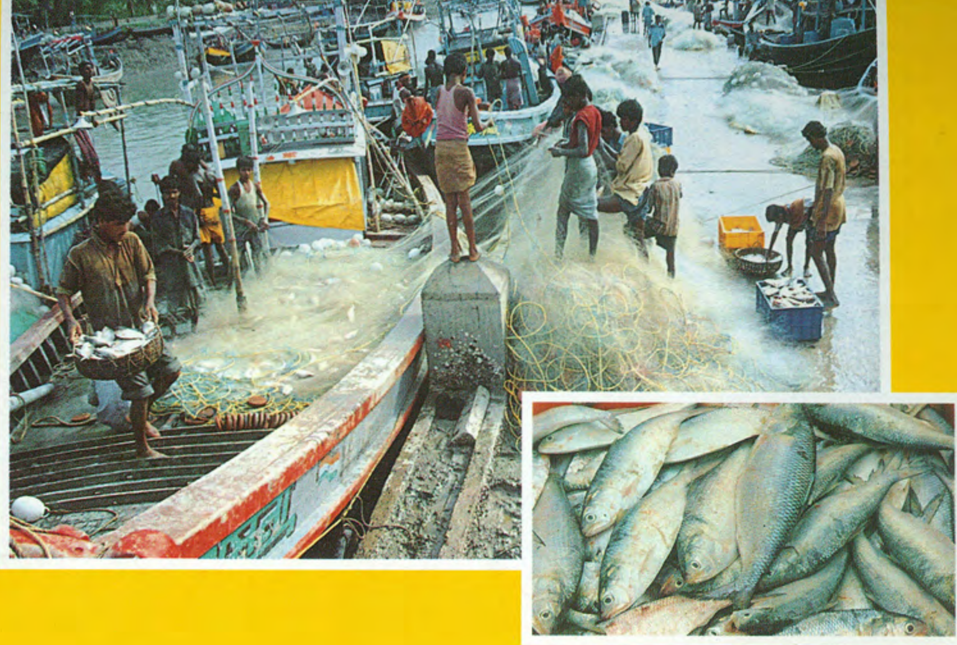

The Hooghly Estuarine System

Ecological flux, fishery resources and production potential

Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore, Kolkata - 700 120, West Bengal

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Prepared by

D. Nath
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Project Participants

Scientists	Dr. D. K. De (upto 31.12.1999) Shri P. M. Mitra (upto 30.6.2001) Dr. A. K. Ghosh (upto 31.7.2001) Dr. D. Nath Dr. R. N. Misra, Shri H. C. Karmakar, Dr. U. Bhowmick Dr. B. C. Jha
Technical Assistance	Shri N. C. Mondal (upto 31.12.2001) Shri H. K. Sen (upto 31.1.2002) Shri A. R. Paul (upto 31.5.2003) Shri Sukumar Saha, Shri M. P. Singh, Dr. B. K. Biswas, Shri T. Chatterjee, Shri P. Biswas, Shri Arunava Mitra, Shri D. Sanfui, Shri B. N. Das, Smt. A. Sengupta, Shri P. Singh (upto 30.6.2001) Shri C. P. Singh, Shri S. Mondal, Shri A. K. Barui, Shri B. B. Das, Shri D. Saha

PREFACE

The Hooghly estuary, a distributary of Ganga- Bhagirathi river, located within the state of West Bengal, India, spanning across about 0.8 million ha is a positive estuary of mixohaline nature. The estuarine system lies between latitude 21 – 23^{0} N and longitude 88 – 89^{0} E and comprising a network of many estuarine distributaries and creeks apart from principal river, the Hooghly and its tributaries, the Rupnarayan is famed to be largest estuarine system of the world. The Hooghly estuarine system is highly productive, since it receives substantial quantities of silt load and nutrients along with huge volume of fresh water from Ganga. During tidal period significant amount of nutrients enter into the main channel and its tributaries making the entire system highly productive. The system undergoes major multispecies commercial fishery providing earnings to millions of fishermen and fish traders.

For assessment of ecological parameters and estimation of fish catch from the estuarine system, survey was conducted by Central Inland Fisheries Research Institute, Barrackpore during 1961-62 to 1977-78. But the commissioning of Farakka Barrage in April, 1975 has resulted in major changes in the ecology, associated environment and fisheries of the estuary. Therefore, a paramount need was felt to undertake fresh study to assess the change in catch and effort structure and ecology of the estuary under the new scenario and accordingly fresh study was undertaken by the Institute from 1983-84. The study was continued till 2003 to assess the changes in ecology in relation to fish production. The entire work along with significant findings for the period 1998-99 to 2002-03 was incorporated in the form of a bulletin, so that it may serve as a guideline to the planners, fishery scientists, researchers and fishers.

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INTRODUCTION

India is gifted with a large coastline and vast stretches of coastal wetlands. Estuaries and backwaters, which also includes mangroves, mud flats, bays etc. extend over a large part of the coasts. There are fourteen major and a number of small and minor rivers opening either into Bay of Bengal or Arabian Sea. Except four, all the major rivers open into the former and from estuaries at their confluences. It has been estimated that out of a total area of 19.25 lakhs sq. hectares of estuaries, 13.25 lakhs sq. hectares are on the East Coast. The coast has the largest estuary formed by the rivers Ganges and Brahmaputra and criss-crossed by a number of small rivers. The Gangetic delta is the biggest of its kind in the world and stretches over an area of about 20,000 sq.km., the major part of which, however, is in Bangladesh.

The Hooghly estuarine system, which is constituted by the first offshoot of river Ganga - the Bhagirathi, flows southwards through the lower Ganga deltic plane and joins Bay of Bengal in Sunderbans. It is one of the most important estuarine system of the country because of (1) its origin from the largest mountain river, (2) heavy monsoonal discharge from a very vast basin and (3) very long tidal zone. Being a very active tidal estuary, it has physico-chemical and biological characteristics of its own. The main estuary is classified as a positive estuary in the mixohaline range, where mixing of freshwater and regular tidal influxes have created a steady gradient from marine to freshwater conditions. This gradient is mainly governed by the amount of freshwater discharge during different seasons of the year.

Physical features of Hooghly estuarine system

River Ganga, after traversing a distance of about 2000 km, bifurcates near Farakka into major offshoot Padma, which flows further eastwards to Bangladesh and a minor offshoot Bhagirathi which flows southwards to Bay of Bengal through lower deltic region of West Bengal. Almost in the middle of its course, near Nabadwip, it is further joined by two other small offshoots, Jalangi and Churni and enters the tidal zone where it is called as Hooghly. The total length of tidal Hooghly estuary is about 295 km and it lies between the latitude 21° 31' N and 23° 30' N and longitude 87° 45' E and 88° 45' E and covers the districts of Nadia, Hooghly, North and South 24-Parganas, Howrah and East Midnapur in West Bengal State. In lower reaches it is further joined by several tributaries like Ajoy, Damodar, Roopnarayan and Haldi. Before meeting to Bay of Bengal, the estuary bifurcates near Sagar island into main estuary Hooghly and river Muriganga which has got connection with river Thakuran and Matla, forming the Sunderban estuarine complex.

The catchment area of the estuary includes a wide area from where the freshwater drainage is received directly into an estuary through the tributaries. The amount of annual freshwater discharge by Ganga, Damodar and Roopnarayan into Hooghly is about 97200, 16200 and 621000 million cubic feet respectively from the catchment area of about 11900 sq. meters.

The climate in Hooghly estuary is generally hot and humid during major part of the year. Active monsoon covered almost 4 months (June to September) of the year. The climate of the area is chiefly influenced by the monsoon. The mean rainfall is around 1700 mm.

Ecosystem Characteristics

The Hooghly-Matla estuary is a tide-dominated delta, which has a funnel shape. Tides facilitate transportation of sediment, replenishment of nutrients, flushing out of wastes and mixing of fresh and salt waters. The tides are semidiurnal with two high and two low tides in a day. The tides are unequal, varying in time and range depending on the location of a place in the estuary.

The estuary is characterised by strong tides (5 to 7m amplitude) during summer season from February to May and during pre-winter season and relatively weaker tides during the winter months. This corresponds to the rising of mean sea level at the Hooghly mouth in February, reaching a peak by September and falling down by winter months. Tidal influence is seen in the estuary up to 290 km, from the sea face. The tides create an important intertidal zone, which harbour characteristics biota. The intertidal zone has silt flats often mixed with mid to varying degrees.

Tides have strong influence on water quality parameters. In addition to tides, water movement is caused by surface and bottom currents. The latter carry plankton upstream and also maintain salinity gradients. The circulation of water is of importance in maintaining populations of sessile or sedentary benthic organisms, majority of which have planktonic dispersal stages. Tides also help in transporting some of the euryhaline marine organisms from the sea into the estuary.

Salinity is an important factor which influences the distribution and biology of living organisms. It is very much influenced by tides and is highly variable, ranging from 3.6 to 32.77 gl^{-1} depending on the place and season. It was observed that there was no well defined saline water at the bottom. In comparison, the fluctuations in temperature between 21.7°C and 32.2°C and pH 7.9 and 8.3 of water are modest. The latest investigations had recorded 14.0°C and 34.0°C as the average minimum and maximum temperatures of water respectively. The range of pH varied from 7.35 to 8.40 in the region between Budge Budge and Bakkhali. There had been a fall in temperature and increase in pH in the downstream direction (Sen *et al.*, 1994).

The depth and width of the estuary also varied with the place and season, depending on the influx of freshwater and distance from the sea. The maximum breadth and depth recorded at Diamond Harbour were 4.65 km and 28.0 m (during monsoon) respectively, while the same measurements were reduced to 0.75 km and 16.0 m respectively at Calcutta (Kidderpore). The most upstream area coming under saline influence is Barrackpore and here the breadth and depth were 0.54 km. and 18.0 m. respectively (Bose, 1956). The average depth of the estuary measures about 2.8 m (at 200 km. upstream) and 8.3 m at sea faces (Sen *et al.*, 1994).

The turbidity was very high during monsoon months (2500 ppm) but very low (25 ppm) during winter season. The estuarine ecosystem with its variable physico-chemical and hydrological characteristics is constantly under a flux. These variable factors restrict the movement of organisms and only those which could adapt to these conditions can survive in the estuary. A somewhat near stable conditions prevail during the period from February to June in the Hooghly estuary. In the Matla estuary the fluctuations in physico-chemical characters are less pronounced. About a hundred years ago Matla was connected to the Hooghly river by Bidyadhari, which is totally dried up now leaving the former as a tidal river.

Taxonomic Diversity

Biodiversity of the estuary consists of terrestrial, freshwater and marine communities. The islands and reclaimed areas have been colonized by terrestrial insects, spiders, oligochaets and vertebrates. The freshwater forms include molluscs, insects, crustaceans and amphibians. Seventeen animal phyla have their representatives in the estuary.

The available data indicates that a total of (all living organisms) 1498 species were reported from different parts of the estuary. Fauna with a total of 1267 species has the maximum component, and by excluding terrestrial and freshwater species (about 300 Nos.) it is seen that aquatic fauna of the estuary constitute 76.3 per cent of the total faunal species known.

Faunistic profile of the estuary

Estuarine fauna fall under two broad categories, resident and non-resident. The former include mainly a number of invertebrates such as molluscs, polychaets, crustaceans and a few vertebrates. Majority of them are detritus feeders and many have significant roles in the process of detritus formation. Meiofauna, peanut worms, crabs etc. assist in the formation of detritus. As detritus feeders these animals are conditioned by the availability of suitable substrate and hence these are abundant where the conditions are favourable. Non-resident forms are mostly planktonic or nektonic. Some of these animals spend their lives in the estuary either as adults or as juveniles. Biological and physiological adaptations of many species in the estuary are worth investigating.

The document is mainly aimed at presenting an inventory of the less known groups of animals. There are papers on the ecology and pollution in the Hooghly estuary, on groups such as Cnidaria, Mollusca, Annelida (Polychaeta), Crustacea, Echinodermata, intertidal fishes, Amphibia and Reptilia. Some are exhaustive treatments, at least those on Mollusca and Polychaeta, while other are useful inventories.

Pollution

`There have been several studies on the pollution in the estuary. The estuary has a thickly populated urban and highly industrialized centres of hinterland, such as Calcutta metropolis and Haldia Complex. These centres generate domestic/ municipal sewage and industrial effluents, which find their way into the sea. The agricultural run off also add to the pollution load. The existence of port and shipping through the estuary further complicates the situation in the Hooghly - Matla estuarine complex. There are a number of small and large industries on the banks of the river Hooghly. The number of industries varied between 40 and 215. The industries which may cause pollution from point sources include paper, textiles, chemicals, pharmaceuticals, plastics, shellac, food, leather, jute, pesticides, oil etc. The studies have revealed that domestic/municipal sewage contribute maximum (68.95%) pollution to the estuary. The impact of pollution on biota was seen at short distance below the out fall but overall there has been a poor biological quality of the estuary near industries indicating a general deterioration in the ecological conditions.

Heavy metals are the normal constituents in the marine and estuarine environment. Pollution of Hooghly estuary with trace metals has been on the rise (Mitra *et al.*, 1994). Seddentary organisms are adversely affected by the trace metal pollution. Bio-accumulation of trace metals in the tissues of benthic molluscs has been investigated (Mitra and Chowdhury, 1993). Some of these organisms (*Nerita articulata, Littorina undulata, Cymia lacera, Columbella* sp. and *Crassostrea cucullata* investigated and other species of molluscs) may turn to be indicator species, which may be useful in biological monitoring of the estuary. Mitra and Chowdhury, (1993) have suggested *Crassostrea cucullata* and *Balanus* sp. as useful organisms in monitoring the ecological conditions of the estuary. The former occurs in saline zone of the estuary, whereas the latter can survive under fluctuating physico-chemical conditions. It survives even in the upper reaches of the estuary where the salinity falls to 0.8 ppt during monsoon and in the mouth of the estuary with salinity ranging 28 ppt during pre-monsoon period. Overall it was observed that *Cymia lacera* and *Crossostrea cucullata* contained higher concentrations of Zn, Cu, Mn in their tissues than other molluscs during monsoon period.

A close scrutiny of the literature reveals that earlier studies carried out almost 20 years ago, laid emphasis on hydrology and general distribution of different planktonic groups in the estuary without studying detail the composition, occurrence, abundance and variation of different species and groups, the recent studies, made an attempt in this direction, and confined to a very small area in the lower zone. Therefore, the present investigation were undertaken in order to study the hydrobiological features of the entire estuarine system, its plankton and benthos and their occurrence, production and variation with time and space along with the impact of important physico-chemical condition of the estuary on biota. The present bulletin reports the consolidated results of the work carried out between the period 1998-99 to 2002-03 under the research project of Estuarine Division of CIFRI, Barrackpore.

For the past several years the Sundarban distributaries are gradually changing their inflow due to want of headwater discharges from the upper reaches. Heavy deposition of silt is yet another cause for their disconnection from the main Hooghly channel. Inordinate pressure of anthropogenic activities in the area has added to the adverse effect on the productive status as well. These significant changes of diverse nature logically demand a thorough investigation into the ecology and bio-diversity of plankton, fish and prawn production encompassing the entire Hooghly estuarine system in perspective.

This study fills the vital gap in knowledge and information on the ecology and fishery resources of Hooghly estuarine system including its tributaries, distributaries in a comprehensive manner in the context of freshwater discharges through Farakka barrage and irrational exploitation of natural resources. It deals with the physico-chemical characteristics of water and soil, primary production, plankton and macro-zoobenthos in different eco-subsystems, the seasonal abundance and factors responsible for fluctuation of fishery, seasonal abundance of shrimp and fish seed as well as estimation of wanton destruction of economically important shrimp and fish seed from the estuarine system and biological studies of hilsa in the estuarine stretch.

BACKGROUND INFORMATION AND HYDROGRAPHICAL FEATURES

The Hooghly estuarine system of the Gangetic delta is endowed with the largest mangrove vegetation (4264 km^2 in India). It is criss-crossed by many major and minor estuaries in the Sundarbans region. The total area of the system is about 8029 km^2.. It is a positive mixohaline estuary having semi diurnal type of tide. The studies during pre and post Farakka barrage period indicated major changes in the water quality and fishery resources continually. After the commissioning the Farakka barrage in 1975, there is considerable drop in salinity and improvement of water quality and plankton production in Hooghly estuary compared to those during pre Farakka barrage period. Fish production registered an improvement from 9481 tonnes during pre Farakka to 43,000 tonnes during post barrage period and stood at 51,126.1 tonnes as of 1996-97. In recent times the general indicators of habitat quality, by and large, seemed to be favourable for many of the fish and prawn species in terms of ease for migration, breeding and growth. The importance of information on the ecology and fishery resource of the distributaries of Hooghly estuary is now duly valued. The distributaries producing large quantity of organic matter, a significant energy source to the ecosystem and serving as important nursery ground for larval rearing of many commercially important fishes and prawn are in the limelight. Hilsa, the most important anadromous fish of Indian sub-continent, received specific attention in studies on the physiological changes during migration. Attendant with extensive collection of fish seed and prawn seed from the estuary, the problem of wanton killing of juveniles is well recognized. Adequate information and data supportive to the formulation of new policies under the changed conditions are now considered vital to environmental safety and sustainable enhancement of productivity.

Morphometric details of Hooghly estuarine system

The Hooghly estuarine system of the Gangetic delta called Sunderbans (8029 km^2) is located in West Bengal, India between latitude 21 – 23° N and longitude 88 – 89° E and is famed to be the world's largest delta endowed with 4264 km^2 (in India) of mangrove vegetation. The lower portion of the estuarine system is criss-crossed by many major and minor distributaries and supports many important biotic communities. The main components of the estuarine system are the main Hooghly channel, its five tributaries, eight adjacent distributaries situated in the lower marine zone.

The Hooghly estuary, a distributary of the Ganga - Bhagirathi, is a positive estuary of mixohaline nature exhibiting semi-diurnal type of tide. Based on geo-morphological classification, the Hooghly and Ichamati are termed as coastal plain estuaries, while Matla, Saptamukhi, Thakuran and Bidya come under coastal plain salt marsh estuaries. The Hooghly estuarine system tends to receive substantial quantities of silt load and nutrients along with huge volume of freshwater from Ganga. During high tide a significant part of nutrients in the main channel enters into the distributaries turning the entire system highly productive. The active tidal regime is felt up to a distance of 200 km as of now, whereas it used to be marked up to 300 km upstream during pre-Farakka period. Before commissioning of Farakka barrage, Hooghly estuary was starved of adequate freshwater flow since bulk of the freshwater used to run through river Padma. As a consequence it gradually became inactive over time. The situation changed with the Farakka barrage feeding the main Hooghly estuary directly by the Ganga through feeder canals and the Bhagirathi. The additional discharge of sufficient freshwater into the system contributed to a significant tangible change in the ecology of the estuary. Most remarkably, it brought about a considerable decrease in salinity as well as a positive change in the distribution pattern and availability of plankton, micro/macro zoobenthos, prawn and fish fauna in the estuarine system in comparison to the scenario in pre-Farakka barrage period.

FISH CATCH AND EFFORTS STATISTICS

Total fish catch:

The methodologies for collection of data and estimation of fish catch from the estuary were same as developed by CIFRI (Dutta *et al.* and Mitra *et al.*).

The estimated total annual catch from the Hooghly - Matla estuarine system fluctuated from 62165.4 to 72098.7 t during the period 1998-99 to 2002-03 with an average catch of 66027.0 t per year showing a sharp increase of catch of 36.1% as compared to the average catch of the previous 5 years *i.e.* from 1993-94 to 1997-98 (Fig. 2). The rise in total catch (Table 1) during the year 2000-01 is ascribable to the enhanced catch (59% higher over previous year) at Digha center, following increased landings of a number of species *viz.*, Hilsa, *Sciaena biauritus, Pama pama, Pampus argenteus and* prawns. The decline in the total catch during 1999-00 and 2002-03 follows from a considerable fall in quantum of catch of Hilsa and winter migratory bagnet fishery. The yearly catch covers the period from March to February in order to account for the seasonal winter migratory bagnet catches during mid October to early February.

Zone-wise fish catch

The Hooghly estuary is divided into four strata or zones (Fig.1) based on salinity, fishing and landing pattern, distribution of crafts & gears and geographical contiguity in order to decipher fish catch statistics in a meaningful manner.

a. Zone I extending from Nabadwip to Baranagar (Kolkata) on main channel.
b. Zone II between Baranagar and Diamond Harbour on main channel.
c. Zone III (Lower zone) including entire estuarine area of Sunderbans and the tract below Diamond Harbour on main channel.
d. Zone IV containing Rupnarayan tributary, joining the main channel about 19 km above Diamond Harbour.

Zone I, II and IV together constitute the upper estuary & Zone III the lower estuary. Out of four zones, the lower zone, as usual remained the most productive and contributed nearly 96.9 to 97.6% of the annual catch of the estuary during the study period, while the upper estuary *i.e.,* Zone-I, II & IV together contributed nearly 2.4 to 3.1% of the total annual catch. The Zone-wise catch is depicted in Table 2 & Fig. 3.

Month-wise catch structure

The exploitation for fish catch in the Hooghly estuary is recorded to be continuous through out the year. During the study period the maximum average catch of 59.2% was recorded in the winter months of November, December and January, while the minimum average catch of 4.5% was observed during the summer months of March to June. The rest of the months (July to October & February) together accounted for a moderate catch of 36.3 % (Fig. 4).

