure of the species diversity at any instant of time is based on Shannon–Wiener Theory (1964) which indicates that the more complex the community is, the greater will be the values of its species diversity and stability (MacArthur, 1955). A crude measure of the stability of a community over a given time can be obtained from the range of values of species diversity calculated within certain time period. MacArthur (1955) hypothesized that community stability is a function of food web complexity. The greater the links in any food web the more stable the community. Paine (1966) found that the lack of stability in a community is due to a unique set of interaction among the species and between the species and physical environment. Thus, evenness of the species in a community and diversity of species in an area are two sides of the same coin. Diversity tends to be higher in older communities and low in newly established ones.

Index of dominance. Within a major community or group there are species or groups which largely control the energy flow and strongly affect the environment of all other species and they are known as ecological dominants. The degree to which the dominance is concentrated in one or many species can be expressed by an appropriate index of dominance, that sums up each species importance in relation to the community as a whole. The index of dominance (Simpson, 1949) is the sum total of the squares of the proportion of the species in the community. The value varies from zero to one. Higher diversity values reflect diversified resources in the habitat available for components of the community. Decreased values indicate increase by an average species resulting in the lowering of the number of coexisting species in the community. Any community is characterized by a few common species with large number of individuals in association with many rare species with few individuals. The few common species or ‘dominants’ largely account for the energy flow in each trophic level, but it is the large number of rare species that mostly determine the species diversity of the community (Odum, 1971). The ratio between the number of species and the importance values (numbers, biomass, productivity, etc.) of individuals is called species diversity. It tends to be low in physically controlled ecosystem and high in a stable and biologically controlled ecosystem. Species diversity has a number of components,
particularly, on species richness and individual richness (Preston, 1948, Good, 1953 and Brillouin, 1960)

Margalef's index estimates species richness independently of the sample size. The changes in community structures can be explained numerically with diversity index and are useful in assessing water quality based on the principles, that clean water supports high community diversity while polluted waters have less diversified biota (Margalef, 1968)


In estimating species diversity probably the most widely used index is the Shannon-Weiner (1949) index. This index is one of the best for making comparisons where one is not interested in separating out diversity components because it is reasonably independent of sample size. The value of this index can theoretically range from 0 to infinity. However, values normally range from 0 to 4. Wilhm and Dorns (1968), after examining diversity in a range of polluted and unpolluted streams, concluded that the value of \( H \) greater than 3 indicated clean water, values in the range of 1 to 3 were characterized by moderately polluted conditions and values less than 1 characterize heavily polluted conditions.

\[
H = -\frac{1}{N} \sum_{i=1}^{n} \frac{n_i}{N} \log_2 \frac{n_i}{N}
\]

Where, \( H \) = Shannon-Weiner Index
\( n_i \) = importance value (density or number) of individual species
\( N \) = total of the importance values (density or number) of species

2) Simpson’s Dominance Index (Simpson, 1949)

Simpson’s index gives more weight to the more abundant species in a sample. The addition of rare species to a sample causes only small changes in the value of \( D \). The higher the value of \( D \), the lower the diversity. The value of \( D \) ranges from 0 to 1. This value when subtracted from one gives the actual measure of diversity. The value of this index \((1-D)\) also ranges between 0 and 1, but now, the
greater the value the greater the sample diversity. The value of reciprocal index starts with 1 as the lowest possible figure. This figure would represent a community containing only one species. The greater the value the greater the diversity. The maximum value is the number of species in the sample. It is important to ascertain which index has actually been used on comparative studies of biodiversity.

\[ D = \sum \left( \frac{n_i}{N} \right)^2 \]

Where, \( D \) = Dominance index

\( n \) = the importance value (number or density) of a particular species

\( N \) = the total importance values (number or density) of all species

Simpson's Index of Diversity = 1 - D

3) Margalef's richness index (1958, as modified by Brower and Zar, 1977)

One of the major components of species diversity is called the 'species richness' or variety components of species diversity or Margalef's diversity index (d) and is expressed by simple ratio between total species (s) and total number or importance values (N). This index commonly varies between 1 and 5 and larger the index the healthier the waterbody. When it tends towards 1 pollution is thought to increase and damage should be suspected.

\[ D = \frac{S-1}{\log_e N} \]

Where, \( S \) = total number of species

\( N \) = total number of individuals of all the species
4) Evenness Index (Pielou, 1966)

Another component of diversity is called ‘evenness’ or ‘equitability’ in the apportionment of individuals among the species in a community. It is noted that both evenness and Shannon-Weiner behave inversely to the index of dominance, since high values indicate a low concentration of dominance.

\[ J = \frac{H}{\log S} \]

Where, \( J \) = evenness index  
\( H \) = Shannon-Wiener Index  
\( S \) = Number of species