Species composition of catches

In addition to prawn and mackrel, mainly 25 species are identified to represent commercial catches of Hooghly estuary. The species contributing less than 1% of the total catch individually are clubbed together and classified as 'miscellaneous' category.

Species composition of catches of Hooghly-Matla estuary :

The year-wise catch, species-wise catch, average catch (averaged over the years) and average percentage catch (%) are enumerated in Table 3 & Fig. 5. The dominant species in order of abundance comprised *Harpodon nehereus* 12.7-19.8% (av. 16.4%), *Tenualosa ilisha,* 10.2-21.9% (av. 15.7%), *Pama pama,* 10.0-12.3% (av. 11.2%), *Setipinna* spp., 6.4-11.3% (av. 8.3%), *Trichiurus* spp., 5.9-8.5% (av. 7.5%), prawns, 4.2-7.3% (av. 6.0%), *Arius jella,* 5.1-5.8% (av.5.4%), *Sciana biauritus,* 0.0-3.4% (av.3.1%), *Coilia* spp.,1.7-4.2%(av.2.7%), *Pampus argenteus,* 1.3-4.0% (av.2.6%), *Ilisha megaloptera,* 1.3-2.2% (av.1.9%) and Mackrel, 0.8-2.1% (av.1.2%). These species together accounted for 76.4-85.8% (av. 82.0%) of the total catch of the estuary.

T. ilisha, Harpodon nehereus, Pama pama, T.jella, Coilia spp., *Setipinna spp.,Trichiurus spp., I. Megaloptera, P. argenteus,* and prawns constitute the major portion (72.5% to 81.5%) of the lower zone catches, whereas in the upper estuary *Setipinna* spp., *P.pama, S. panijus, P.paradiseus, P.pangasius* and the prawn, *Macrobrachium rosenbergii* were found to be most abundant, barring *T.ilisha,*. These freshwater species along with hilsa and small sized prawns formed 82-88%, 91-94% and 85-89% of the total catches of Zone I, II & IV respectively. Freshwater species in the upper estuary (Zone I, II & IV) contributed 46.1 to 99.9 t in which the dominant species were *Rita rita* (2.8-7.2 t), *Aorichthys aor* (5.3-13.9 t), *Macrobrachium rosenbergii* (2.8-12.2 t) , *Glossogobius giuris* (3.4-12.2 t), *Eutropiichthys vacha* (2.4-9.1 t) , *Rinomugil corsula* (3.9–10.1 t) accounting for nearly 2.5 to 5.1 % of total catch of upper estuary (Table 4).

Grouped species-wise, the figures for total catch, average catch and percentage contribution to the total average annual landings during 1998-99 to 2002-03 are enumerated in Table 5. The dominant groups were the Clupieds 23.3-31.6 % (av.29.4 %), Bombay duck 12.7-19.8 % (av. 16.4%), Sciaenids 12.2-15.7 % (av. 14.3%), Ribbon fishes 5.9-8.5 % (av. 7.5%), Prawns 4.2-7.3 % (av. 6.0 %), Cat fishes 5.7- 6.3 % (av. 5.9 %), Polynemids 0.7- 0.8 % (av. 0.8%).

WINTER MIGRATORY BAGNET CATCH AT LOWER ESTUARY

Winter Migratory Bagnet Fishery (WMBF):

During the winter months (October to early February), bagnet fishing is, by far, a common sight with large number of fishermen migrating in groups from different parts of the estuary to some vantage pockets of the coastal belt. The fishing parties as they are called, set up numerous fishing camps and seen avidly engaged in bag net fishing and fish drying. This fishery activity is generally termed as winter migratory bag net fishery.

In order to facilitate a clear understanding, an inventory of probable number of active groups of fishermen and their holdings in term of crafts and gears was prepared well ahead of the recording fish catch and effort data. All the fishing camps (khuties) engaged in winter bagnet fishing operations were accounted for exclusively, for this purpose. Sampling days were selected adopting systematic sampling, a conventional sampling design. Data on total fish catch and effort were recorded from all the camps based on field observations spread over three / four sampling days in a month. A few random samples were examined to derive at the species composition of the catches.

The complete statistics on the number of fishermen engaged in fishing in different centers, total number of bagnets operated and the number of mechanized boats and non-mechanized boats engaged on yearly basis from 1998-99 to 2002-03 are presented in Table 6, Table 7 & Table 8. It reveals from the analyses that the numerically the fishing camps, nets, boats, fishermen population have tended to mark a gradual increase over the years.

The estimated catch of WMBF in lower estuary fluctuated within 24417.4 to 28417.4 t showing an average of 26710 t per season which worked out to 33.7 to 45.7% (av. 40.5%) of the total catch of the Hooghly estuary and an average CPUE of 40.20 to 64.85 kg (Fig. 6) during the period 1998-99 to 2002-03. Table 9 & Table 10 depict the total catch and CPUE as rising in trend well up to 1999-00 and thereafter plunging to the level of 24274 t (40.25 kg) during 2000-01. Interestingly, though the total catch kept on reviving in 2001-02, the CPUE did not follow suit, as it could marginally increase to 47.5 kg only. The CPUE further declined to 44 kg during 2002-03, consequent upon tremendous increase in 'efforts' during recent years. The fishing intensity in recent years has been on the increase as seen from the marked rise in number of fishing units from 1670 in 1999-00 (year of highest catch & CPUE during 1998-99 to 2002-03) to 2776 in 2002-03 registering a 67% increase. This in itself spells the warning signal for the future, as the level of exploitation of the estuary and increase of effort beyond a point is detrimental to environmental sustainability.

The seasonal catch of winter migratory bagnet fishery, mainly comprising of small sized fishes, accounted for 34.5 to 47.1% of the total catch from the lower estuary (Zone III) and 33.7 to 45.7% of the total catch of the Hooghly estuary. The species-wise catch from 1998-99 to 2002-03 along with their average catch and percentage composition are presented in Table 11. The dominant species contributing to the WMBF in order of abundance were *H.nehereus, Setipinna sp., Trichiurus spp., P.pama, Coilia spp.*, prawns, *A.jella, I. megaloptera, P.paradiseus, O.militaris, P.argenteus.* They formed 75.9 to 85.6 % (av.80.2 %) of the total catch of WMBF. Barring some of the economic species like *P.paradiseus, P.argenteus* and T.ilisha, most of the catches landed during WMBF are sun dried. Dried fishes are traded mainly in Uluberia along with various other marketing centers.

HILSA CATCH BY SELECTIVE GEARS FROM THE ESTUARINE SYSTEM

Hilsa fishery of Hooghly estuary

Dictated by market value and popular preference, *Tenualosa ilisha* ranks as the prime fish and commercially the most important fishery of the estuary. The monsoons (July-October) is earmarked as the main season for hilsa fishery, as the fish from the inshore areas of the sea ascends upstream mainly for spawning seeking freshwater stretches of the estuary.

FIG. 1 : HOOGHLY ESTUARY AND ITS VARIOUS FISHING ZONES

Landing of Hilsa catch from fishing boat

Hilsa catch along with drift-gill net bringing out from fishing vessel

Lifting of Hilsa from drift-gill net

Collection of *P.monodon post larvae* in the estuary

Hilsa catch kept in the plastic sheet at the river bank before sending to assembly centre

A labour in an assembly centre filling basket with Hilsa & Ice

Loading of truck with fish
in an assembly centre

Catch of Hilsa juveniles ready for
sending to fish landing centre

The Hilsa catch in Hooghly estuary is characterized by wide fluctuations alluding normal scope of prediction. The annual catch of the species from the Hooghly estuary varied from 6448.2 to 15799 t during 1998-99 to 2002-03 with an average catch of 10382.9 t (Table-3), showing 65.3% annual growth of catch compared to the average catch of 6279.6 t of previous 5 years (from 1993-94 to 1997-98). The annual contribution of the species to the total yield was found to be in the range of 10.2 to 21.9% (average being 15.7%). However, Hilsa catch from the estuary was the highest during 2000-01 (15799 t) (Fig. 7). This spurt in hilsa yield in 2000-01 and the encouraging average catch levels in recent years apparently results from the combined effect of tremendous increase of effort, induction of modern fishing methods and improved infrastructure. As a surprising aberration, however, the annual catch of the species plunged down to 6448. 2 t during 2002-03 (Table-3) due to poor catch of hilsa during monsoon. The hilsa catch in different stretches of the estuary is presented in Table 12 & Fig. 8.

Barring the catches of winter migratory bag net fishery, Hilsa in fact forms the mainstay of the estuarine fish catches, contributing 17.8 to 33.0 % to total annual fish catches. About 80-90% of the hilsa were captured during monsoon months (July-October) mostly by engaging drift gill nets (locally known as 'chadi jal', 'dholi jal', 'kona jal' etc.). Besides this, gill nets, purse nets (locally known as 'sanglo jal') and set gill nets (locally known as 'nangar jal') are also among the selective gears exclusively used for catching hilsa. In the upper estuary (especially in Zone I) presents a scenario where all types of nets including drift gill nets, purse nets and set gill nets are in operation during the monsoons.

In the prime fishing season of the monsoons when the fish migrates up along the river course for breeding in freshwater, large size fishes corresponding to 3-, 4- and 5- year age group in the length range of 20 to 55 cm were seen to dominate the catches of hilsa. Contrastingly enough, the mean length of hilsa, which was observed to be 356mm during period 1961-62 to 1993-94 (Mitra *et al.*) has markedly dipped to 325mm (Table-13) as observed during this study. This is not only represents an alarming situation, but also signals deteriorating recruitments of the species in foreseeable future. One in escapable option however may be strictly to regulate mesh size of the operating gears to thwart the imminent danger.

CPUE of hilsa gears:

The CPUE (catch per unit effort) of different hilsa gears in upper estuary during the period 1998-99 to 2002-03 is presented in Table 14. In zone-I, Zone-II and zone-IV the CPUE of drift gill nets varied from 0.58 to 0.95 kg, 0.77 to 1.48 kg and 0.88 to 1.16 kg respectively during the period 1998-99 to 2002-03. Average CPUE of Hilsa gear in the lower marine zone, which contributes nearly 70- 90% of the total

Hilsa catch in the monsoons varied between 92 and 228 kg during the period 1998-99 to 2002-03.

Wanton destruction of juvenile hilsa

Post larvae, fry, fingerlings and juveniles of hilsa are available in plenty in the upper stretches of the Hooghly estuary during November to May and sometimes even up to July. This corresponds to the season when they start down stream migration towards the sea. Indiscriminate exploitation through very small meshed nets, particularly bag nets and small seine nets, generally lead to large-scale destruction of the species. As estimated, the catch of the juveniles fluctuated between 44.1 and 151.0 t averaging 85.1 t per year during the period of study (Table 15). The size and weight of the juveniles, as observed ranged from 6.2 to 15.5 cm and 2.0 to 28.0 g respectively.

GEAR-WISE COMPOSITION OF FISH CATCH

A number of different types of gear are operated round the year for commercial fishing in the estuary. A few selective gears are exclusively employed for catching commercially important species whereas majority of them are used for multi-species exploitation. Bagnets and drift-gill nets constitute the most dominant gears (Fig. 9) in the entire Hooghly estuary. These two types account for 66.1 to 76.7% (av. 71.0%) and 21.4 to 32.2% (av.27%) respectively of the total catch as observed in this study. In other words, these nets collectively contribute 97.3 to 98.6% (av.98.0%) of the total catch of the estuary. Thus it leaves only 2% of the total catch of the estuary coming from the gears such as trawl nets, seine nets, purse nets, lift nets, cast nets, set- gill nets, set berrier nets, traps, hooks & lines etc. At Digha center, 65.2 to 80.6% (av. 70.7%) and 18.1 to 34.3% (av.28.5%) of total Digha catch came from bag nets and drift-gill nets respectively. The combined catch of these two nets varied from 98.7 to 99.5% (av. 99.2%) of the total Digha catch. The gear-wise composition of catch of Hooghly estuary exclusively is presented in Table-16 for the year 1998-99 to 2002-03.

INVENTORY OF HILSA CRAFTS AND GEARS IN LOWER ESTUARY

An inventory on Hilsa-specific crafts and gears (drift–gill nets) operating in the lower estuary was set up in 1999-2000. The data reveals that a combined strength of 1672 drift–gill fishing units equipped with over 4 lakhs (441510) pieces of net in the size range of 40' x 18' to 60' x 30', 1572 number of trawlers varying in capacity between 15 and 105 HP and 2292 number of non-mechanized boats were in operation in the lower zone of the Hooghly estuary. For effective fishing, a sizeable number of drift-gill net pieces, varying between 60 and 400 are laced together to form a 'ber' (circle) depending on size of fishing and area of operation.

LENGTH- WEIGHT RELATIONSHIP OF FISH SPECIES

Length-weight relationship worked out for several commercially important species is depicted in the Table 17.

ESTIMATED POTENTIAL FISH-CATCH YIELD

The estimated total catch from the Hooghly–Matla estuarine system showed an increasing trend over the years. There has been a simultaneous rise in the intensity of fishing effort as well from year to year resulting from mechanization of fishing vessels and modernization of associate infrastructures. This provides the backdrop to study and evaluate the extent to which the estuary could support sustainable fish yield paving the way to arrive at the practical potential yield. The task however, is not so easy except when full-scale experimental fishing is resorted to. The lower estuary, which contributes 90 - 96% of the total yield of the estuary, cannot provide data on effort except for winter migratory bagnet fishery. In this case, the entire range of active fishermen groups could not be contacted on the spot as the catches arrive from the scattered and remote fishing ground directly to assembly centers for disposal of the stock. Since multi-species fish are exploited in the estuary by multiple gears with wide-ranging mesh size, the effective evaluation of effort in each case becomes an insurmountable problem further. Estimation of MSY by surplus production model could not be attempted in absence of effort data based on calibration of gears. As such, the time series data on total catch from 1993-94 to 2002-03 were used to obtain the maximum catchable potential yield (Algaraja, 1984). The maximum catchable potential yield or C_{max} value was worked out as 67,855.1t. The average catch of the last five years more or less was of the same order (66,027 t).

During the period from 1998-99 to 2002-03, Hooghly estuarine fisheries registered an annual average growth rate of 36.1 %, as computed from the present average annual catch (66027 t) and the figure (45524.4 t) during previous 5 years period (from1993-94 to 1997-98). The observed average yield (66027 t) is well within the domain of Maximum Sustainable Yield (MSY: 67855.1 t). It testifies that the estuary is presently being exploited closer to its optimum level. Exerting more efforts would mean a further reduction in CPUE as well as total catch of the estuary and eventually might lead to over fishing. In order to save the status of fishery pushed to an uneconomic level, it is high time to control fishing pressure from further thrusts and maintain its sustainability.

Problems Identified in the Management of Fisheries of the Estuary :

The Hooghly estuarine system is basically a multi species system exploited by multi gears. At present, the fishermen are operating selective or multi species gears with wide range of mesh size to capture a particular size range of species. So, analysis of length frequency data of various species from commercial catches poses problem due to selectivity of gear as a result of deployment of gears having various mesh sizes. Estimation of surplus production models could not be done for want of effort data and for effort data further, it is essential to calibrate the gears for standardization of effort data.

Fishermen are also very reluctant to allow measurement of priced fishes like *T.ilisha, P.paradiseus etc.* at the landing sites for expecting damage due to handling of the species and this perhaps can be overcome by undertaking experimental fishing.

Indiscriminate exploitation of fry, fingerlings, early juvenile and juveniles of many species (*T.ilisha, Pama pama, P. paradiseus, M. rosenbergii, S. phasa* etc.) by very small meshed nets, particularly bag nets and seine nets in the upper estuary, where they are found to inhabit are subjected to wanton destruction and severely effect the yield of the estuary. Operation of these nets in the upper estuary may be prohibited or peak period of abundance of young ones of these species in the upper estuary may be declared as closed seasons for operation of small meshed nets in the upper estuary.

IMPORTANT BIOTIC COMMUNITIES OF THE ESTUARINE SYSTEM

Plankton :

The plankton population of Hooghly main channel fluctuated within the range of 198-514 u/l. River Matla and Ichhamati harboured higher density of plankton in the range of 390-468 u/l and 308-437 u/l, respectively. The freshwater stretch of the estuary supported relatively higher plankton population followed by high and low saline stretches (Table 18).

Under the impact of mangrove vegetation in the surrounding river basin of the distributaries, the Jharkhali stretch of river Matla seemed to be relatively better poised in terms of the proliferation of plankton, both phyto and zooplankton.

A closer scrutiny of phytoplankton species revealed the a clear dominance of Bacillariophyceae and Cyanophyceae. The members of Chlorophyceae were more pronounced in the freshwater stretch, such as Nabadwip. Similarly the members of Dinophyceae were observed to be restricted mainly to high saline stretches and mangrove areas. *Cyclops* sp and nauplei constituted the bulk of zooplankton population followed by rotifers, protozoans and cladocearns. The members of rotifers were more conspicuous at Jharkhali stretch of Matla and freshwater stretch at Nabadwip indicating substantial organic load in the systems.

Seasonal variations among the planktonic community indicated relatively better plankton proliferation during winter months followed by summer. However, except for the bacillariophycean forms among phytoplankton being remarkably ubiquitous in distribution, all other groups had a strong strong seasonal preference. Relatively higher population and species diversity in respect of cholorophyceae and cyanophyceae were recorded during post-monsoon and summer months, respectively. Similarly, euglenoids were more common during monsoon and post-monsoon months.

Significantly, a depression in the distribution of the predominantly centric diatoms of saline waters, *Coscinodiscus* spp, was confirmed, as it could not be recorded up to Kakdwip. This indicates either extension of freshwater stretch or at least a considerable decline in salinity regime in this estuarine system owing to additional ingress of freshwater from overhead discharge from Farakka barrage. Besides, many freshwater species have also been recorded from the gradient and low saline zones as classified in earlier years.

Bottom biota :

During the period under report the average annual population of macro-benthic fauna in the Hooghly estuary fluctuated in the range of 3581-5089 number / m^2 (Table 19 & Fig. 10). The seasonal variation of benthic population in the Hooghly estuarine system including the distributories like Matla and Ichhamati indicated much larger community size during monsoon followed by summer. Gastropods (82.81-97.36%) emerged as the most predominant macro-benthic invertebrates followed by bivalves (2.75-12.24%). Harwood-point followed by Dhamakhali and Nabadwip appeared to be more congenial for the greater colonization of macro-benthinc forms as evidenced from relatively better numerical crop strength. However, the distribution of bivalves was more common in Bakkhali followed by Jharkhali and Hasnabad. Matla and Ichhamati rivers linked to the tendency of harbouring relatively higher population of chironomids and oligochaetes and clearly indicative of increasing organic load in these systems ascribable to various anthropogenic activities.

The qualitative structure of benthic abundance revealed the dominance of molluscs (gastropods) like *Thiara tuberculata, Cerithidea cengulata, Littorira seabra* , *L. melanostoma, Nerita articulata* and *Bellamys bengalensis.* Among the bivalves *Nactra inzonica, Barnia candida* and *Polymesoda bengalensis* were predominant. Oligochaetes and chironomids were also encountered, although their distribution remained sporadic, especially in freshwater stretch. Similar was the case with polychaetes as well.