5) Menhinick’s diversity index (Menhinick, 1964)

\[ D = \frac{S}{\sqrt{N}} \]

Where, \( S \) = total number of species  
\( \sqrt{N} \) = square root of total density

6) Index of similarity (Sorensen, 1948)

The similarity analysis between different wetlands was carried out by computing Sorensen’s Coefficient of Community (CC)

\[ CC = \frac{2C}{A + B} \]

Where \( A \) = number of species in sample A  
\( B \) = number of species in sample B  
\( C \) = number of species common to both the samples
Several statistical methods have been used to analyze the relationship of zooplankton with physico-chemical factors of environment. An attempt was made to assess the relative effectiveness of various techniques for the variables on the zooplankton density. Techniques used for the present study included simple and multiple correlation, one-way analysis of variance, stepwise multiple regression and hierarchical cluster analysis. The purpose of multiple correlation and multiple regression is to be able to predict some criterion variable better. There is some improvement in the prediction of the criterion variable when two or more predictors are used than using only one predictor variable. Analysis of variance (ANOVA) was calculated to find out the significance of the differences in density of the species and groups among the collected samples of each site. For this various books on statistics were consulted including Biostatistical Analysis by Zar (2005) and Statistical Methods by Das (2000). Shiddamallayya and Pratima (2008) used Pearson’s correlation matrix to study the correlation among the water quality parameters and presented the percentage similarity of abiotic factors in the form of a dendrogram. Baidya and Choudhury (1985) found out the correlation among the hydrological parameters and the copepod population with water temperature and salinity. Sarkar and Choudhury (1986) established the correlation among the observed copepod species of Hugli estuary. Khan (1995) studied the correlation between salinity and copepod population.

4.2.3. ii.a) ANOVA (one-way analysis of variance)

Analysis of Variance is a statistical technique for the “separation of variation due to a group of causes from the variation due to other groups.” The method is based upon an unusual result that the equality of several population means can be tested by comparing the sample variances using F distribution. t-statistic is used for testing whether two population means are equal. The analysis of variance test may be taken as an extension of this test for the case of more than two means. The assumptions in ANOVA are that the samples are independently drawn, populations are normally distributed with a
common variance and the effects of various components are additive (Das, 2000)

If the means of all the populations were equal, then the variability "between groups" would result only from chance and hence would be the same as the variability arising from "within groups". On the other hand, if the population means were not equal, the variability "between groups" would be more than the variability "within groups". The measure of variability used in the analysis of variance is called a "Mean Square". One mean square is used to measure the variability within groups. This is based on the sum of squared deviations of the observations within each group, the derivations being taken from the respective group means, and has degrees of freedom "total sample size minus the number of samples". The "Sum of Squares" within groups, as it is called, when divided by the number of degrees of freedom provides the "Mean square within groups" which represents a measure of variability due to chance or "experimental error". The other mean square is used to measure the differences existing, if any, "between the groups". It is obtained by dividing "Sum of squares between groups" by the degrees of freedom. The F value is obtained by dividing the mean square between groups by the mean square within groups. This is then compared with standard F-values at 5% and 1% level of significances. If the observed value of F equals or exceeds the theoretical value of F, the population means are not considered to be equal; otherwise, they may be taken to be equal. If the means of all the populations are equal, there is no group-effect and the mean square between groups will also represent variability due to chance alone. Consequently, when the group means in the population are equal, the mean square within groups and the mean square between groups should not be much different and their ratio should be close to one.

4.2.3.ii. b) Correlation

Correlation is the mutual relationship between two variables. Direct correlation exists when a rise or fall in the value of one parameter is associated with a corresponding rise or fall in the value of the other. If one parameter increases, there is no definite increase or decrease in the other parameter, and then there is no correlation between the two parameters. The correlation is said to be
positive when a rise in one parameter causes the rise in the other parameter
and it is negative when a rise in one parameter causes the fall in the other
parameters If the variable trends between these parameters follow a straight-
line path, there is a linear correlation between them Interrelationship between
the parameters is quantified by a numerical measure called as coefficient of
linear correlation. The linear correlation coefficient ‘r’, has a value between (+)
1 and (-) 1 A value of (+) 1 represents a perfect positive correlation A value of
-1 represents a perfect negative correlation The correlation between the
parameters is characterized as strong, when it is in the range of (+) 0.8 to 1.0
and (-) 0.8 to (-) 1.0, moderate, when it is having value in the range of (+) 0.5
to (+) 0.8, and (-) 0.5 to (-) 0.8, and weak, when it is in the range of 0.0 to (+)
0.5 and 0.0 to (-) 0.5 In order to determine the significance of the correlation
coefficients calculated, the following procedure was adopted as a test of
significance T-value was calculated using the following expression

\[
t_{cal} = r \sqrt{n-2} / 1-r^2
\]

where ‘r’ is the observed correlation coefficient and ‘n’ is number of pairs

To test the significance of ‘r’, a hypothesis, Ho The population correlation
coefficient is zero, was made P-value, which is the smallest probability at
which Ho would be true, was calculated by taking the degrees of freedom as n-
2 and the t_{cal} values The level of significance, α and the p-value calculated
was compared If p-value calculated ≤ α then reject Ho If p-value calculated >
α, then do not reject Ho (Bathusa and Saseetharan, 2007)