WATER AND SOIL PARAMETERS AND PRIMARY PRODUCTION PROFILE OF THE DISTRIBUTARIES OF THE HOOGHLY ESTUARY

The physico chemical characteristics and primary production of different centers of Hooghly estuary and other distributaries are depicted in Table 20 and their average values are shown in Table 21 & Fig. 11.

a) Physico-chemical regime

i) Temperature

The minimum water temperature (13.7 – 15°C) was recorded during winter (January - February), while maximum (31 - 34°C) was found during summer (May - June). Thermal stratification was not detectable in the Hooghly estuarine system, presumably due to tidal effect. Average water temperature of the distributaries ranged between 24.72 and 26.4°C. Bhagabatpur was marked for the minimum while the maximum was recorded at Dhamakhali. The water temperature regime in Hooghly estuary as well as the distributaries is apparently conducive for growth of fish and other aquatic organisms.

ii) Transparency

The Secchi disc transparency was generally low (average 18.4 - 31.4 cm) in the distributaries - the lower value being marked at Dhamakhali and the higher at Moipeeth. In Hooghly estuary, minimum transparency was recorded at the gradient zone (Diamond Harbour to Kakdwip) compared to freshwater (Nabadwip) and marine (Frazerganj) zones. The turbulence due to tides may be the cause for low transparency in gradient zone. Transparency was found to be maximum during winter and early summer while it was minimum during monsoon and post monsoon.

iii) Dissolved oxygen

Maximum dissolved oxygen (mg l^{-1}) was recorded at Haldia (av. 6.9) followed by Nabadwip (av. 6.8) and Moipeeth (av.6.8). Dissolved oxygen content in the Hooghly estuary and its distributaries maintained the level in the range of 6.3 - 6.9 which indicate that this system was very congenial for fish growth. D.O. content in Hooghly estuary during the period was significantly higher compared to that during pre-Farakka period. This may be attributed to increase in freshwater discharge into the estuary after commissioning of Farakka barrage.

iv) pH

The water in Hooghly estuary and its distributaries was slightly alkaline in reaction (av. pH 7.9 - 8.3), which is considered as congenial for aquatic habitats. Haldi and Bidya had slightly lower pH compared to other estuaries.

v) Total alkalinity

Minimum total alkalinity was recorded at Frazergnj (106.1 mg l^{-1}) and Jharkhali (103.4 mg l^{-1}), while higher contents were found at Hasnabad (133.7 mg l^{-1}) and Nabadwip (126.3 mg l^{-1}). Thus contents were higher in freshwater zones compared to those at high saline zones. At all the centers, the total alkalinity was maximum during winter/summer and minimum during monsoon/post-monsoon period. Total alkalinity contents in all the distributaries were suitable for aquatic life and fish growth.

vi) Free CO_2

Free CO_2 content ranged between 3.51 mg l^{-1} and 5.2 mg l^{-1}, which indicated that the distributaries were moderately free from aquatic pollution and without any adverse effect on the aquatic habitat. In fact, free CO_2 in small quantity is considered desirable around this level aiding photosynthesis by plankton and algae.

vii) Salinity

In Hooghly estuary is classified into three distinct zones based on salinity pattern - freshwater zone (Nabadwip to Uluberia), gradient zone (Diamond Harbour to Kakdwip) and marine zone (Kakdwip to sea face). Maximum salinity was recorded at Jharkhali (26.35 g l^{-1}) followed by Frazerganj (22.24 g l^{-1}), Bhagabatpur (19.24 g l^{-1}) and Moipeeth (18.7 g l^{-1}). Lower salinity was noted at Dhamakhali (13.9 g l^{-1}), Harwood Point (8.28 g l^{-1}), Haldia (5.4 g l^{-1}) and Hasnabad (3.75 g l^{-1}). However, Nabadwip at freshwater region of Hooghly estuary had very low salinity (0.052 g l^{-1}).

viii) Nitrate

Nitrate content in Hooghly estuary ranged between 0.15 and 0.29 mg l^{-1}, the freshwater region having higher contents compared to that in other regions. The contents in other distributaries varied from 0.13 to 0.21 mg l^{-1} - the minimum content being noted at Haldia and maximum at Jharkhali.

ix) Phosphate

Maximum phosphate content (0.094 mg l^{-1}) in Hooghly estuary was found in the freshwater zone, followed by gradient zone (0.079 mg l^{-1}), while lower content was recorded at the marine zone (0.07 mg l^{-1}). In other distributaries phosphate ranged between 0.056 and 0.11mg l^{-1}, the minimum being recorded at Jharkhali and maximum at Hasnabad. It is evident that phosphate content tends to be high, when salinity is low and as the salinity increases phosphate content declines.

x) Silicate

Maximum silicate content was recorded at freshwater zone (0.4 mg l^{-1}; Nabadwip), followed by gradient zone, (6.69 mg l^{-1}; Harwood Point), while the marine zone in Hooghly estuary contained minimum silicate content (3.2 mg l^{-1}; Frazerganj). The distributaries also presented a similar scenario. Here silicate content ranged between 3.45 and 6.6 mg l^{-1} - the minimum being noted at Jharkhali and maximum at Haldia. Silicate content showed similar trend as that of phosphate i.e., an inverse relationship with salinity in the estuaries

xi) Calcium and Magnesium

Calcium and magnesium are two important nutrients favouring enhancement of aquatic productivity. The freshwater region (Nabadwip) showed the calcium and magnesium content as moderately good (Ca - 34.9 and Mg 8.1 mg l^{-1}), while higher values (Ca 161.91 and Mg 308.75 mg l^{-1}) were recorded at gradient zone. The maximum contents (Ca 376 and Mg 698 mg l^{-1}) were noted at the marine zone of Hooghly estuary. It is interesting to note that at freshwater region Calcium content was higher than Magnesium, but at the gradient and marine zones Magnesium content was higher than that of Calcium. Calcium and Magnesium were maximum (Ca 468.9 and Mg 819.6 mg l^{-1}) in Matla, followed by Thakuran (Ca 423 and Mg 653 mg l^{-1}). A slightly lower contents were recorded at Haldi and Ichamati.

xii) Specific conductivity

Specific conductivity was minimum (0.47 millimhos/cm) at the freshwater zone, which rose to a higher value at gradient zone (11.16 millimhos/cm). As usual the maximum value was observed at marine zone (22.7 millimhos/cm) of Hooghly estuary. Among other distributaries, Sp. conductivity (millimhos/cm) was maximum at Matla (24.57), followed by Thakuran (22.4) and Saptamukhi (20.93) while slightly lower values were recorded at Bidya (13.1), Haldi (8.7) and Ichamati (6.4). From the data, it is apparent that Matla, Saptamukhi, Thakuran resemble the marine zone of Hooghly estuary while, Bidya, Haldi and Ichamati resemble the gradient zone.

xiii) Total dissolved salt

Total dissolved salt content was minimum (0.30 g l^{-1}) at freshwater zone, followed by gradient zone (6.6 g l^{-1}), while it was maximum at the marine zone (14.8 g l^{-1}) in Hooghly estuary. Among the distributaries, it was highest at Matla (15.96 g l^{-1}) followed by Thakuran (14.5 g l^{-1}), Saptamukhi (13.61 g l^{-1}), Bidya (8.5 g l^{-1}) and Haldi (5.7 g l^{-1}). However, Ichamati (4.2 g l^{-1}) had lower contents which resembled the gradient zone of Hooghly estuary.

xiv) Sulphate

Sulphate content showed a similar trend as sp. conductivity or salinity. It was minimum at freshwater zone (13.3 mg l^{-1}) with an increasing trend towards the gradient zone (133.98 mg l^{-1}). The maximum content was recorded at the marine zone (212.3 mg l^{-1}) in Hooghly estuary. In the distributaries, it was maximum at Saptamukhi (222.3 mg l^{-1}), followed by Matla (187.53 mg l^{-1}), Thakuran (179 mg l^{-1}). Bidya (148.0 mg l^{-1}), Haldi (113.5 mg l^{-1}) and Ichamati (84.1 mg l^{-1}) had slightly lower contents which resembled gradient zone of Hooghly estuary. Sulphate in soluble form is considered to be an important content in water bodies as it aids oxygen supply during anaerobic conditions.

xv) Total nitrogen

Maximum total nitrogen was found at Matla (0.53 mg l^{-1}) followed by Hooghly freshwater zone (0.51 mg l^{-1}) and Thakuran (0.51 mg l^{-1}), while minimum content was recorded at Ichamati (0.20 mg l^{-1}). Nitrogen being one of the primary nutrients, the data indicated that Hooghly estuary and its distributaries were productive in terms of nitrogen availability.

xvi) Hardness

Hardness was minimum at freshwater region (121.1 mg l^{-1}) which increased in gradient zone (1778.7 mg l^{-1}) but the maximum value was recorded at the marine zone (3847 mg l^{-1}) of Hooghly estuary. Among the distributaries, maximum hardness was noted at Matla (4587.8 mg l^{-1}), followed by Thakuran (3769 mg l^{-1}) Saptamukhi (3571.1 mg l^{-1}). Bidya (2564 mg l^{-1}), Haldi (1666 mg l^{-1}) and Ichamati (1434 mg l^{-1}) had lower contents, which resemble the gradient zone of Hooghly.

b) **Primary production**

The primary production of Hooghly and other distributaries are depicted in Table 20 and their average values are shown in Table 21 & Fig. 12.

Primary production varied greatly depending on climatic factors, turbulence and turbidity of the estuarine waters. Both gross and net primary production was low during monsoon in Hooghly estuary and its distributaries due to high turbulence, low transparency and poor sunlight. Maximum primary production was recorded during winter and pre-summer due to clear weather, high transparency and profuse sunlight.

(i) Gross primary production

In Hooghly estuary maximum gross production (mgC/m^3/hr) was recorded at freshwater zone (74.2) followed by marine zone (60.4) and gradient zone (60.2). Amongst the distributaries, maximum GPP (mgC/m^3/hr) was recorded at Haldi (72.6) and Thakuran (72.6), followed by Saptamukhi (64.0) and Bidya (60.0), while Ichamati (59.2) and Matla (58.4) showed slightly lower values.

(ii) Net primary production

Maximum net primary production (mgC/m^3/hr) was found at Thakuran (50.5) followed by Haldi (45.1), freshwater Hooghly (40.1), marine zone Hooghly (39.0), while Matla (35.84), Ichamati (35.4), Saptamukhi (36.3) and Bidya (33.3) had slightly lower production.

(iii) Community respiration

Community respiration (mgC/m^3/hr) was maximum at freshwater zone of Hooghly (36.9) followed by Bidya (33.8), Saptamukhi (33.4) and Haldi (33.2), while lower values were found at Ichamati (28.7), Matla (27.75), Hooghly gradient zone (28.5), Thakuran (26.4) and marine zone of Hooghly (25.6).

c) **Soil characteristics**

In the Hooghly estuary and its distributaries the soil is alluvial and mostly silty clay loam in texture. The soil characteristics of the distributaries are depicted in Table – 22 & 23 and Fig. 13.

Hooghly estuary receives nutrient loaded sediment from the Ganga riverine system. The fertile soil continues to be distributed over all the distributaries during high tide. The bottom sediments subjected to the process of high tide, bore tide and low tide, are well raked up continually to release nutrients into the water phase imparting high productivity. In fact the Hooghly estuary is one of the most productive estuaries of the world, which is evident from the following soil parameters:

Soil pH

The soil reaction of Hooghly estuary and its distributaries was slightly alkaline (pH range 8.32 – 9.73, average 8.47 – 9.32) which was conducive for aquatic productivity.

Specific conductivity

Specific conductivity (millimhos/cm) of bottom sediments ranged from 0.37 to 8.46 millimhos/cm. Nabadwip in freshwater zone of Hooghly had minimum (0.37 - 0.43) value, while Frazergange (3.25 - 4.13), Jharkhali (5.0 - 8.46), Moipeeth (5.38 - 6.8), Bhagabatpur (4.0 - 5.35) and Dhamakhali (2.3 - 4.07) had higher values indicating moderate to slightly higher soil salinity.

Total Nitrogen

Maximum total nitrogen (%) was recorded at Bhagabatpur (0.065) followed by Moipeeth (0.064, Jharkhali (0.063), Hasnabad (0.062) and Frazerganj (0.061), while minimum content was noted at Harwood Point (0.054).

Available Nitrogen

Maximum available nitrogen (mg/100 g) was noted at Moipeeth (15.17) followed by Bhagabatpur (14.58), Jharkhali (13.83), Dhamakhali (13.83) and Harwood Point (13.63), while slightly lower content was found at Frazerganj (12.25).

Available Phosphorus

Maximum available phosphorus (mg/100 g) was observed at Moipeeth (5.19), followed by Bhagabatpur (4.44), Dhamakhali (4.25) and Hasnabad (4.12), while slightly lower contents was recorded at Jharkhali (3.79), Haldia (3.55), Harwood Point (.3.47), Nabadwip (2.36) and Frazerganj (2.14).

Organic Carbon

Maximum organic carbon (%) was recorded at Nabadwip (0.73), followed by Dhamakhali (0.71), Moipeeth (0.69), Jharkhali (0.69) and Bhagabatpur (0.66). Slightly lower values were noted at Haldia (0.63), Frazerganj (0.60) and Harwood Point (0.57) while minimum was recorded at Hasnabad (0.55).

Free Calcium Carbonate

Hooghly estuary and its distributaries are very rich in calcium carbonate, which is very conducive for aquatic habitat. Free calcium carbonate (%) was maximum at Nabadwip (12.64), followed by Frazerganj (12.19), Hasnabad (11.98), Bhagabatpur (11.6), while minimum content was noted at Dhamakhali (11.06).

C/N ratio

C/N ratio ranged between 8.72 and 12.3 and the minimum value was noted at Haldia and maximum at Jharkhali. In general, the C : N ratio was very congenial for fish growth.

Qualitatively, the Hooghly estuarine water reflected remarkable consistency with no significant perturbations in most of the physico-chemical parameters over the past several years. This observation is a prominent indicator signaling the extent of stabilization in estuarine environment following the upwelling phase inducted by Farakka discharges. In contrast, other estuaries constrained by restricted flow of freshwater discharge differed from Hooghly in respect of abiotic and biotic characteristics. In Hooghly estuary three distinct zones could be identified based on salinity pattern and other physico chemical factors - a freshwater zone (Nabadwip to Uluberia), gradient zone (Diamond Harbour to Kakdwip) and marine zone (Kakdwip to sea face). Even so, Haldi and Ichamati maintained oligohaline conditions, while Saptamukhi, Thakuran, Matla and Bidya could be described as Hyper-haline in terms of salinity fluctuation. Water transparency in hyper haline estuaries was generally higher compared to that in oligohaline ones. Dissolved oxygen fluctuated within a narrow but moderately productive range (5.3 - 8.0 mg l^{-1}). Alkaline pH (7.8 - 8.2), low concentration of free CO_2 (2.8 - 8.2 mg/l), high levels of calcium (27.6 - 954 mg l^{-1}), magnesium (133.2 - 939 mg l^{-1}) and sulphate (31 - 318 mg l^{-1}) contributed synergistically creating an ambience for sustained productivity in the entire estuarine system. The nutrient status of the distributaries as indicated from the range and concentration of nitrate (0.13 - 0.29 mg l^{-1}), phosphate (0.06 - 0.11 mg l^{-1}) and hardness (1434 - 4588 mg l^{-1}) was also remarkably good for the aquatic ecosystem. However, the silicate content (3.24 - 6.7 mg l^{-1}) was somewhat low in the distributaries compared to that in freshwater region (8.4 mg l^{-1}).

The soil reaction was slightly alkaline which was by and large conducive for aquatic life. Soil salinity continued to maintain between moderate to slightly higher as indicated by specific conductivity. Moderate contents of organic carbon, available nitrogen, total nitrogen and available phosphorus and rich calcium carbonate content indicated that nutrient release was very facile in this system under the supportive and favourable environmental and physico-chemical factors such as temperature, water flow, tides, water reaction etc. Reduced nutrient load in soil was beneficial, since chance of formation of toxic and growth inhibitory substances (nitrite, NH_3, CH_4 etc) was almost negligible. The silty clay loam texture of soil and the C : N ratio were also conducive for survival and growth of fishes and prawns.

d) Heavy metals

The concentration of heavy metals in water of the Sundarban estuaries is depicted in Table 24 & Fig. 14. The zinc content in water ranged from 0.004 to 0.161 mgl^{-1} with mean values varying from 0.019 to 0.065 mgl^{-1}. The minimum and maximum concentrations were recorded at Ichamati estuary during 2001 and 2002 respectively. However, Zinc content was comparatively lower in Dhamakhali (Bidya) and higher at Jharkhali (Matla). The metal concentration showed an increasing trend in Bidya and Thakuran, while it showed a decreasing trend in Ichamati, Haldi and Saptamukhi estuaries. In general, Zn content in water was low and within permissible range for aquatic environment. Copper content ranged from Tr to 0.076 mgl^{-1} and its mean values varied from 0.002 to 0.064 mgl^{-1}. The copper content in water apparently did not exceed safe limits. The concentration of copper showed decreasing trend during 2001 compared to those during 2000 from all the estuaries. Chromium content in the estuarine water ranged from Tr to 0.161 mgl^{-1} and its mean values ranged from 0.011 to 0.074 mgl^{-1}. The data indicated that average chromium content in Matla, Saptamukhi and Thakuran were slightly above the permissible limit during 2001. In other estuaries, chromium concentration slightly exceeded the permissible range only on one or two occasions. Cadmium content in water ranged from 0.001 to 0.093 mgl^{-1} with mean values between 0.001 to 0.072 mgl^{-1}. Cadmium concentration remained above safe limit during 2000 in all the estuaries, which subsequently decreased to acceptable levels in Matla, Saptamukhi and Thakuran. Lead content varied from 0.003 to 0.477 mgl^{-1}, while the mean concentration ranged from 0.009 to 0.41 mgl^{-1}. The data indicated that all the Sundarban estuaries harboured lead contents above the permissible level during 2000. During 2001, however, only Matla, Saptamukhi and Thakuran had lead above permissible range. Manganese content ranged from Tr to 0.096 mgl^{-1} and the mean varied between 0.005 and 0.075 mgl^{-1}. The study indicated that Matla and Thakuran had manganese levels above the permissible range for most part of 2001 and 2000. Bidya and Saptamukhi occasionally showed slightly higher values. In general manganese content was within permissible range in the rest of the Sundarban estuaries. Iron content in water ranged between Tr and 0.429 mgl^{-1} and the mean values ranged from 0.028 to 0.254 mgl^{-1}. From Table 24, it is apparent that iron content was generally within safe limit. In Matla, Saptamukhi, Thakuran and Haldi, however the iron content occasionally increased beyond the permissible range during 2000.

The heavy metal contents in soils from Sundarban estuaries are presented in Table 25 & Fig.15. Zinc content varied from 21.26 to 87.91 mg kg^{-1}, with minimum being recorded at Matla and maximum at Hooghly Estuary. Mean zinc content varied from 51.27 to 77.88 mg kg^{-1}. Zinc contents at most of the sampling sites were higher during 2001 compared to that of 2000. Ichamati estuary had highest values during 2001. Copper content in the soil ranged between 2.56 and 118.41 mg kg^{-1}, with the minimum being recorded at Dhamakhali (Bidya) and the maximum at Saptamukhi. The mean contents ranged between 13.06 and 45.52 mg kg^{-1}.

Cu contents were, lower during 2000 compared to that of 2001. Chromium content in the bottom sediment ranged 16.74 to 44.68 mg kg^{-1}, the minimum being recorded at Hooghly and maximum at Saptamukhi. The mean values ranged between 20.3 and 32.86 mg kg^{-1}. The concentration was higher during 2001, compared to that in 2000. Cadmium content ranged from 0.04 to 4.02 mg kg^{-1}, with the minimum being noted at Bidya and the maximum at Matla. The mean content ranged from 1.06 to 4.02 mg kg^{-1}. Unlike copper, chromium and żinc, cadmium content was higher during 2000 compared to that in 2001. Lead content varied from Tr to 58.61 mg kg^{-1}. Lead content showed an increasing trend at Bidya, Hooghly, Saptamukhi and Thakuran, while it showed decreasing trend at Matla, Ichamati and Haldi. The manganese contents in the estuarine soils were moderately high (105.86 and 596.38 mg kg^{-1}). The yearly mean values showed minimum at Haldi (131.30 mg kg^{-1}) during 2000, while maximum values were recorded at Ichamati (476.86 mg kg^{-1}) during 2001. Like Cu, Cr, Zn, and Pb, manganese also showed increasing trend. The soils in Sundarban estuaries were rich in iron (1088.75 to 86654.75 mg kg^{-1}). The yearly mean ranged from 13245.88 to 27440.92 mg kg^{-1}, the minimum being recorded at Ichamati during 2000 and the maximum at Hooghly during 2001. Iron showed an increasing trend at Bidya, Hooghly, Haldi and Ichamati, while a decreasing trend was noted at Matla, Saptamukhi and Thakuran during the study period.

A large number of industrial units (about 150) are discharging their effluents in the Hooghly estuary (Ray, 1980; Ghosh *et al.*, 1980). Though, the physico-chemical parameters of the Sundarban Estuaries are not seriously affected by the industrial effluents (Nath and De, 1999), many industries releasing heavy metals are a cause for concern as they may eventually get deposited in the Hooghly and other Sundarban estuaries. Even if the effect of heavy metal pollution is to be generally localised near the source, it is fairly likely that during the monsoon flow and floods the pollutants may spread to extensive areas, (Konhauser *et al.*, 1997). In the present investigation, according to surface water criteria (Table 27) given by Kopp

(1970), it was found that zinc, copper, manganese and iron contents of water in these estuaries were generally low and within permissible range. However, cadmium and lead contents were slightly above the permissible range and chromium content also showed slightly higher values in Saptamukhi, Thakuran and Matla estuaries. Heavy metal content in soils of the estuaries indicated that their conentration was moderately high in sediments (Table 25) in all the estuaries of Sundarban. Iron contents were very high, followed by manganese and zinc, while lead, chromium, copper and cadmium contents were comparatively low (Table 26). The results indicated that heavy metals are gradually contaminating the Sundarban estuaries, particularly lead, cadmium, chromium and manganese. Appropriate monitoring and control measures need to be taken to protect these estuaries. Metal pollution has been well documented from the upper and middle stretch of Ganga (Singh *et al.,* 1993). Varma, (1995) and Munshi *et al.,* (2000) have observed that many species had vanished from the Subarnarekha river due to heavy metal pollution. Discharge of different types of effluents from city sewage, textile waste, industrial waste, tannery waste, jute mills, chemical factories *etc.* are responsible for heavy metal pollution load in Hooghly estuary, which is ultimately reaching other Sundarban estuaries. Most of the heavy metals coming to these estuaries are either precipitated in insoluble forms by alkaline water (pH 8.8- 9.2) or adsorbed into bottom sediment (Konhauser *et al.,* 1997). Jain and Ali (2000) also found that Cd absorption increases with increasing pH. Ghosh *et al.* (1997) found that Cu, Cd and Pb in their divalent state, form complexes with humic acid. The stability of this complexes increase with rise in pH and fall in ionic strength of the medium. The humic acid extracted from sediment characteristically act as a stronger complexing agent compared to that from sewage. This may explain the lower level of Cu, Cd and Pb in the estuarine water as they may be forming complexes with humic acid present in bottom sediment (Organic carbon 0.5-1.5 %) or precipitated at the prevailing alkaline nature of water (pH 8.0-8.4) and sediments (pH 8.4-9.3).

From this study it is inferred that the heavy metals in Sundarban estuarine sediments were mostly present in insoluble, bound state and very low quantities were liberated into water phase by soil-water exchange. However, no clear evidence is found whether the heavy metals in Sundarban estuaries come from Hooghly estuary or they are naturally present in the soil minerals, for which further investigations are required.

FISH AND PRAWN SEED RESOURCES OF COMMERCIALLY IMPORTANT SPECIES

Estuarine finfish and shell fish seed prospecting

The estuarine finfish and shellfish seed prospecting investigation in Sundarbans was carried out by personal interview of the seed collectors through a structured schedule developed for the purpose and latter verified by actual operation of shooting net. The availability of prawn seed varied between 2,534 nos. and 4,638 nos. per man-day whereas fish seed varied between 327 nos. and 508 nos. per man-day. In collected prawn-seed lot, availability of *Penaeus monodon* ranged between 66 nos. and 612 nos. The awful loss by destruction of fish/prawn seed, incidental to the process of assorting *P. monodon* has remained a glaring and long drawn out bane in history of estuarine fisheries. It has now been possible to control it to a reasonable extent through participatory approach and mass awareness campaigns carried out by the Institute. Periodic assessments have confirmed that about 24 percent of the seed collectors are practically releasing back the fish/prawn to the water body after assorting the *P. monodon* seed.

SOCIOLOGICAL PROFILE OF THE PRAWN AND FISH SEED COLLECTORS IN SUNDERBANS

Occupational health hazards

The development of prawn and fish industry largely depends on steady and adequate supply of seed of desired species. Sundarbans with its estuarine creeks, canals and thick mangrove cover offer excellent nursery grounds for most of the euryhaline finfish and shellfish. Millions of tiny larvae, post larvae or juveniles of several species enter into the ecosystem along with high tides. Lured by regular and quick cash income, the poor population of Sundarbans irrespective of religion, cast, age, sex have *en masse* taken to seed collection as an avocation for their livelihood. About 4 lakh people in the area are engaged in this profession. During collection of seed, the collectors are forced to spend long hours in waist-deep water. Consequently a sizeable cross-section of seed collectors often fall victim to various diseases. This crucial problem was addressed in an investigation carried out in some villages of Sundarbans. A sample consisting of 240 participants were personally interviewed for investigation. The age of the seed collectors varied between 11 and 60 years. The female ratio among the seed collectors being higher, the incidence of disease in females was more numerically and in frequency. The seed collectors spent on an average 2-12 years sticking to this profession. As many as 34 percent of them could make to a monthly income of Rs. 1,000/- and about 20 %could make do with Rs. 8,001/- per month. As reported by the respondents [N=200: seed collectors], diseases in order frequency of occurrence include skin diseases (48%), leucorrhoea (41 %), eye problem (38%), stomach disorder (33.5%), loss of body hair (29%), weakness (26%), problem of urination (12%), irregularity in menstruation (11%), palpitation and nausea (10%), blood pressure, heart problem (9%), irritation & burning sensation in the body (6%). Similar statistics in the control population [N=40: non-seed collectors], however indicated the diseases to cover eye problem (30%), stomach disorder (25%), heart diseases (10%), diabetes (20%), tuberculosis (10%), asthma (10%), leprosy (5%), headache (10%) and gonorrhoea (5%). Most of the

A boy segregating *P.monodon* post Larvae

Heap of destructed fish & prawn seed after segregation of *P.monodon* post larvae

Segregated catch of *Mystus gulio.*
in a landing centre

A busket full of estuarine prawns
in a landing centre

respondents (56.5%) reported increased intensity of the diseases during Summer. About 58% of them (both male & female) were addicted to smoking bidi and 33.5% to chewing of betel. A dismal 12 percent of them ever consulted a qualified doctor while a non-significant 10.5 percent sought help from the quacks and 5 percent unsurely chose to rely on indigenous plants for treatment of diseases. The ground reality of course is that poverty in Sundarbans especially among people whose livelihood rests on seed collection, can not afford to bear the cost of treatment. In the bizarre situation like this, only philanthropic welfare measure from Govt. and/or NGOs an massive effort could alter it for the better.

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Table 1 : Total catch (in t) of Hooghly estuary and Digha centre

Year	Hooghly Estuary	Digha Centre	Total
1998-99	47565.8	17691.1	65256.9
1999-00	44477.4	17688.0	62165.4
2000-01	44012.5	28086.2	72098.7
2001-02	44717.0	22576.4	67293.4
2002-03	40299.1	23021.6	63320.7

Table 2 : Zonewise total catch (in t) from Hooghly estuary

Year	Zone- I	Zone-II	Zone-III	Zone-IV	Total
1998-99	589.5	693.1	63361.8	612.5	65256.9
1999-00	603.8	686.5	60367.9	507.2	62165.4
2000-01	595.6	528.7	70264.2	710.2	72098.7
2001-02	562.3	483.0	65670.8	577.3	67293.4
2002-03	828.7	498.0	61356.7	637.3	63320.7

Table 3 : Species composition of catches (in t) of Hooghly-Matlah estuary

Species	1998-99	1999-00	2000-01	2001-02	2002-03	Average	%
T.ilisha	11580.5	6539.2	15799	11547.7	6448.2	10382.9	15.7
L.tade	0.8	0.8	0.6	0.8	12.4	3.1	0.0
L.parsia	21.2	18.2	17.6	31.7	57	29.1	0.0
L.calcarifer	108.5	20.1	17.5	9	40.3	39.1	0.1
S.panijus	28.6	19.2	82	37.8	232.4	80.0	0.1
P.paradiseus	421.6	361.3	568.9	328.2	240.8	384.2	0.6
P.indicus	113.9	98.6	66.8	88.5	163.3	106.2	0.2
E.tetradactylum	22.8	21.8	23.6	30.4	30	25.7	0.0
S.biauritus	2178.3	2115.9	3383.1	2398.6	28.9	2021.0	3.1
Coilia spp.	2713.1	2103.6	1338.2	1115.4	1571.7	1768.4	2.7
P.pama	6552.8	7645.1	7957	7172.9	7700.6	7405.7	11.2
H.toli				11.9		2.4	0.0
I.megaloptera	1249.3	1215.2	1609	1445	853.1	1274.3	1.9
Anodontostona spp.	32.3	14.8	7.2	5.5	43.8	20.7	0.0
M.gulio	24.6	24.5	21.4	47.2	38.9	31.3	0.0
Setipinna spp.	4164.5	7011.7	4775	6197.5	5129.7	5455.7	8.3
C.dorab	900.9	373.8	362	282.7	581	500.1	0.8
P.pangasius	133.6	11.1	26.8	44.9	222.5	87.8	0.1
A.jella	3350.1	3488.2	4170.1	3437.6	3451.3	3579.5	5.4
O.militaris	192.8	216.1	216.5	164.5	244.9	207.0	0.3
P.canius	1.8		0.3	2.1	5.4	1.9	0.0
Lutjanus spp.	31.3	196	267.7	220.2	110.8	165.2	0.3
Trichiurus spp.	5223.1	3655.5	4979	5735.7	5031.3	4924.9	7.5
H.nehereus	8318.2	12302.8	9275.9	11815.1	12358.6	10814.1	16.4

P.argenteus	1436.6	807.7	1850.1	2053.7	2508.5	1731.3	2.6
Prawns	2729.9	3916.2	4359.4	4170.6	4615.1	3958.2	6.0
Mackrel	1356.2	700.1	588.6	538.8	754.7	787.7	1.2
Miscellaneous	12318.3	9212.5	10289.3	8302.1	10745.6	10173.6	15.4
Feshwater species	51.3	75.4	46.1	57.3	99.9	66.0	0.1
Total	**65256.9**	**62165.4**	**72098.7**	**67293.4**	**63320.7**	**66027.0**	**100.0**

Table 4: Catch (in t) of freshwater species in upper estuary

Species	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**
M.rosenbergii	7.2	12.2	6.7	2.9	2.8
A.aor	8.9	13.9	11.8	12.4	5.3
R.rita	11.9	21.2	11.2	11.9	15.6
E.vacha	2.4	9.1	3.7	3.6	8.1
R.corsula	8.2	5.8	3.9	5.3	10.1
G.guris	12.2	10.7	4.7	7.7	3.4
Others *(W.attu,L.rohita,C.catla, C.mrigala, A.coila, C.garua* etc.)	0.5	2.5	4.1	13.5	54.6
Total	**51.3**	**75.4**	**46.1**	**57.3**	**99.9**
% contribution to total upper estuary catch	***2.7***	***4.2***	***2.5***	***3.5***	***5.1***

Table 5 : Group-wise composition of catches (in t) of Hooghly-Matlah estuary

Species group	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**Average**	**%**
Clupieds	20608.3	17243.5	23883.2	20600.2	14583.7	19383.8	29.4
Catfishes	3702.9	3739.9	4435.1	3696.3	3975.2	3909.9	5.9
Polynemids	558.3	481.7	659.3	447.1	434.1	516.1	0.8
Sciaenids	8731.1	9761	11340.1	9571.5	7729.5	9426.6	14.3
Mullets	22	19	18.2	32.5	69.4	32.2	0.0
Ribbon fishes	5223.1	3655.5	4979	5735.7	5031.3	4924.9	7.5
Bombay duck	8318.2	12302.8	9275.9	11815.1	12358.6	10814.1	16.4
Prawns	2729.9	3916.2	4359.4	4170.6	4615.1	3958.2	6.0
Others	15363.1	11045.8	13148.5	11224.4	14523.8	13061.1	19.8
Total	**65256.9**	**62165.4**	**72098.7**	**67293.4**	**63320.7**	**66027.0**	**100.0**

Table 6 : Centre-wise concentration of migratory fishermen in winter migratory bagnet fishery in lower estuary

Centre	1998-99	1999-00	2000-01	2001-02	2002-03
Frazerganj	300	225	286	382	558
Bokkhali	258	172	201	452	518
Upper Jamboo	2668	2621	2567	2653	1050
Lower Jamboo	1563	1050	1560	1418	810
Kalisthan	936	607	785	1075	1482
Sagar Island	895	815	1073	2022	2110
Total	**6620**	**5490**	**6472**	**8002**	**6528**

Table 7 : Centre-wise concentration of bag nets in winter migratory bagnet fishery in lower estuary

Centre	1998-99	1999-00	2000-01	2001-02	2002-03
Frazerganj	128	128	141	139	212
Bokkhali	115	98	103	198	214
Upper Jamboo	464	565	669	728	414
Lower Jamboo	328	269	393	397	314
Kalisthan	192	134	227	284	442
Sagar Island	434	476	642	972	1180
Total	**1661**	**1670**	**2175**	**2718**	**2776**

Table 8 : Centre-wise concentration of boats in winter migratory bagnet fishery in lower estuary

Centre	1998-99	1999-00	2000-01	2001-02	2002-03
Frazerganj	55(41)	56(43)	59(47)	59(51)	80(67)
Bokkhali	46(26)	47(30)	48(32)	100(65)	96(73)
Upper Jamboo	116(98)	127(118)	115(112)	125(105)	60(60)
Lower Jamboo	72(63)	62(56)	83(78)	72(60)	50(50)
Kalisthan	58(38)	37(30)	57(41)	58(49)	90(77)
Sagar Island	151(50)	170(68)	217(76)	336(131)	390(160)
Total	**498(316)**	**499(345)**	**579(386)**	**750(461)**	**766(487)**

Table 9 : Centre-wise catch (in t) of winter migratory bagnet fishery in lower estuary

Centre	1998-99	1999-00	2000-01	2001-02	2002-03
Frazerganj	1128.3	1125.4	940.2	1000.1	2701.7
Bokkhali	598.5	508.0	595.7	852.9	1219.7
Upper Jamboo	10463.9	13783.6	9886.3	12170.6	5674.6
Lower Jamboo	6975.2	6487.1	5690.4	6576.1	4450.9
Kalisthan	3465.8	4032.4	2837.1	4364.7	4134.0
Sagar Island	2943.8	2480.9	4325.1	3152.5	2748.6
Total	**25575.5**	**28417.4**	**24274.8**	**28116.9**	**27165.8**
% contribution to total catch	***39.2***	***45.7***	***33.7***	***41.8***	***42.9***

Table 10 : Centre-wise CPUE (kg) of winter migratory bagnet fishery in lower Hooghly estuary

Centre	1998-99	1999-00	2000-01	2001-02	2002-03
Frazerganj	34.47	33.70	23.01	29.79	42.89
Bokkhali	23.80	22.89	24.09	20.31	18.07
Upper Jamboo	72.59	79.69	47.80	63.68	88.48
Lower Jamboo	67.60	81.58	46.73	64.34	93.30
Kalisthan	69.96	101.86	39.00	67.47	71.55
Sagar Island	34.47	27.40	31.58	19.97	11.93
Total	**58.11**	**64.85**	**40.20**	**47.54**	**43.99**

Table 11 : Species-wise composition of catches (in t) in winter migratory bagnet fishery in lower estuary

Species	1998-99	1999-00	2000-01	2001-02	2002-03	Average	%
T.ilisha			2.8	21.7		4.9	0.0
L.tade						0	0.0
L.parsia						0	0.0
L.calcarifer						0	0.0
S.panijus	0.2	0.2	31.6	0.4	10.1	8.5	0.0
P.paradiseus	159.2	158.7	167	132.4	78.6	139.2	0.5
P.indicus				3.1	0.5	0.7	0.0
E.tetradactylum				13.6	0.3	2.8	0.0
S.biauritus				2.2		0.4	0.0
Coilia spp.	2252.7	1543.5	836.9	704.4	579.9	1183.5	4.4
P.pama	2126.3	2866.5	1451.1	2231.6	2075.4	2150.2	8.1
H.toli				11.5		2.3	0.0
I.megaloptera	167	176	122.5	221.5	65.1	150.4	0.6
Anodontostona spp.				4.6		0.9	0.0
M.gulio				1.8		0.4	0.0
Setipinna spp.	3504.6	5692.3	3482.8	5055.5	4341.4	4415.3	16.5
C.dorab	4.8		14.1	29.5	4.6	10.6	0.0

P.pangasius	78.3		6.4	118.9	14.4	43.6	0.2
A.jella	215.8	300.1	437.4	220.7	171.5	269.1	1.0
O.militaris	136	173.5	96	37.4	183.3	125.2	0.5
P.canius				0.9		0.2	0.0
Lutjanus spp.						0	0.0
Trichiurus spp.	3703	· 2014.7	3764.2	3821.1	2126.4	3085.9	11.6
H.nehereus	7096.2	10454.2	6998.4	9109.4	9669.3	8665.5	32.4
P.argenteus	86.4	83.7	79.7	109.8	108.2	93.6	0.4
Prawns	597.5	867.5	1409.8	1568.1	1206.2	1129.8	4.2
Mackrel				4		0.8	0.0
Miscellaneous	5447.5	4086.4	5374.1	4692.8	6530.5	5226.3	19.6
Total	**25575.5**	**28417.3**	**24274.8**	**28116.9**	**27165.7**	**26710.0**	**100.0**

Table 12 : Hilsa catch (in t) of Upper estuary, Lower estuary & Digha centre

Year	Upper Estuary	Lower Estuary	Total	Digha Centre	Grand Total
1998-99	528.6	8464.2	8992.8	2587.7	11580.5
1999-00	305	5037.1	5342.1	1197.1	6539.2
2000-01	354.1	9436.1	9790.2	6008.8	15799
2001-02	391.4	7358.9	7750.3	3797.4	11547.7
2002-03	480.7	3697.6	4178.3	2269.9	6448.2
Average	411.9	6798.8	7210.7	3172.2	10382.9
%	4	65.5	69.5	30.5	100

Table 13 : Mean length (mm) of different species

S. No	Species	Range	Mean length(mm)
1	*Trichiurus spp*	114-830	359.01
2	*S.taty*	65-174	125.75
3	*H.nehereus*	103-462	217.99
4	*Coilia spp.*	50-219	132.47
5	*P.pama*	52-227	117.85
6	*P.paradiseus*	55-185	133
7	*P.argenteus*	75-206	107.9
8	*L.megaloptera*	118-281	196.72
9	*A.jella*	77-242	118.92
10	*O.militaris*	72-214	121.61
11	*H.toli*	90-145	114.81
12	*C.ramcaraty*	107-192	128.96
13	*T.ilisha*	207-490	325.47

Table 14 : Gear-wise CPUE of Hilsa in upper estuary during 1998-99 to 2002-03

Year	Zone- I			Zone- II	Zone- IV
	Driftgill net CPUE(kg)	Purse net CPUE(kg)	Setgill CPUE(kg)	Driftgill net CPUE(kg)	Driftgill net CPUE(kg)
1998-99	0.95	0.36	1.78	1.48	1.16
1999-00	0.58	0.21	0.78	0.82	1.02
2000-01	0.63	0.23	0.71	0.77	0.88
2001-02	0.79	0.4	-	1.85	1.15
2002-03	0.81	0.58	1.42	1.29	1.06

Table 15 : Estimated annual wanton destruction (in t) of hilsa juveniles

Year	Catch(in t)
1998-99	53.4
1999-00	44.1
2000-01	151.0
2001-02	100.1
2002-03	77.0
Average	85.1

Table 16: Gear-wise composition of catches (in t) of Hooghly-Matlah estuary

Gears	1998-99	1999-00	2000-01	2001-02	2002-03	Average	%
Trawl	69.5	72.5	57.8	65.5	118.9	76.8	0.1
Large seine							0.0
Small seine	1058.1	302.5	661.5	374.7	813.9	642.1	1.0
Purse	18.7	11.4	5.2	16.7	22.6	14.92	0.0
Drift	20381	13283.3	23208	18166.7	14096.4	17827.1	27.0
Lift	15.4	10.4	7.7	5.9	14.3	10.7	0.0
Cast	14.5	37.9	17.3	16.9	8.6	19.0	0.0
Bag	43159.1	47711.6	47505.9	48157	47744.1	46855.5	71.0
Set-gill	10.6	16.5	1.2		2.9	6.2	0.0
Setbarrier	161.9	229.4	166.3	143.5	187.8	177.8	0.3
Traps	1.5	2.1	0.7	5.5	24.7	6.9	0.0
Hooks	173	96.3	159	189.1	113.3	146.1	0.2
Bholaber	193.6	377.4	285.7	142.4	165.1	232.8	0.4
Tapsia		14.1	22.4	9.5	8.1	10.8	0.0
Total	**65256.9**	**62165.4**	**72098.7**	**67293.4**	**63320.7**	**66027.0**	**100.0**

Table 17 : Length- Weight relationships with results of tests for the value of b

Sl.No.	Species	a	b	r	t	
1	*T.ilisha*	0.009128	3.0795	0.972	1.589	
2	*L.parsia*	0.00816	3.1342	0.9972	1.659	*
3	*L.tade*	0.009033	3.0218	0.9738	0.162	
4	*S.panijus*	0.001833	3.3686	0.9918	2.646	***
5	*P.paradiseus*	0.004127	3.1203	0.9902	1.525	
6	*E.tetradactylum*	0.003257	3.2138	0.9321	4.472	***
7	*P.pama*	0.004071	3.1651	0.9982	1.679	*
8	*I.megaloptera*	0.018221	2.9615	0.8706	0.342	
9	*S.phasa*	0.002959	3.1985	0.7569	4.552	***
10	*P.pangasius*	0.023575	3.3112	0.9175	2.011	**
11	*L.calcarifer*	0.01826	3.1213	0.9703	1.332	
12	*P.argenteus*	0.006025	3.3189	0.9462	3.429	***

* P< 0.10 ** P < 0.05 *** P < 0.01

Table 18 : Year-wise average plankton production (April to March), u/l

Years	Stretch/Centres	Total plankton (u/l)	Phyto-plankton (u/l)	Zooplankton (u/l)	Dominant species
	HOOGHLY				
1998-99	***Freshwater stretch*** Nabadwip	425	324	101	*Oscillatoria, Rhabdoderma, Scenedesmus, Pediastrum Slenastrum, Cosmarium, Closterium,Navicula, Melosira, Pinnularia, Gomphonema, Cyclops, Brachionus,* Nauplii
	Low saline stretch Moipeeth, Bhagwatpur	238	147	91	*Nitzschia, Navicula, Melosira, Gyrosigma, Cyclotella, Anabaena, Cyclops, Brachionus,* Protozoans, Nauplii
	High saline stretch Bakkhali	369	312	57	*Coscinodiscus, Rhizosolenia, Pleurosigma, Navicula, Peridinium, Cyclops,* Nauplii
	MATLAH				

	Jharkhali	390	265	125	*Nitzschia, Cymbella, Navicula, Coscinodiscus, Cyclotella, Melosira, Scenedesmus, Oscillatoria, Lyngbya, Anabeana, Nostoc, Keratella, Brachionus, Protozoans, Cyclops, Diphanosoma,* Nauplii
	ICHHAMATI				
	Hasnabad	308	265	43	
1999-2000	***Freshwater stretch*** Nabadwip	384	291	93	
	Low saline stretch Moipeeth, Bhagwatpur	198	113	85	
	High saline stretch, Bakkhali	402	331	71	
	MATLAH				
	Jharkhali	412	219	193	
	ICHHAMATI				
	Hasnabad	356	298	58	
2000-2001	***Freshwater stretch*** Nabadwip	514	360	150	
	Low saline stretch Moipeeth, Bhagwatpur	233	165	68	
	High saline stretch, Bakkhali	417	322	95	
	MATLAH				
	Jharkhali	395	286	109	
	ICHHAMATI				
	Hasnabad	360	245	115	
2001-2002	***Freshwater stretch*** Nabadwip	428	283	145	
	Low saline stretch Moipeeth, Bhagwatpur	229	167	62	
	High saline stretch, Bakkhali	355	197	158	
	MATLAH				
	Jharkhali	458	282	176	
	ICHHAMATI				
	Hasnabad	408	334	74	

2002-2003	***Freshwater stretch*** Nabadwip	390	287	103	
	Low saline stretch Moipeeth, Bhagwatpur	210	145	65	
	High saline stretch, Bakkhali	415	289	126	
	MATLAH				
	Jharkhali	468	246	222	
	ICHHAMATI				
	Hasnabad	437	341	96	

Table 19 : Year-wise average of Zoo-macrobenthic population in Hooghly-Matlah Estuarine system

Years	**Total average population (M^2)**	**Gastropods**	**Bivalves**	**Others**
Hooghly				
1999	4100	3559 (86.81%)	418 (10.19%)	123 (3.0%)
2000	3981	3712 (93.25%)	171 (4.29%)	98 (2.46%)
2001	3564	3470 (97.36%)	66 (1.85%)	28 (0.79%)
2002	5089	4357 (85.62%)	623 (12.24%)	109 (2.14%)
2003	4055	3829 (94.67%)	143 (3.52%)	83 (2.04%)
Matlah	3799	3482 (91.66%)	134 (3.52%)	183 (4.81%)
Ichhamati	2977	2465 (82.81%)	82 (2.75%)	430 (14.44%)

Table 20 : Physico-chemical characteristics and primary production of different centres of Hooghly Estuary and other distributaries during the period May 1998 to March 2003.