Correlation coefficients were calculated to evaluate the parametric
relationships between the biotic and abiotic factors supposedly in interaction

4.2.3.ii.c) Multiple regression analysis

In any aquatic system, the occurrence and life cycle of an organism depend on
the various physico-chemical water parameters. To find out the subset of
physico-chemical parameters, stepwise multiple regression method was
followed Thus, a ‘p’-x variable (physico-chemical parameters) that best
predicts the response (faunal density) was chosen. This is a universal selection statistical procedure in which the only random variable is y and x’s are treated as non-random. The significance of β’s has been tested with the help of t-statistic. The square of multiple correlation coefficients R², for each model indicates the variation in density explained by the p-variable. The significance of R² is tested with the help of F-statistic.

Multiple regression is a statistical technique which allows us to predict the score or value of one variable on the basis of its score on several other variables. Independent variables or the predictor variables are those variables, which are useful in predicting the scores on another variable called the dependent or the criterion variable. The stronger the correlation, the closer is the scores and more accurate is the prediction. The beta value or the standardized regression coefficient is a measure of how strongly each predictor variable influences the criterion variable. The higher the beta value, the greater the impact of the predictor variable on the criterion variable. R is a measure of the correlation between the observed value and the predicted value of the criterion variable. R square or coefficient of determination (R²) is the square of this measure of correlation and indicates the proportion of this variance in the criterion variable. R square tends to somewhat over-estimate the success of the model when applied to the real world, so an Adjusted R Square value (R²_adj) is calculated which takes into account the number of variables in the model. In a stepwise multiple regression analysis, the number of predictors to be selected and the order of entry are both decided by statistical criteria.

The multiple correlation coefficient generalizes the standard coefficient of correlation. The significance of a multiple coefficient of correlation can be assessed with an F ratio.

Significance test

In order to assess the significance of a given R², we can compute an F ratio as
where $Y$ = the dependent variable 
$J$= a set of independent variables 
$N$= the number of observations

Attempt has been made in this study to explain the fluctuation in zooplankton density with various physico-chemical factors. Zooplankton density of the selected dominant species is the dependent variable and the physico-chemical factors are the explanatory variables or independent variables.

Stepwise multiple regression technique was followed in order to find out which variables have statistically significant impact on zooplankton density and a relation is established in the form of an equation. A total of 12 independent variables for DRJ, 11 independent variables for NGB, 10 independent variables for SNB and 9 independent variables for GNB were considered.

Based on the results of the multiple correlation values the order of entry of the variables into the regression method was determined. For each independent variable the $R^2$ value together with its beta coefficient are reported. For each model, $R^2$ indicates the variations in density of the zooplankton group. For regression of the zooplankton species density and richness with primary productivity, the standard beta coefficient and the standard error of estimation together with the values are reported. The standardized beta coefficients give a measure of the contribution of each variable to the model. $t$ and $p$ (Significance) indicates impact of each predictor variable – a big and absolute $t$ value and a small $p$ value suggests that a predictor variable is having a large impact on the criterion.

4.2.3.ii.d) Cluster analysis

The term cluster analysis (Tryon, 1939) encompasses a number of different algorithms and methods for grouping objects of similar kind into respective categories using some measure of similarity or distance. In other words,
Cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. Hierarchical cluster analysis is an agglomerative method that begins with each observation being considered as separate clusters and then proceeds to combine them one by one. As a result more and more objects are linked together and larger clusters of increasingly dissimilar elements are formed. Finally, in the last step, all objects are joined together. In these plots, the horizontal axis denotes the linkage distance. Thus, for each node in the graph (where a new cluster is formed) we can read off the criterion distance at which the respective elements were linked together into a new single cluster.

There are several types of hierarchical clustering. In the single linkage (nearest neighbor) method used here, the distance between two clusters is determined by the distance of the two closest objects (nearest neighbors) in the different clusters. This 'strings' objects together form clusters and the resulting clusters tend to represent 'long chains'.

The data obtained was subjected to statistical analysis using relevant software programme, SPSS (ver 11.0) with windows XP and PC and with BMDP (ver 10.0) on Solaris 9.5 Sun Enterprise 3000.