Parameters	Harwood Point (Hooghly)	Bhagatput (Saptamukhi)	Moipeeth (Thakuran)	Dhamakhali (Bidya)	Haldia (Haldi)	Hasnabad (Ichamati)	Jharkhali (Matlah)	Frazerganj (Hooghly)	Nabadwip (Hooghly)
W.T. (^{0}C)	24.2-26.8	22.5-25.95	24.42-26	25.22-28.58	24.6-26	24.2-26.5	25.4-25.97	23.9-26.5	24.6-25.2
Trans. (cm)	20.8-21.5	24.3-32.83	27-34	15.6-20	17.2-20	19-21	23.6-24.7	21-27.5	21.2-22.5
DO (mgl^{-1})	6.4-6.83	6.3-7.1	6.3-701	5.8-6.95	6.3-8	6.1-6.7	6.1-6.7	6.3-6.69	6.7-6.9
pH	8.01-8.1	7.85-8.13	8.05-8.12	7.8-8.1	7.9-8	8.03-8.11	8.08-8.11	8.09-8.19	8.06-8.2
TA (mgl^{-1})	109-124.5	100.7-113.5	104-117	114.5-126	111-126	126.5-145.3	96.5-106.5	96.33-118	118-131
FreeCO_2(mgl^{-1})	4.45-4.8	4.4-4.6	4.6-5.05	3.5-8.2	3.0-4.6	4.8-5.8	3.5-4.5	2.8-4	3.2-4.55
Cl (gl^{-1})	4.8-5.5	9.1-12.1	8.9-11.3	6.4-9.1	2-3.7	1.2-2.6	14.3-14.9	9.1-15.2	0.006-0.0448
Salinity (gl^{-1})	7.38-9.90	16.4-21.8	16-20	11.6-16.3	3.7-6.7	3.24-4.7	25.9-26.9	22.24-26	0.0466-0.058
NO_3 (mgl^{-1})	0.094-0.235	0.12-0.27	0.11-0.28	0.102-0.212	0.095-0.160	0.097-0.21	0.07-0.33	0.116-0.165	0.2195-0.42
PO_4 (mgl^{-1})	0.052-0.119	0.05-0.09	0.05-0.09	0.05-0.1035	0.067-0.161	0.079-0.134	0.05-0.07	0.064-0.083	0.0625-0.116
SO_4 (mgl^{-1})	66.3-191.7	96-318	98-245	70.7-230.5	69.8-159	31.0-124.7	98.4-272.8	91.7-277.5	6.0-15.9
SiO_2 (mgl^{-1})	5.05-7.8	3-6.8	2.2-7.9	3.225-7.5	3.7-8	4.2-7.3	2.1-4.6	3.0-4.2	6.425-10.97
Ca (mgl^{-1})	114.3-244.73	223.5-702	219-930	146.3-312.7	112-525	76.3-374	284.2-954	192.4-593.2	27.6-44.08
Mg (mgl^{-1})	246.3-371.8	457-846.3	471-843	235.7-495.2	233-291.5	133.2-296.1	238-994.3	389-939	3.80-15.12
Sp. Cond. (m mhos/cm)	8.3-11.45	18.4-22.65	19.8-24	8.82-15.9	6.8-10.7	2.3-10.7	22.4-27.23	16.6-26.03	0.63-0.54
TDS (gl^{-1})	5.4-7.5	12-14.7	12.9-15.6	5.73-10.33	4.38-7	1.52-7	14.53-17.76	16.8-16.9	0.234-0.35
Total N(mgl^{-1})	0.206-0.82	0.21-0.82	0.18-0.88	0.22-0.612	0.138-0.574	0.18-0.57	0.135-1.15	0.168-0.47	0.4526-0.596
Hardness (mgl^{-1})	1312-2025	2433-4238	2970-4287	1800-3863	1277-2527	746.7-1873	3900-5458	2100-4766	105.3-132
GPP ($mgC/M^3/hr$)	54.1-66.7	50-81.3	51.4-86.5	41.7-83.33	50.2-104	45.8-69	40.8-68.75	50-70	54.1-86.1
NPP ($mgC/M^3/hr$)	33.3-40	29.1-51	31.9-64.6	27-42.7	29.3-61.6	26.4-40.6	21.9-44.8	33.3-44.9	33.3-51.025
RP ($mgC/M^3/hr$)	25.2-35.0	25-50	23.3-28.8	22-50	22.5-51.8	23.3-39	18.75-38.75	20-30	25-48.3

Table 21 : Average physico-chemical characteristics and primary production of different centres of Hooghly Estuary and other distributaries during the period. May 1998 to March 2003.

Parameters	Harwood Point (Hooghly)	Bhagatput (Saptamukhi)	Moipeeth (Thakuran)	Dhamakhali (Bidya)	Haldia (Haldi)	Hasnabad (Ichamati)	Jharkhali (Matlah)	Frazerganj (Hooghly)	Nabadwip (Hooghly)
W.T. (^{0}C)	25.05	24.72	25.1	26.4	26	25.4	25.63	25.43	24.8
Trans. (cm)	21.03	28.28	31.4	18.4	19	20.5	24.12	25	22
DO (mgl^{-1})	6.65	6.72	6.8	6.3	6.9	9.5	6.42	6.53	6.8
pH	8.06	8.04	8.1	7.95	7.92	8.1	8.096	8.14	8.29
TA (mgl^{-1})	119.5	110.53	112	120.3	117	133.7	103.45	106.11	126.3
FreeCO_2(mgl^{-1})	4.6	4.48	4.9	5	4	5.2	3.97	3.51	4.1
Cl (gl^{-1})	4.57	10.65	10.3	7.7	3	2.1	14.56	13.08	0.022
Salinity (gl^{-1})	8.28	19.24	18.7	13.9	5.4	3.75	26.35	22.24	0.052
NO_3 (mgl^{-1})	0.162	0.178	0.176	0.16	0.13	0.15	0.21	0.149	0.293
PO_4 (mgl^{-1})	0.079	0.063	0.06	0.08	0.1	0.11	0.056	0.07	0.094
SO_4 (mgl^{-1})	133.98	222.30	179	148	113.5	84.1	187.53	212.3	13.3
SiO_2 (mgl^{-1})	6.69	4.95	4.4	5.34	6.6	5.6	3.95	3.241	8.4
Ca (mgl^{-1})	161.91	389.9	423	302.4	208	167	468.89	376	34.9
Mg (mgl^{-1})	308.75	596.71	653	417.6	275	244	819.61	698	8.1
Sp. Cond. (m mhos/cm)	11.16	20.93	22.4	13.1	8.7	6.4	24.57	22.7	0.47
TDS (gl^{-1})	6.6	13.61	14.5	8.5	5.7	4.2	15.96	14.8	0.3
Total N(mgl^{-1})	0.413	0.374	0.51	0.39	0.35	0.20	0.525	0.34	0.51
Hardness (mgl^{-1})	1778.7	3571.1	3769	2564	1666	1434	4587.8	3847	121.1
GPP ($mgC/M^3/hr$)	60.23	63.99	72.6	60.0	72.6	59.2	58.37	60.4	74.2
NPP ($mgC/M^3/hr$)	36.06	36.31	50.5	33.3	45.1	35.4	35.84	39	40.1
RP ($mgC/M^3/hr$)	28.5	33.39	26.4	33.8	33.2	28.7	27.75	25.6	36.9

Table 22 : Physico-chemical characteristics of bottom soils of different centres of Hooghly Estuary and other distributaries during the period April 1998 to March 2003.

Parameters	Hasnabad	Frazerganj	Nabadwip	Harwood Point	Jharkhali	Moipeeth	Haldia	Dhamakhali	Bhagabatpur
Av. pH	8.63	9.32	8.47	8.89	8.87	8.93	8.81	8.78	8.9
Range	8.32-8.81	9.27-9.37	8.32-8.62	8.45-9.13	8.56-9.12	8.5-9.2	9.37-9.08	8.46-9	8.55-9.3
Av. Sp. Cond.	1.53	6.39	0.395	3.02	6.72	6.02	1.99	3.274	4.798
Range (m mhos/cm)	1.02-1.9	3.25-4.133	0.366-0.425	2.6-3.43	5.025-8.46	5.375-6.8	1.89-2.12	2.3-4.07	4-5.35
Av. Total N (%)	0.062	0.061	0.059	0.0543	0.063	0.064	0.0604	0.0614	0.065
Range (%)	0.051-0.083	0.058-0.064	0.054-0.065	0.037-0.078	0.044-0.08	0.05-0.09	0.043-0.10	0.039-0.09	0.050-0.103
Av. Nitrogen	13.53	12.25	12.54	13.63	13.83	15.17	13.44	13.83	14.58
Range (mg/100gm)	10.2-15.5	9.94-14.56	11.49-13.62	10.5-16.4	9.93-18.4	12.5-17.79	8.8-16.8	10.3-15.69	11.9-16.8
Av. Phosphorus	4.12	2.14	2.358	3.47	3.791	5.19	3.55	4.25	4.44
Range (mg/100gm)	3.4-4.75	1.633-2.65	2.183-2.533	2.5-2.16	3.4-4.72	3.8-7.3	3.2-4.11	3.8-4.72	3.79-4.7
Av. Organic Carbon (%)	0.55	0.60	0.73	0.57	0.694	0.69	0.63	0.71	0.664
Range (%)	0.41-0.66	0.51-0.68	0.696-0.76	0.38-0.78	0.48-0.855	0.51-0.98	0.44-1.0	0.4-1.17	0.51-1.09
Av. Free $CaCO_3$ (%)	11.98	12.19	12.64	11.13	11.12	11.16	10.73	11.06	11.6
Range (%)	8.4-14.25	11.0-13.7	10.66-14.62	6.7-14.75	8.7-14.58	7.7-14.75	7.2-13.7	8.0-13.25	8.0-15.5
Av. Sand	39.8	42.92	44.66	39.6	38.6	39.35	40.2	38.85	40.18
Range (%)	38-44	39.33-46.5	43.33-46	36-44.25	35-42.5	34.44	35-46.5	35-45	36.45.2
Av. Silt	44.78	43.92	43.63	44.15	45.5	42.65	42.65	44.45	44.88
Range(%)	41-49	41.5-46.33	41.6-45.66	41.25-46	42.75-47	40-44	41.25-44	43-46	41.7-49
Av. Clay(%)	15.35	13.17	11.75	16.25	16.0	17.9	16.95	16.7	14.9
Range(%)	12-21	12.0-14.33	11-12.5	13-20	13.25-20	12.25-26	12.25-21	11.75-21	13-20
Av. C/N	10.55	10.10	12.3	10.97	12.175	11.08	8.724	11.71	10.8
Range	9.04-11.96	9.6-10.6	11.7-12.9	10.1-11.95	10.7-14.7	10.2-12.5	10-11.9	10.3-13	10.2-12

Table 23 : Soil conditions of Hooghly estuary and other distributaries of Hooghly estuary

Year	pH	Sp.Conmm mhos/cm	Total Nitrogen %	Av. N_2 mg/100g	Av P_2O_5 mg/100g	Organic Carbon %	Free $CaCo_3$ %	Sand %	Silt %	Clay %	C / N
Hasnabad											
1998	8.32	1.02	.051	10.2	3.4	.51	8.4	39	42	19	10.0
1999	8.49	1.25	.051	11.9	4.5	.61	10.4	38	41	21	11.96
2000	8.73	2.0	.054	15.1	4.31	.58	12.75	39	49	12	10.74
2001	8.80	1.87	.072	15.5	4.75	.66	14.25	39	47.7	13.25	9.04
2002	8.81	1.52	.083	14.9	3.62	.41	14.12	44	44.2	11.5	11.02
Av.	8.63	1.53	.062	13.53	4.12	.55	11.98	39.8	44.78	15.35	10.55
Range	8.32 - 8.81	1.02 - 1.87	.051 - .083	10.2 - 15.5	3.4 - 4.75	.41 - .66	8.4 - 14.25	38 - 44	41 - 49	12 - 21	9.0 - 12
Bak Khali											
2001-02	9.37	4.133	.058	14.56	1.633	.51	11.0	39.33	46.33	14.33	
2002-03	9.27	3.25	.064	9.94	2.65	.68	13.37	46.5	41.5	12.0	
Av.	9.32	3.69	.061	12.25	2.14	59.5	12.19	42.92	43.92	13.17	
Range	9.27 - 9.37	3.25 - 4.133	.058 - .064	9.94 - 14.56	1.633- 2.65	.51 - .68	11.0 - 13.19	39.33- 46.5	41.5- 46.33	12.0 - 14.33	
Nabadwip											
2001-02	8.62	0.366	.054	13.62	2.533	.696	10.66	43.33	45.66	11.0	
2002-03	8.32	0.425	.065	11.49	2.183	.76	14.62	46	41.6	12.5	
Av.	8.47	0.395	.059	12.54	2.358	.728	12.64	44.66	43.63	11.75	
Range	8.32 - 8.62	.366- .425	.054- .065	11.49- 13.62	2.183- 2.533	.696- .76	10.66- 14.62	43.33- 4.6	41.6 - 45.66	11.0 - 12.5	
Harwood Point											
1998	8.45	2.6	.037	10.5	3.4	.38	6.7	36	44	20	10.3
1999	8.76	3.43	.047	11.4	3.93	.54	9.0	36	46	18.0	11.5
2000	9.02	3.35	.046	16.4	3.4	.55	12.2	41	46	13	11.95
2001	9.12	2.82	.0635	15.3	4.16	.62	13.0	40.75	43.5	15.5	
2002	9.13	2.9	.078	14.58	2.50	.78	14.75	44.25	41.25	14.5	10.1
Av.	8.89	3.02	.0543	13.63	3.47	.574	11.13	39.6	44.15	16.25	10.97
Range	8.45 - 9.13	2.6 - 3.43	.037 - .078	10.5 - 16.4	2.5 - 4.16	.38 - .78	6.7 - 14.75	36 - 44.25	41.25- 46	13.0 - 20.0	10.1 - 11.95
Jharkhali											
1998	8.56	8.46	.044	9.93	3.7	.48	8.7	35	47	18	10.9
1999	8.61	7.5	0.055	12.7	3.4	0.81	8.75	36	44	20	14.7
2000	9.08	6.75	0.059	18.4	3.44	0.73	11.2	39	47	14	12.4
2001	9.123	5.925	0.08	14.14	4.72	0.593	12.375	40.5	46.25	13.25	
2002	9.1075	5.025	0.08	14.005	3.695	0.855	14.575	42.5	42.75	14.75	10.7
Av.	8.896	6.72	0.063	13.83	3.791	0.094	11.12	38.6	45.4	16.0	12.175
Range	8.56 - 9.123	5.025- 8.46	.044 - .08	9.93 - 18.4	3.4 - 4.72	.48 - .855	8.07 - 14.575	35 - 42.5	42.75- 47	13.25- 20.0	10.7 - 14.7
Moipeeth											
1998	8.5	6.8	.050	12.3	3.8	.51	7.7	34	40	26	10.2
1999	8.88	5.61	0.056	15.2	5.7	0.70	9.75	35	42	23	12.5
2000	9.0	6.75	0.056	15.3	7.3	0.65	11.1	41	43.5	15	11.6
2001	9.19	5.55	0.07	17.79	4.16	0.593	12.5	42.75	44	13.25	
2002	9.095	5.375	0.098	15.27	4.98	0.98	14.75	44	43.75	12.25	10.02
Av.	8.93	6.02	.064	15.17	5.19	.69	11.16	39.35	42.65	17.9	11.08
Range	8.5 - 9.19	5.375- 6.8	.05 - .098	12.3 - 17.79	3.8 - 7.3	0.51 - 0.98	7.7 - 14.75	34.0 - 44.0	40.0 - 44	12.25- 26.0	10.2 - 12.5

Haldia

Year	PH	Sp.Con m mhos/cm	Total Nitrogen %	Av. N_2 mg/100g	Av P_2O_5 mg/100g	Organic Carbon %	Free $CaCo_3$ %	Sand %	Silt %	Clay %	C / N
1998	8.37	1.96	.043	8.8	3.2	.44	7.2	35	44	21	10.2
1999	8.69	2.12	.046	10.8	43.63	0.53	8.75	37	42	20	11.52
2000	8.9	1.87	0.048	16.8	4.11	0.57	11.25	41	43	16	11.9
2001	9.08	1.97	0.065	16.52	3.57	.6	12.75	41.5	43.0	15.5	11.53
2002	9.01	2.05	0.10	14.2.9	3.24	1.0	13.7	46.5	41.25	12.25	10
Av.	8.81	1.99	0.0604	13.44	3.55	0.628	10.73	40.2	42.65	16.95	8.724
Range	8.37 - 9.08	1.87 - 2.12	.043 - 0.10	8.8 - 16.8	3.2 - 4.11	.44 - 1.0	7.2 - 13.7	35 - 46.5	41.25- 44	12.25- 21.0	10.0 - 1.9

Dhamakhali

Year	PH	Sp.Con m mhos/cm	Total Nitrogen %	Av. N_2 mg/100g	Av P_2O_5 mg/100g	Organic Carbon %	Free $CaCo_3$ %	Sand %	Silt %	Clay %	C / N
1998	8.46	2.3	.039	10.3	3.8	.40	9.3	35	46	19	10.3
1999	8.70	4.0	0.054	13.8	4.1	.70	8.0	36	43	21	11.9
2000	8.8	2.43	0.048	14.5	4.5	.56	11.75	39	45	16	11.66
2001	9.0	3.57	0.076	15.69	4.14	.70	13.25	39.25	45	15.75	
2002	8.95	4.07	0.09	14.84	4.72	1.17	13.0	45	43.25	11.75	13.0
Av.	8.782	3.274	0.0614	13.83	4.25	0.706	11.06	38.85	44.45	16.7	11.71
Range	8.46 - 9.0	2.3 - 4.07	0.039 - 4.07	10.3 - 15.69	3.8 - 4.72	.4 - 1.17	8.0 - 13.25	35 - 45	43 - 46	11.75- 21	10.3 - 13.0

Bhagabatpur

Year	PH	Sp.Con m mhos/cm	Total Nitrogen %	Av. N_2 mg/100g	Av P_2O_5 mg/100g	Organic Carbon %	Free $CaCo_3$ %	Sand %	Silt %	Clay %	C / N
1998	8.55	4.0	.050	11.9	4.6	.51	8.0	36	44	20	10.4
1999	8.86	5.2	.054	14.2	4.7	.65	10.1	37	46	17	12.0
2000	9.14	4.92	.054	14.3	4.47	.55	11.4	38	49	13	10.2
2001	9.30	5.35	.062	15.68	4.65	.57	13.0	44.7	43.7	11.5	
2002	9.14	4.52	.103	16.8	3.79	1.09	15.5	45.2	41.7	13.0	10.6
Av.	8.998	4.798	.065	14.58	4.44	.664	11.6	40.18	44.88	14.9	10.8
Range	8.55 - 9.3	4.0 - 5.35	.050 - .103	11.9 - 16.8	3.79 - 4.7	.51 - 1.09	8.0 - 15.5	36 - 45.2	41.7 - 49.0	13 - 20	10.2 - 12.0

Table 24: Heavy metals in water (mg l^{-1}) of the Sundarban estuaries (April 2000 – March 2001)

Metal	Estuaries						
	Dhama-khali	Jharkhali	Harwood point	Bhagabat-pur	Moipeeth	Haldia	Hasnabad
2000							
Zn	0.01-0.03 (0.02)	0.03-0.07 (0.05)	0.03-0.04 (0.03)	0.02-0.11 (0.05)	0.02-0.06 (0.04)	0.02-0.09 (0.06)	0.01-0.16 (0.07)
Pb	0.96-0.39 (0.24)	0.38-0.46 (0.42)	0.16-0.31 (0.23)	0.28-0.43 (0.36)	0.28-0.50 (0.38)	0.03-0.26 (0.15)	0.08-0.32 (0.20)
Cd	0.02-0.06 (0.04)	0.06-0.08 (0.07)	0.02-0.04 (0.03)	0.05-0.08 (0.06)	0.05-0.09 (0.07)	0.01-0.03 (0.02)	0.15-0.05 (0.03)
Cu	Tr-0.05 (0.04)	Tr-0.08 (0.06)	Tr-0.05 (0.03)	Tr-0.05 (0.05)	0.01-0.07 (0.04)	Tr-0.04 (0.02)	Tr-0.05 (0.03)
Cr	0.04	0.07	0.05	0.06	0.07	0.04	0.02
Mn	Tr-0.27 (0.01)	0.02-0.05 (0.04)	Tr-0.03 (0.02)	0.01-0.06 (0.05)	0.04-0.09 (0.08)	Tr-0.02 (0.01)	Tr-0.01 (0.01)
Fe	Tr-0.24 (0.11)	Tr-0.33 (0.22)	Tr-0.15 (0.06)	Tr-0.31 (0.19)	Tr-0.41 (0.25)	Tr-0.43 (0.17)	Tr-0.19 (0.08)
2001							
Zn	0.01-0.06 (0.03)	0.02-0.10 (0.05)	0.01-0.05 (0.03)	0.01-0.09 (0.04)	0.01-0.09 (0.04)	0.10-0.09 (0.03)	0.004-0.04 (0.02)
Pb	0.05-0.05 (0.05)	0.09-0.092 (0.09)	0.03-0.04 (0.03)	0.08-0.09 (0.09)	0.05-0.06 (0.05)	0.007-0.009 (0.009)	0.02-0.03 (0.02)
Cd	0.01-0.12 (0.01)	0.26-0.03 (0.05)	0.04-0.06 (0.01)	0.026-0.03 (0.03)	0.016-0.02 (0.02)	0.001-0.002 (0.003)	0.001-0.001 (0.001)
Cu	0.008-0.01 (0.01)	0.026-0.03 (0.01)	0.010-0.012 (0.01)	0.01-0.02 (0.02)	0.010-0.012 (0.01)	0.001-0.003 (0.002)	0.003-0.10 (0.004)
Cr	0.01-0.07 (0.04)	0.02-0.13 (0.07)	0.01-0.06 (0.03)	0.02-0.16 (0.07)	0.01-0.15 (0.07)	Tr-0.09 (0.05)	Tr-0.02 (0.01)
Mn	0.01-0.06 (0.03)	0.02-0.10 (0.06)	0.01-0.04 (0.03)	0.02-0.06 (0.04)	0.02-0.10 (0.05)	0.004-0.03 (0.02)	0.004-0.05 (0.01)
Fe	0.03-0.08 (0.08)	0.19-0.32 (0.24)	0.03-0.07 (0.06)	0.07-0.28 (0.04)	0.09-0.25 (0.14)	0.01-0.12 (0.07)	0.10-0.34 (0.03)

Figures in parentheses are average and others denote range, Tr = trace

Table 25 : Heavy metal contents in soils (mg kg^{-1}) of the Sundarban estuaries (April 2000 – March 2001)

Metal	Estuaries						
	Dhama-khali	Jharkhali	Harwood point	Bhagabat-pur	Moipeeth	Haldia	Hasnabad
2000							
Zn	37.82-57.24 (53.63)	29.90-70.60 (61.8)	28.99-85.98 (55.99)	34.55-77.89 (59.86)	50.55-65.87 (58.78)	47.23-72.59 (67.70)	47.42-75.59 (67.70)
Pb	11.0-14.9 (12.95)	31.0-40.6 (39.32)	25.0-29.1 (27.07)	28.4-30.8 (29.38)	27.0-27.8 (27.39)	20.0-22.9 (36.58)	19.0-20.8 (47.23)
Cd	2.4-2.54 (2.46)	3.8-4.3 (4.02)	2.2-3.1 (2.63)	2.0-2.3 (2.15)	1.8-2.2 (1.99)	1.8-2.2 (1.74)	1.7-1.8 (1.78)
Cu	12.0-14.1 (13.05)	16.0-17.6 (16.82)	31.8-32.5 (32.19)	17.0-17.54 (17.27)	29.0-29.33 (29.16)	19.5-20.3 (19.87)	27.0-27.8 (27.39)
Cr	22.41-32.96 (29.02)	20.26-31.63 (24.14)	19.09-33.05 (28.46)	18.30-24.06 (20.3)	17.57-32.06 (23.43)	22.16-32.53 (26.12)	22.57-33.92 (27.49)
Mn	189.45-197.54 (193.49)	202.62-216.81 (209.71)	119.92-151.92 (135.92)	159.46-181.93 (170.69)	105.86-180.55 (143.21)	120.08-142.52 (131.30)	122.18-199.07 (160.62)
Fe	1125.5-29753.9 (15439.7)	2339.28-43610.64 (22974.96)	8297.5-35282.06 (21789.78)	12927.0-32608.36 (22267.68)	3581.55-32030.9 (23934.63)	1088.75-45947.15 (23517.95)	11417.0-15074.76 (13245.88)
2001							
Zn	44.88-57.37 (52.39)	21.27-70.51 (51.27)	24.75-87.91 (60.54)	34.09-78.06 (66.94)	50.66-78.06 (65.49)	48.10-73.23 (61.40)	48.26-76.1 (67.89)
Pb	BDL-43.1 (24.32)	13.30-44.91 (32.69)	BDL-58.61 (30.94)	15.23-54.75 (39.33)	BDL-57.65 (32.93)	1.06-44.17 (27.70)	19.34-52.3 (40.26)
Cd	0.04-2.47 (1.06)	0.61-4.02 (1.50)	0.39-2.69 (1.42)	0.78-2.15 (1.53)	1.07-2.17 (1.49)	0.5-2.14 (1.58)	0.89-2.92 (1.97)
Cu	2.56-35.86 (19.88)	5.71-28.12 (20.64)	7.66-75.9 (34.87)	4.88-118.41 (45.52)	0.93-32.37 (24.39)	11.12-37.67 (23.23)	5.25-91.97 (37.14)
Cr	24.53-33.84 (27.30)	22.01-34.01 (29.05)	16.74-33.05 (27.74)	18.66-44.68 (32.57)	24.00-41.04 (32.01)	21.56-37.47 (32.87)	23.00-34.6 (31.19)
Mn	190.93-574.75 (357.70)	203.91-561.19 (294.41)	218.52-560.05 (419.10)	182.92-596.38 (344.52)	121.92-529.93 (366.03)	135.22-593.53 (423.09)	131.14-585.74 (476.87)
Fe	3143.9-31775.0 (20385.75)	2678.9-32199.0 (21625.62)	15784.7-86654.7 (27440.92)	12968.0-28151.0 (20270.85)	3475.25-25550.55 (14512.90)	1109.50-58165.50 (24494.56)	11468.0-28830.0 (21553.14)

Figures in parentheses are average and others denote range. BDL = Below detectable limit

Table 26 : Comparative evaluation of heavy metal content in Hooghly estuary

	Water		Soil		Water		Soil		Water		Soil	
	Cu		Cu		Cr		Cr		Zn		Zn	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Dhamakhali	0.038	0.009	13.055	5.678	-	0.037	29.206	28.257	0.019	0.031	53.63	56.03
Jharkhali	0.064	0.016	16.822	5.617	-	0.074	24.136	31.234	0.047	0.057	61.8	54.4
Harwood	0.034	0.011	32.191	3.932	-	0.029	28.465	30.501	0.031	0.03	55.99	69.48
Bhagabatpur	0.05	0.016	17.271	9.068	-	0.072	20.303	34.223	0.05	0.047	59.86	72.86
Moipeeth	0.041	0.011	29.165	9.272	-	0.072	23.416	32.017	0.04	0.048	58.78	68.44
Haldia	0.022	0.002	19.875	3.929	-	0.05	26.122	34.417	0.056	0.03	67.7	64.94
Hasnabad	0.034	0.004	27.393	1.924	-	0.011	27.491	32.103	0.065	0.023	63.14	67.17

	Water		Soil		Water		Soil		Water		Soil	
	Cd		Cd		Pb		Pb		Mn		Mn	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Dhamakhali	0.037	0.01	2.46	1.401	0.24	0.052	12.95	21.75	0.027	0.026	193.494	258.325
Jharkhali	0.071	0.028	4.02	1.802	0.41	0.091	39.32	30.24	0.036	0.063	209.711	334.96
Harwood	0.03	0.005	2.637	1.76	0.23	0.03	27.07	41.25	0.03	0.016	135.918	358.615
Bhagabatpur	0.06	0.028	2.152	1.78	0.356	0.086	9.38	47.36	0.011	0.039	170.692	419.147
Moipeeth	0.072	0.018	1.985	1.63	0.379	0.053	27.39	43.9	0.075	0.045	143.206	344.547
Haldia	0.02	0.002	1.743	1.938	0.154	0.008	36.58	36.58	0.017	0.016	131.302	413.91
Hasnabad	0.031	0.001	1.779	2.34	0.203	0.025	47.23	47.23	0.01	0.014	160.625	449.64

	Water		Soil		Water		Water	
	Fe		Fe		Na		K	
	2000	2001	2000	2001	2000	2001	2000	2001
Dhamakhali	0.011	0.046	15439.7	20385.75	2804.65	1467.06	180.78	71.125
Jharkhali	0.219	0.547	22974.96	21625.62	8105.6	2582.81	168.18	137.66
Harwood	0.057	0.05	21789.78	27440.92	2461.04	858.64	116.6	68.09
Bhagabatpur	0.187	0.135	22767.68	20270.85	4775.04	1907.33	271.02	118.92
Moipeeth	0.254	0.136	23934.63	14512.9	3313.07	1952.26	517.5	109.38
Haldia	0.168	0.063	23517.95	24494.56	1170.6	645.92	101.86	38.1
Hasnabad	0.37	0.019	13245.88	21553.14	3586.35	652.66	100.95	40.42

Table 27 : Surface water criteria for trace elements in public water supplies

Metal	Permissible limit (mgl^{-1})
Cadmium	0.01
Chromium	0.05
Copper	1.00
Iron (filterable)	0.30
Lead	0.05
Manganese (filterable)	0.05
Zinc	5.00

(Kopp, 1970)

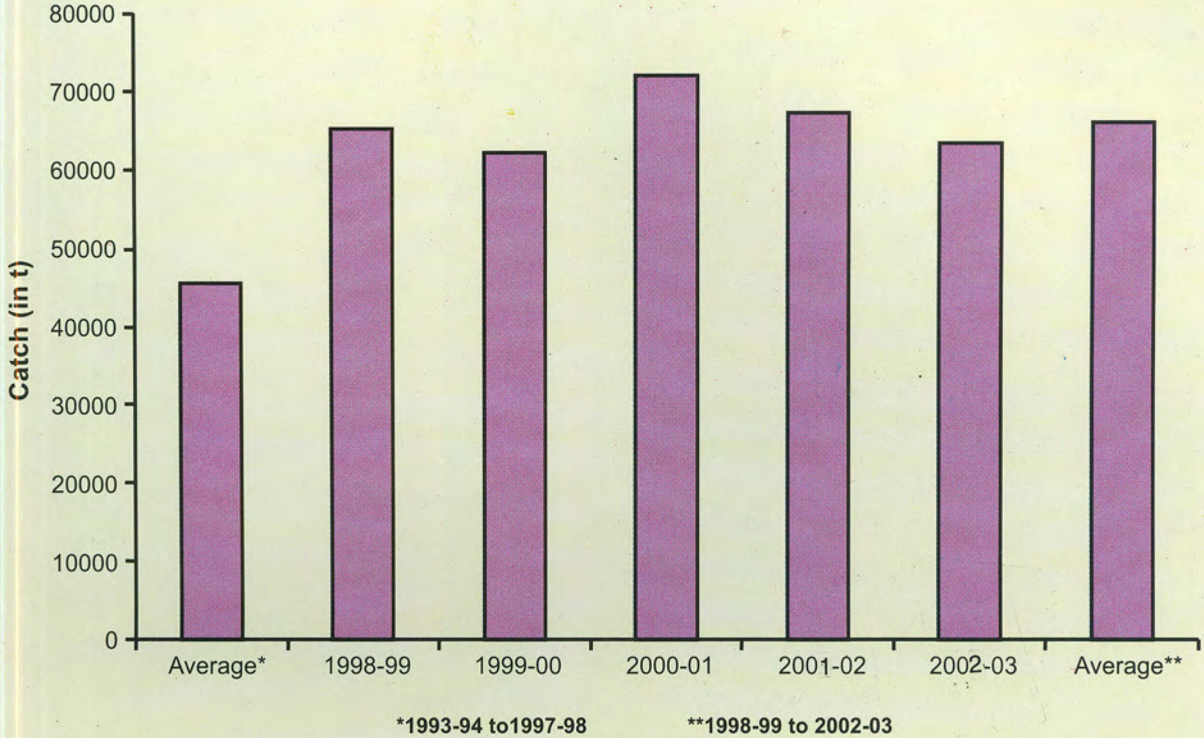


FIG. 2 : TOTAL CATCH (in t) FROM THE HOOGHLY-MATLAH ESTUARINE SYSTEM

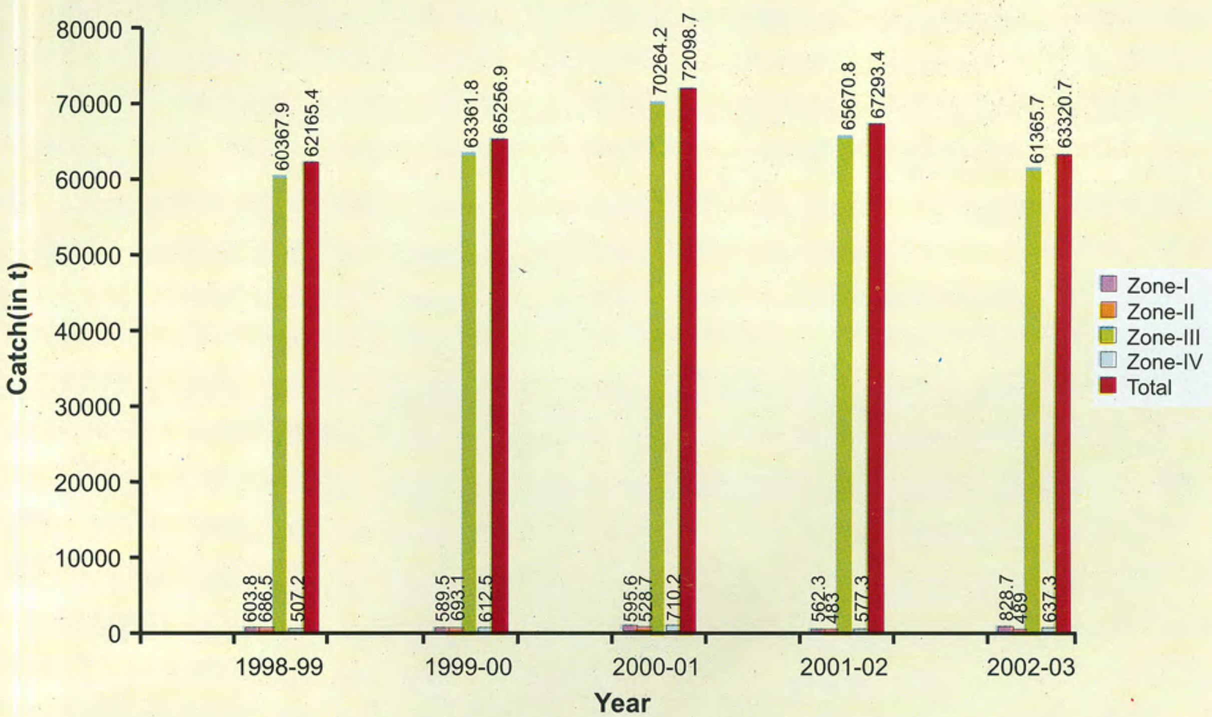


FIG. 3 : ZONE-WISE CATCH (in t) FROM THE HOOGHLY -MATLAH ESTUARINE SYSTEM

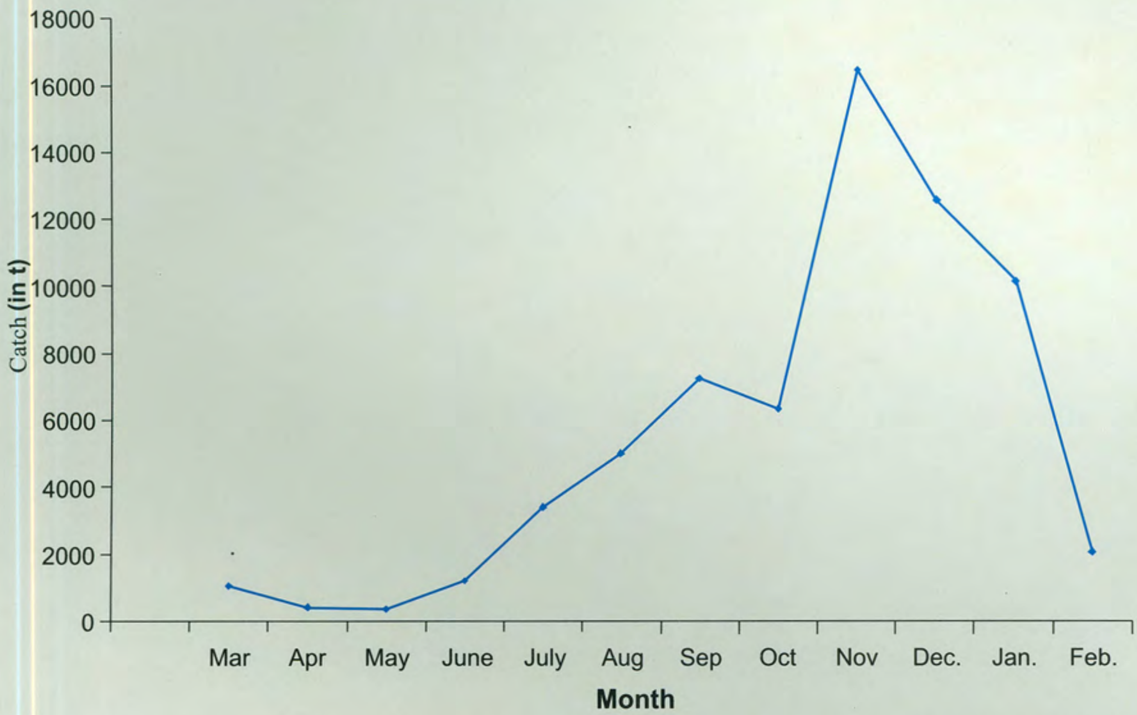


FIG. 4 . AVERAGE MONTHLY CATCH (in t) FROM THE HOOGHLY-MATLAH ESTUARINE SYSTEM

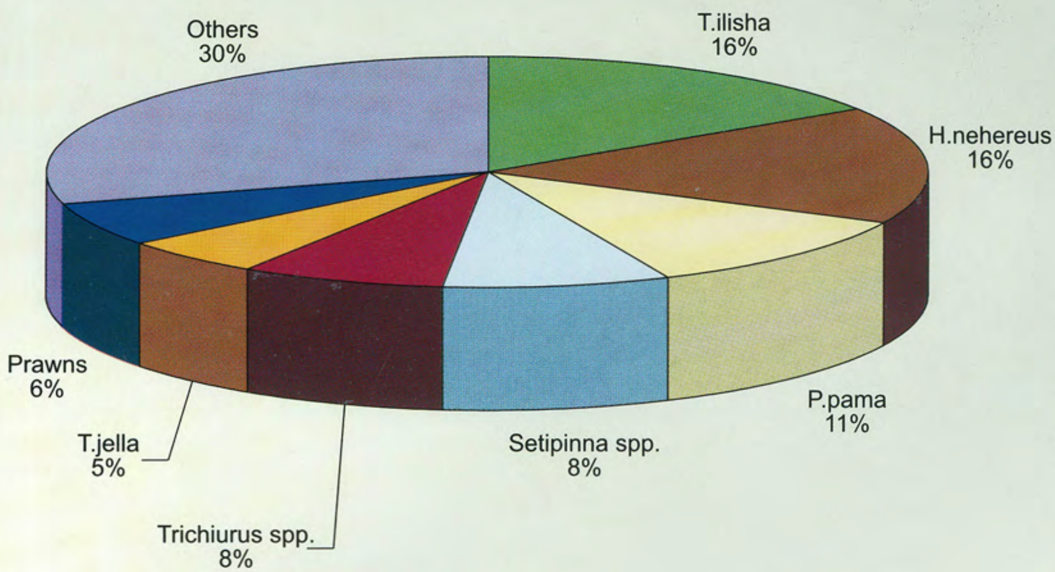


FIG. 5 : SPECIES COMPOSITION OF HOOGHLY-MATLAH ESTUARY

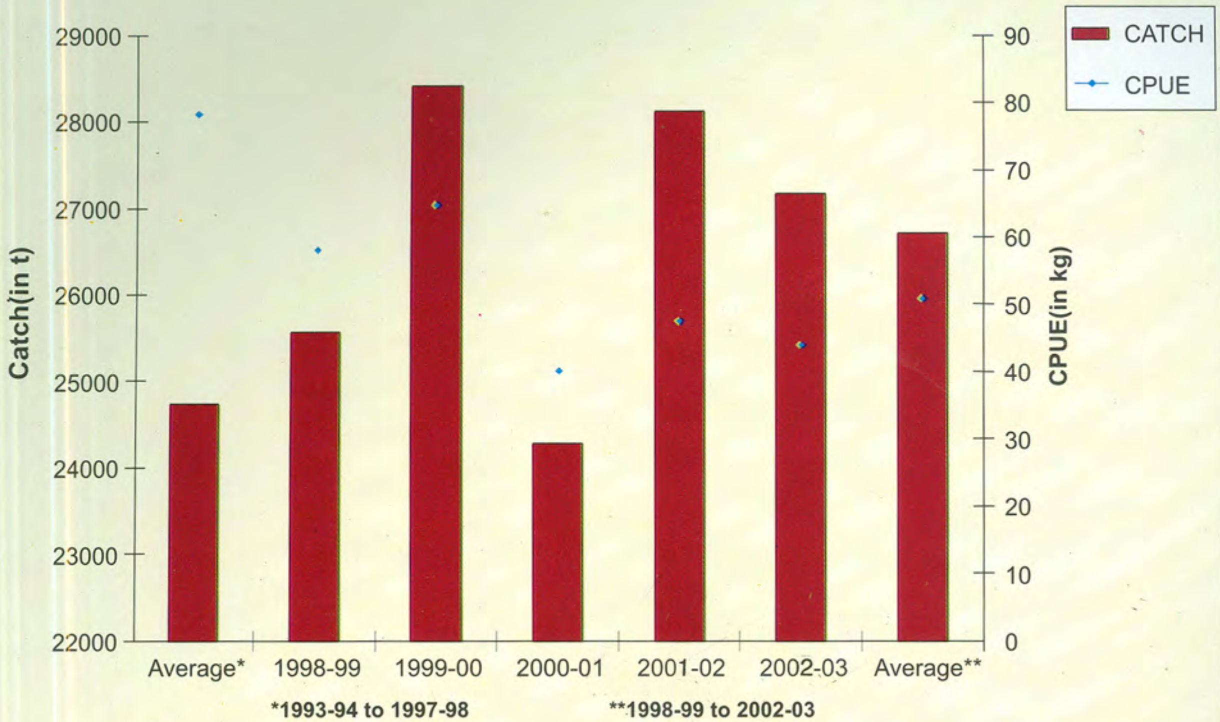


FIG. 6 : TOTAL CATCH (in t) AND CPUE (in Kg) FROM WINTER MIGRATORY BAGNET FISHERY

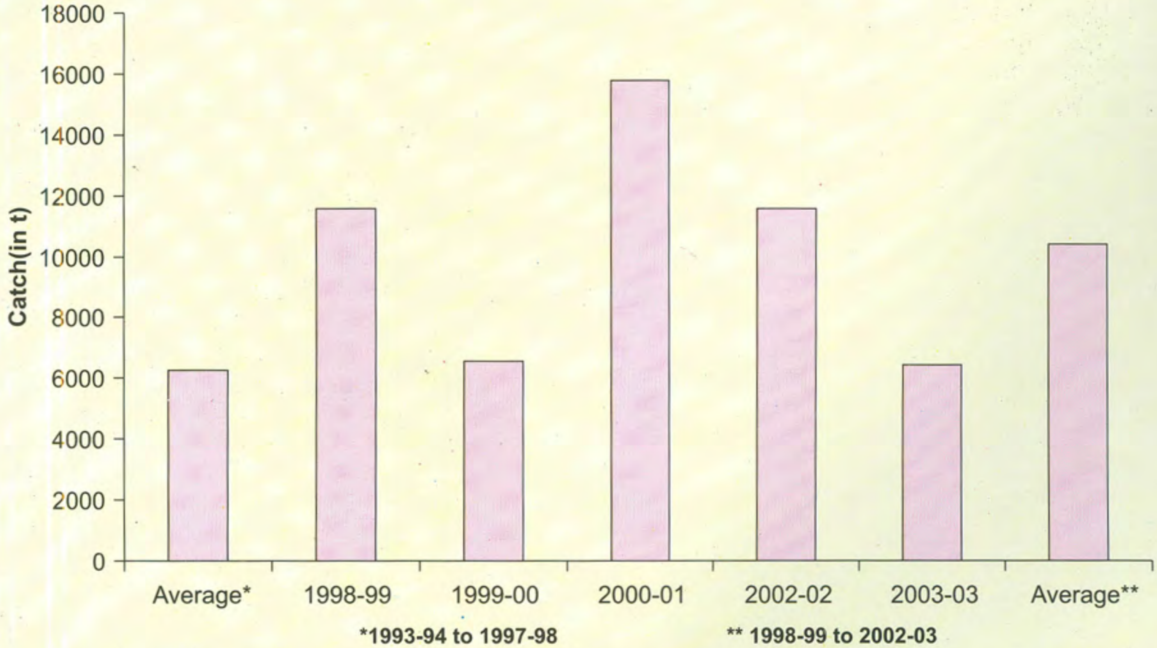


FIG.7 : HILSA CATCH (in t) FROM THE HOOGHLY-MATLAH ESTUARINE SYSTEM

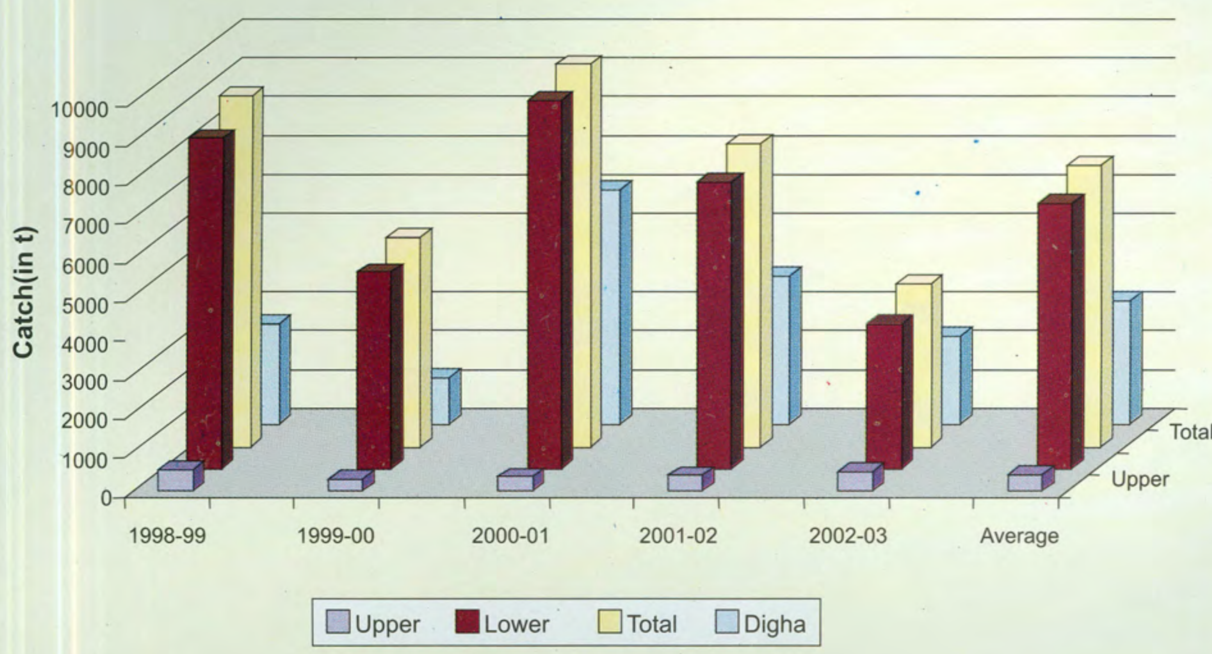


FIG. 8 : HILSA CATCH (in t) OF UPPER ESTUARY, LOWER ESTUARY & DIGHA CENTRE

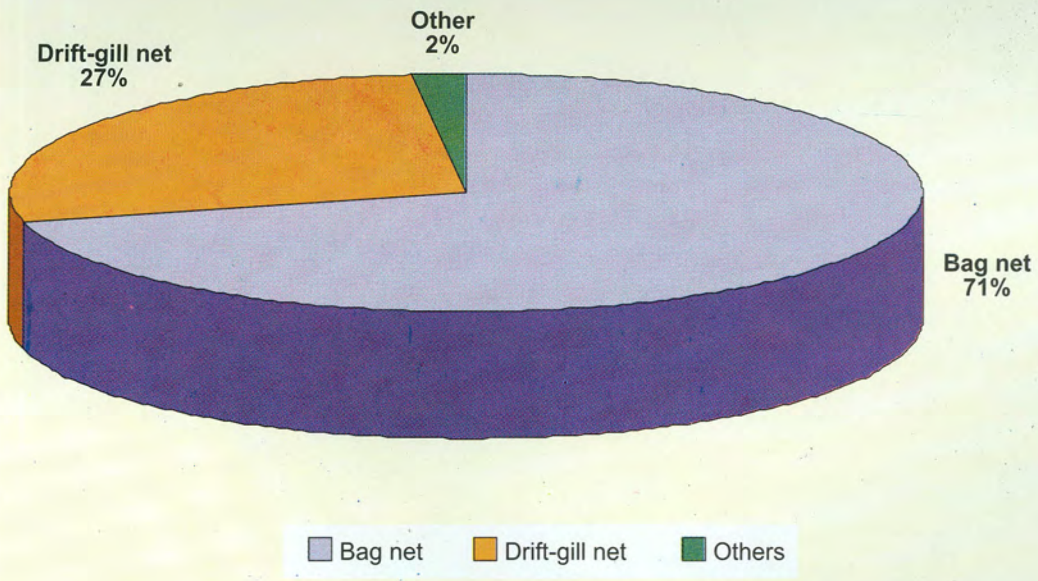


FIG. 9 : GEAR-WISE COMPOSITION OF CATCH FROM THE HOOGHLY - MATLAH ESTUARY

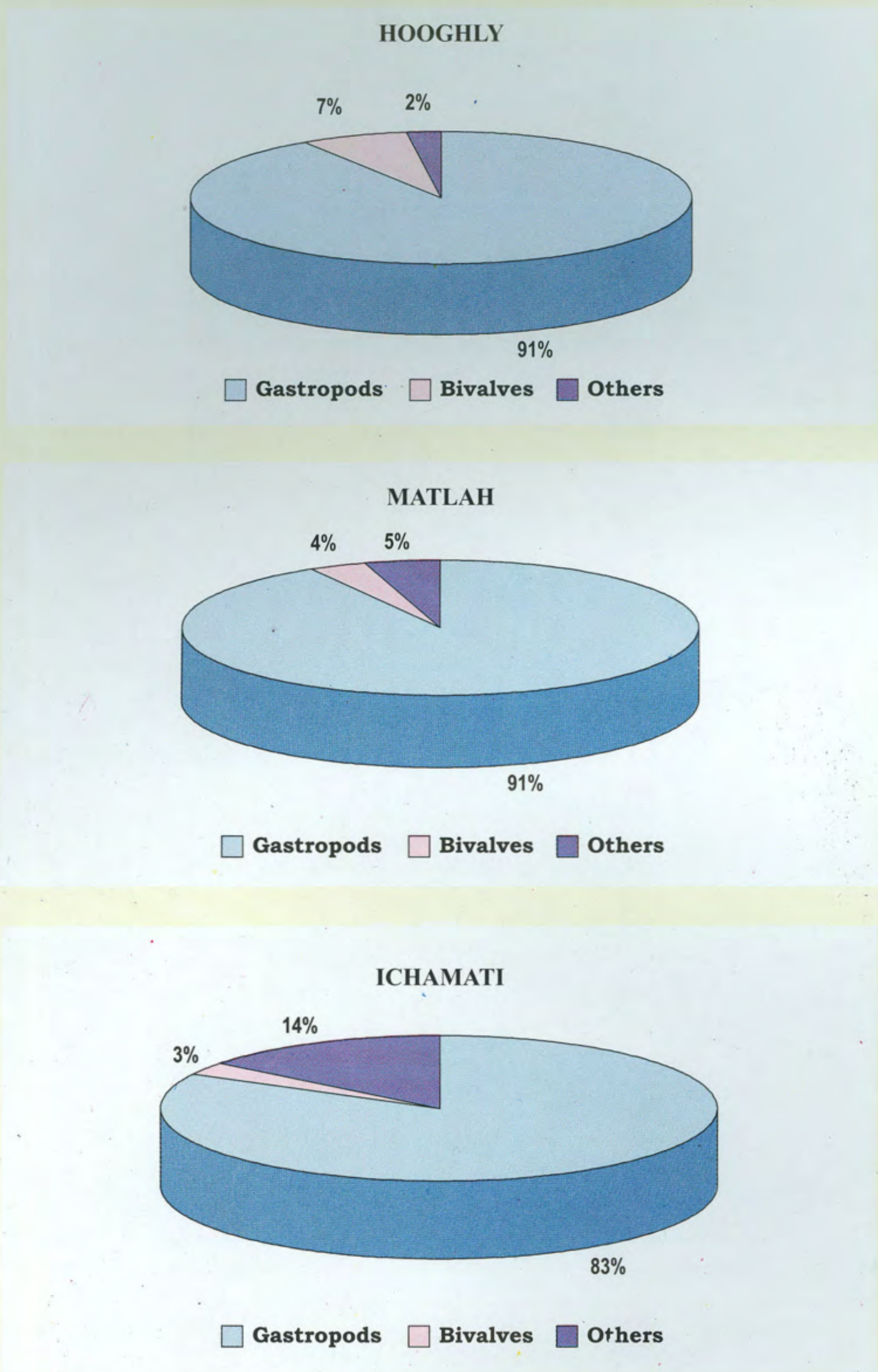


FIG. 10 : GRAPHICAL PRESENTATION OF AVERAGE OF ZOO-MACROBENTHIC POPULATION IN HOOGHLY, MATLAH & ICHAMATI ESTUARY

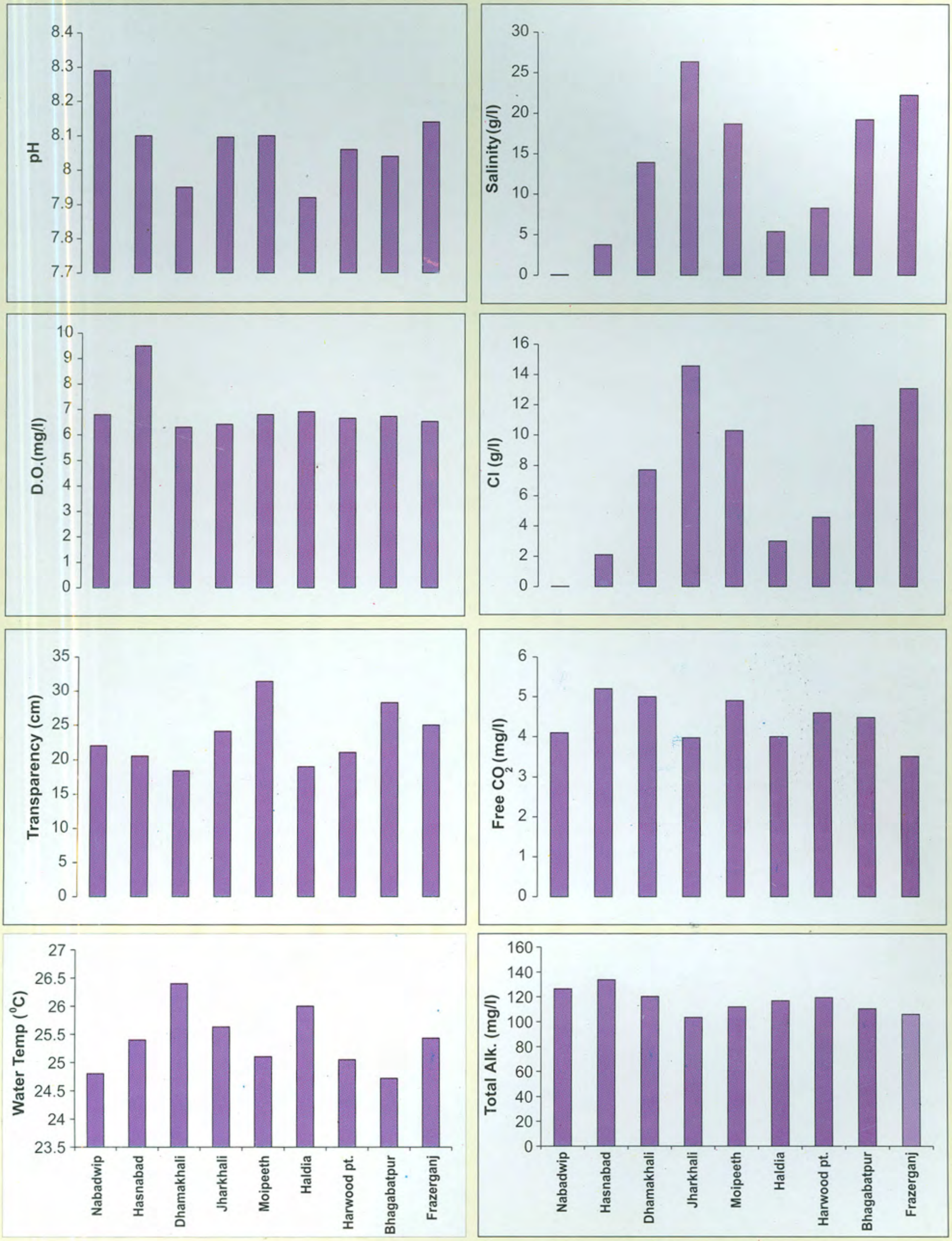
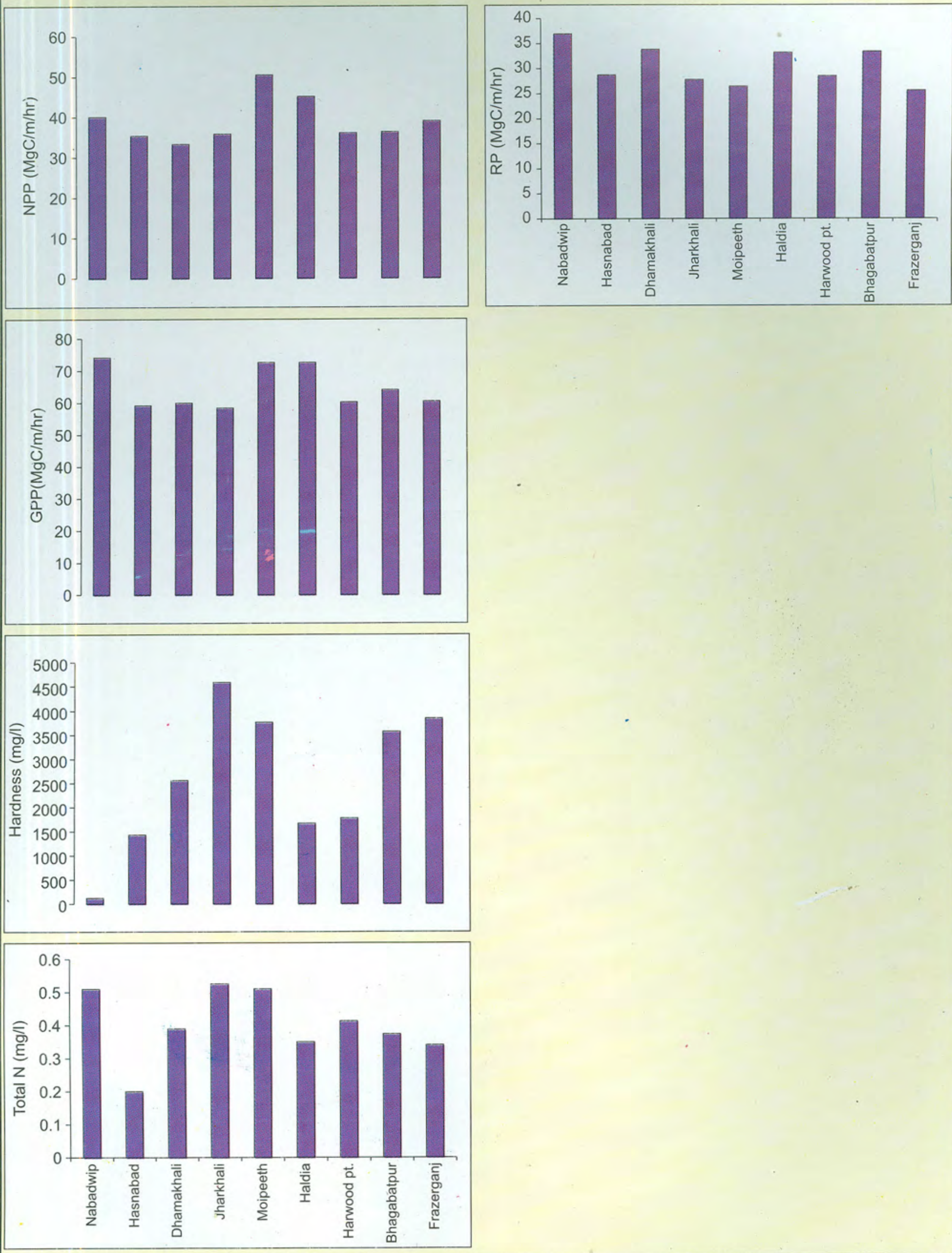


Fig. 11 : AVERAGE WATER CHARACTERISTICS OF DIFFERENT CENTRES OF HOOGHLY - MATLAH ESTAURY

Fig. 11 Contd...


SiO2 (mg/l)
TDS (g/l)
SO4 (mg/l)
Sp. Cond. (mmhos/cm)
PO4 (mg/l)
Magnesium (mg/l)
NO3 (mg/l)
Calcium (mg/l)
Nabadwip
Hasnabad
Dhamakhali
Jharkhali
Moipeeth
Haldia
Harwood pt.
Bhagabatpur
Frazerganj

Fig. 11 Contd...


NPP (MgC/m/hr)
0
10
20
30
40
50
60
RP (MgC/m/hr)
0
5
10
15
20
25
30
35
40
GPP(MgC/m/hr)
0
10
20
30
40
50
60
70
80
Hardness (mg/l)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Total N (mg/l)
0
0.1
0.2
0.3
0.4
0.5
0.6
Nabadwip
Hasnabad
Dhamakhali
Jharkhali
Moipeeth
Haldia
Harwood pt.
Bhagabatpur
Frazerganj

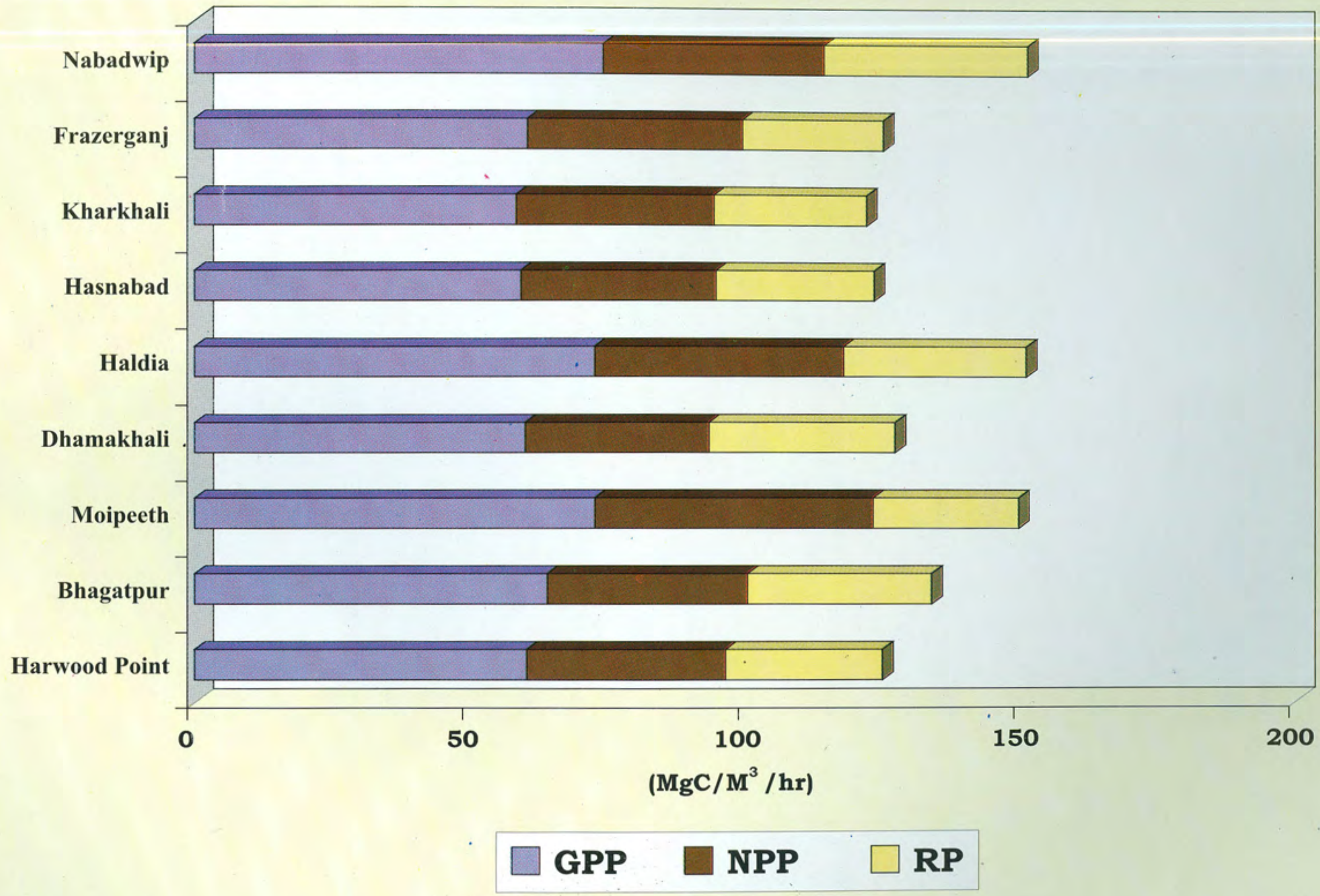


FIG. 12: GRAPHICAL PRESENTATION OF AVERAGE PRIMARY PRODUCTION OF DIFFERENT CENTRES OF HOOGHLY ESTUARY DURING THE PERIOD MAY 1998 TO MARCH 2003

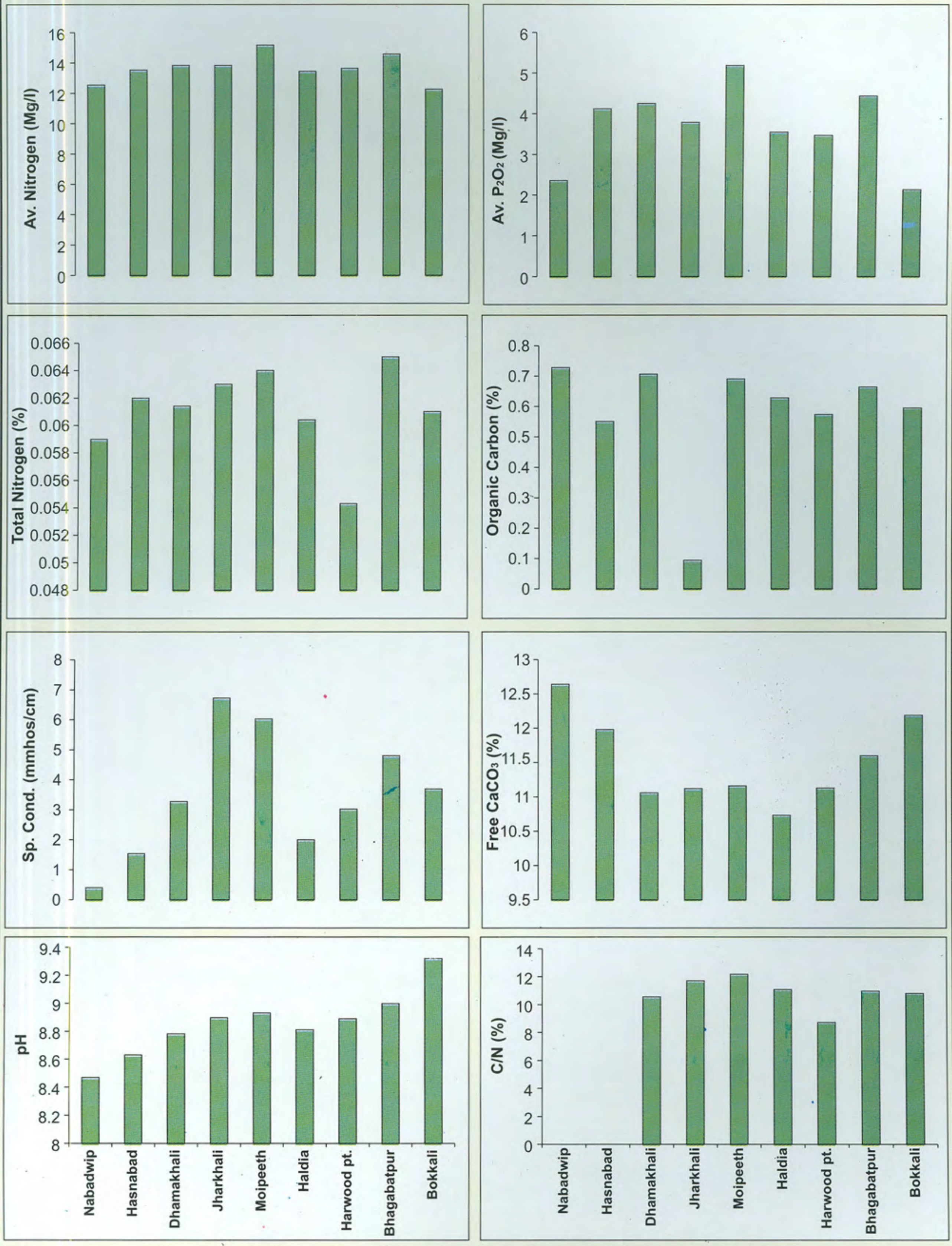
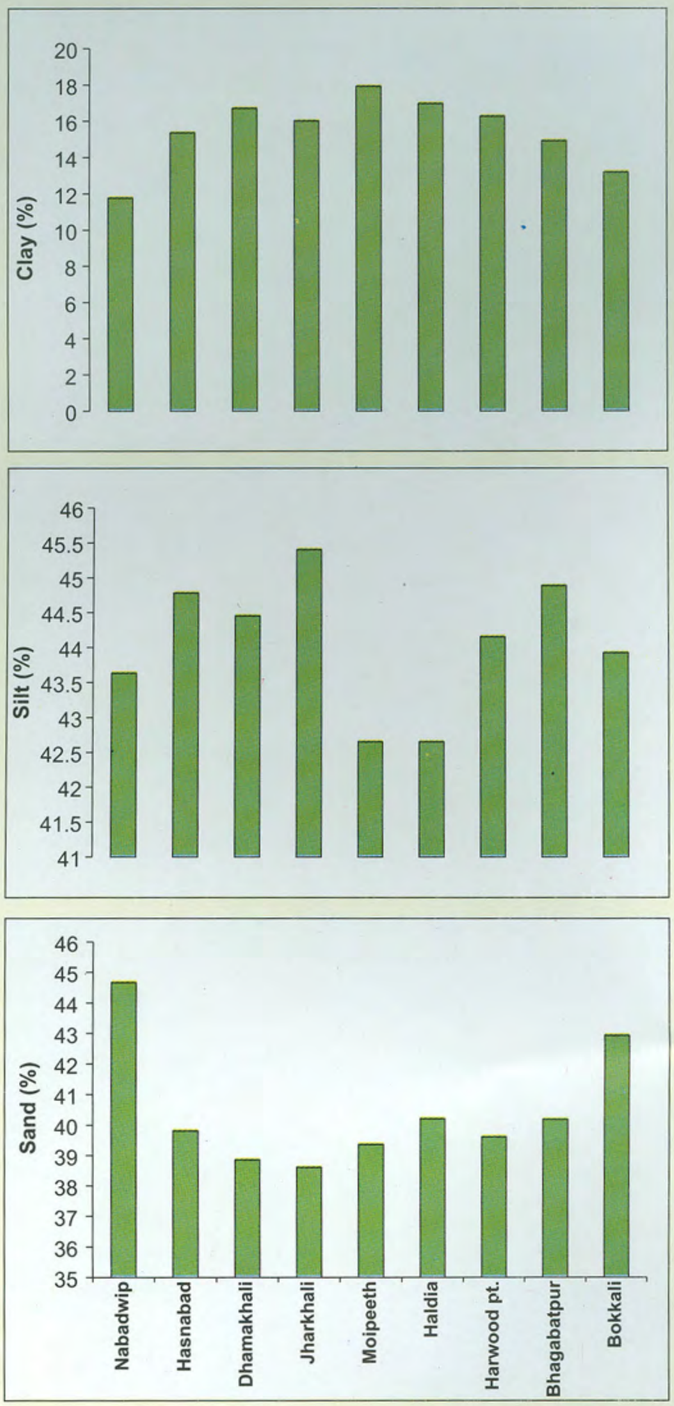


Fig. 13 : AVERAGE SOIL CHARACTERISTICS OF DIFFERENT CENTRES OF HOOGHLY - MATLAH ESTAURY

Fig. 13 Contd.



Clay (%)
Silt (%)
Sand (%)
Nabadwip
Hasnabad
Dhamakhali
Jharkhali
Moipeeth
Haldia
Harwood pt.
Bhagabatpur
Bokkali

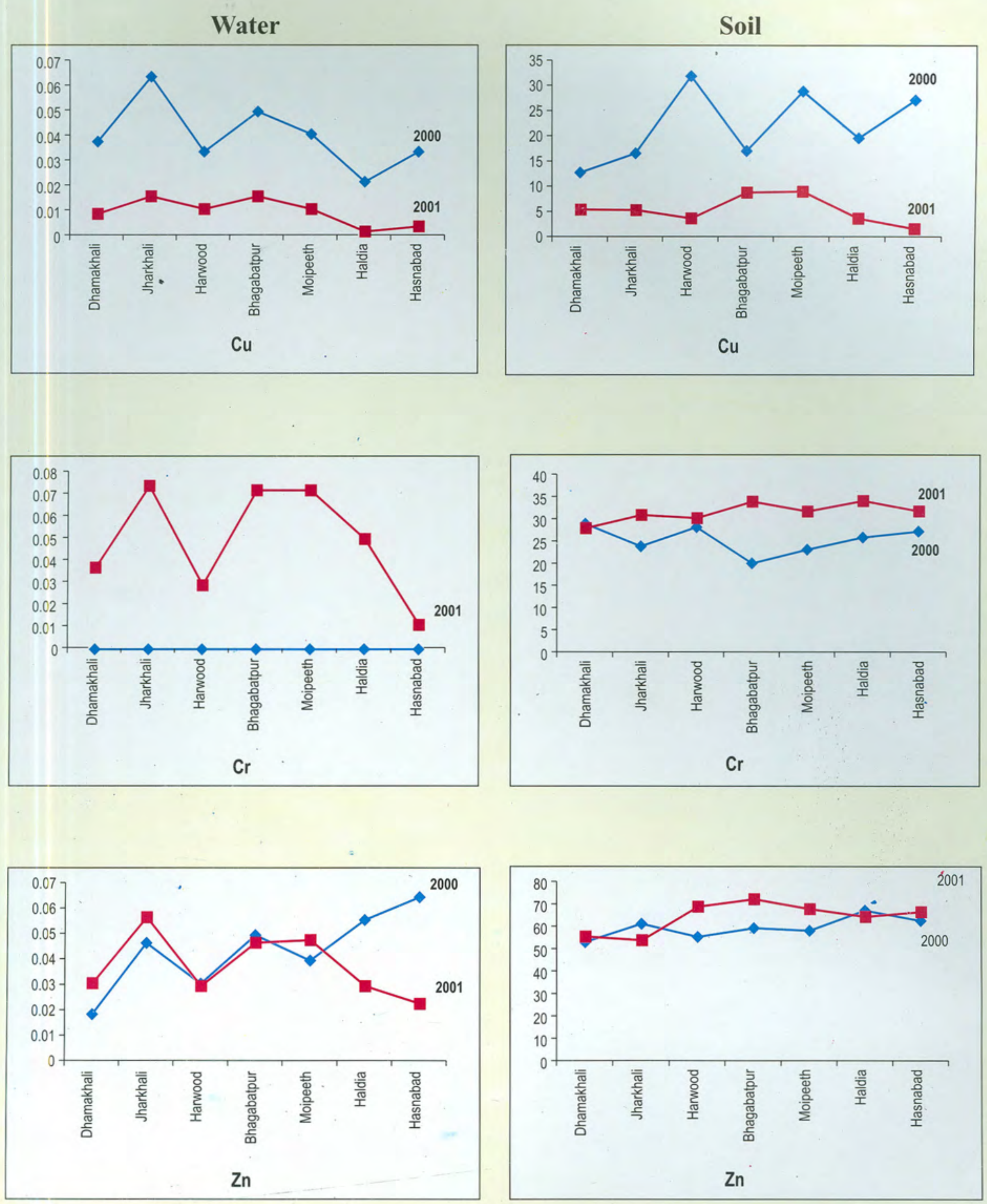


FIG. 14 : GRAPHICAL PRESENTATION OF Cu, Cr & Zn IN WATER AND SOIL PHASE

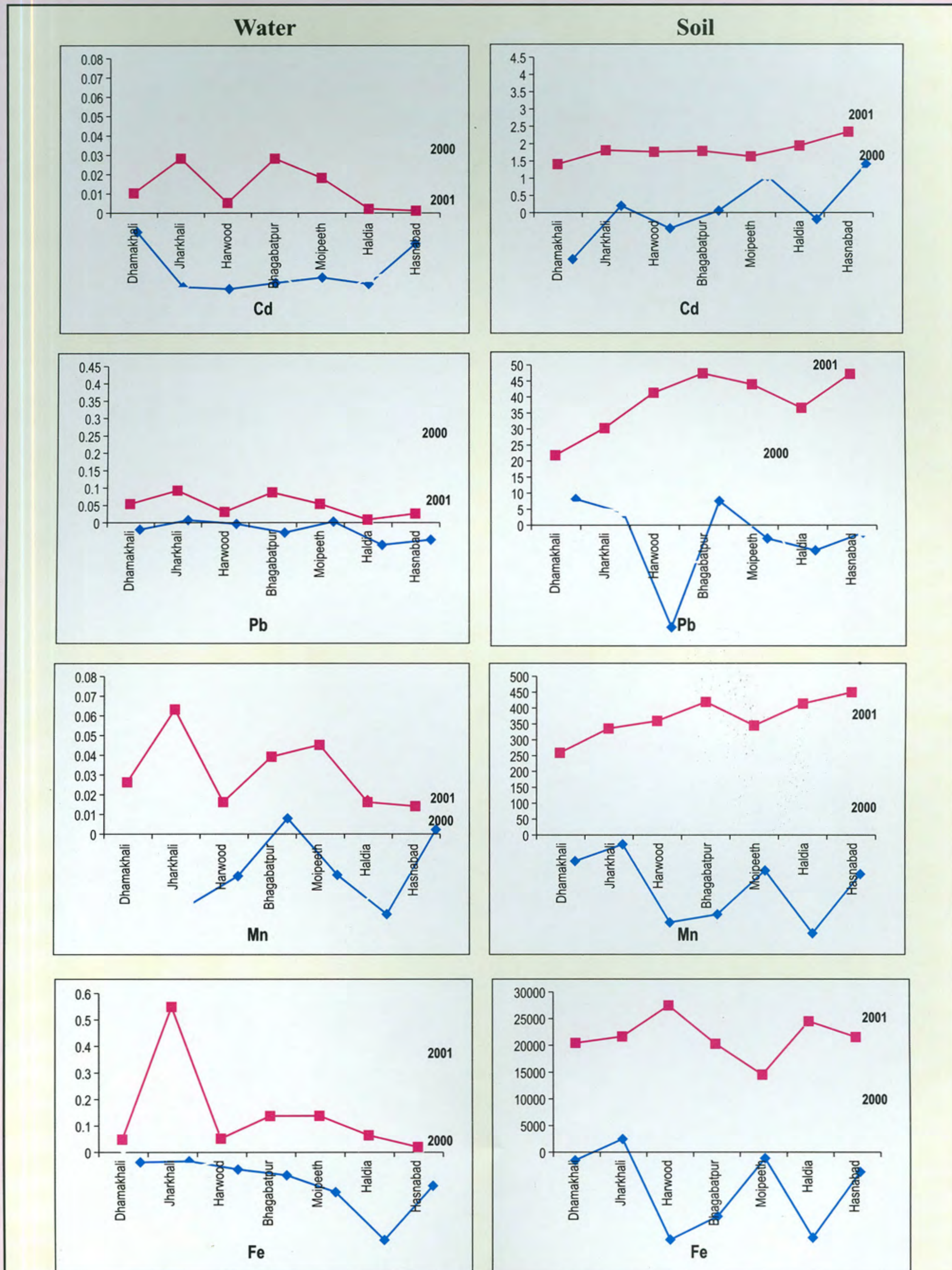


FIG. 15 : GRAPHICAL PRESENTATION OF Cd, Pb, Mn & Fe IN WATER AND SOIL PHASE

Segregated catch of mullet, *Liza tade*
in a landing centre

Segregated catch of *Trichiurus sp.*
in a landing centre

Segregated catch of *Pama pama* in a landing centre

Segregated catch of mullet, *Liza parsia* in a landing centre

Sun drying of bagnet catches during winter migratory bagnet fishery

Sun drying of bagnet catches during winter migratory bagnet fishery

Operation of bagnet in Hooghly estuary

A haul of bagnet catch

Destruction of juvenile of fish being thrown out in the river bank from net and boat

Removal of catch from bagnet

Heap of *Harpodon nehereus* being shorted out from bagnet catches and kept for sundrying

Bagnet catches kept in the plastic sheets in the seashore before they are being sorted out specieswise

Segregated catch of *Lates calcarifer* in a landing centre

Segregated catch of *Eleutheronema tetradactylum* in a landing centre