Impact assessment of coal transportation through barges along the National Waterway No.1 (Sagar to Farakka) along River Ganga

Project Report

ICAR-CENTRAL INLAND FISHERIES RESEARCH INSTITUTE

(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)

BARRACKPORE, KOLKATA 700120, WEST BENGAL

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Project Report

Submitted to

Inland Waterways Authority of India

(Ministry of Shipping, Govt. of India)

A 13, Sector 1, Noida 201301, Uttar Pradesh

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Response to the Query Points of Expert Appraisal Committee

POINT NO. 1. ***Long term, and a minimum period of one year continuous study shall be conducted on the impacts of varying traffic loads on aquatic flora and fauna with particular reference to species composition of different communities, abundance of selective species of indicator value, species richness and diversity and productivity***

Answered in page no. 7 – 12 (methodology) and 31 – 71 (results) of the report

POINT NO.2. ***Impacts of noise generated by the barge movement on Gangetic Dolphin which is declared as a National Aquatic Animal***

Answered in page no. 61 – 67 of the report

POINT NO. 3. ***Energy conservation and other perceived benefits vis-a-vis road and rail transportation***

Answered in page no. 113 - 116 of the report

POINT NO. 4. ***Impact on abundance of economically important fish species (including Dolphin), fish growth and production at varying traffic load***

Answered in page no. 69 - 71 of the report

POINT NO. 5. ***Impact on bank erosion vis-a-vis safeguard measures like stabilization of banks with native vegetation (including mangroves) that will prevent erosion***

Answered in page no. 117 - 124 of the report

POINT NO. 6. ***Impact on the fish catch under varying traffic loads and livelihood of fishermen and their views on the coal transportation by barges***

Answered in page no. 13 – 14 (methodology) and 73 – 85 (results) of the report

POINT NO. 7. ***NTPC shall set up a permanent laboratory of CIFRI at the site to expedite the study w.r.t above parameters and for making scientifically sound conclusions***

Answered in page no. 29 of the report

POINT NO. 8. ***The characteristics of treated sewage which is being reportedly used for irrigation. The coliform count specially has to be monitored and reported***

Answered in page no. 16-17 (methodology) and 109 (results) of the report

POINT NO. 9. ***Accordingly, the study should conclusively come out as to what tonnage of coal can be transported through Waterways i.e. in the proposed route of NW-1 in an environmentally sustainable manner***

Answered in page no. 18 (methodology) and 111 (results) of the report

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EXECUTIVE SUMMARY

NTPC Limited is operating Farakka Super Thermal Power Project (STPP), capacity 2100 MW, in Murshidabad district of West Bengal. In order to supplement the shortfall in availability of domestic coal to the project, it was proposed to import coal through sea route and transport it to Farakka STPP through National Waterway -1 (NW-1). NTPC had approached the Ministry of Environment, Forest and Climate Change (MoEF&CC), for amendment in Environmental Clearance (EC) for Farakka STPP for use of blended coal as well as change in mode of transport from railways to Inland Waterways. The Expert Appraisal Committee (EAC) accorded permission for transportation of coal for one year as a pilot project, subject to undertaking a study on the impact on aquatic ecology and fisheries of the river. The study report was presented in the 38th EAC Meeting (Thermal Power) on 26.06.2015. The EAC recommended that the study should be continued on long term basis, at least for one year. Accordingly, the Inland Waterways Authority of India (IWAI) awarded a consultancy project on "Impact assessment of coal transportation through barges along the National Waterway No.1 (Sagar to Farakka) along river Ganga" to ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore, to address the queries of the EAC on possible environmental and social impacts of the project.

Inland Waterway Transport (IWT) is an environment-friendly mode of transport, compared to the polluting surface based modes of transport. It is non-water consumptive mode of transportation. It facilitates reduction of pressure on Railway network and National Highways, relieving congestion, which in turn, reduces number of vehicles & goods train, leading to reduction of carbon emission and project footprint. Furthermore, execution of IWT requires minimum land acquisition, therefore, positive impact on terrestrial ecology & biodiversity, agricultural activities as well as on the livelihood of the people.

The river Ganga has highly complex ecology and supports numerous flora and fauna interdependent on each other and on the quality of the fluvial aquatic environment. Frequent movement of barges along the waterways, although an economical proposition, may exert certain impact on the distribution as well as on well being of aquatic communities in the river stretch, which in turn might affect the fishers and other riparian population, depending directly or indirectly on the goods and services of the river for livelihoods. Hence, the study aimed at identifying the possible immediate impact of barge movements on various ecological, fisheries and socio economical components. Specifically the investigation was carried out to assess the impact on biotic community; impact on fish catch and livelihood of fishers; impact on water and sediment qualities; characterisation of sewage generated in the barges and estimation of optimum barge traffic load without serious eco-biological and social impacts.

To facilitate the study by ICAR-CIFRI, the Institute has established a field laboratory within the NTPC plant area as per the project agreement and the facility is fully functional.

Results of the study revealed no significant changes in water quality parameters in the river due to the current movement of barges in this short period of time, except increase in turbidity up to 5% in the shallow channel stretches and near the bank areas immediately after barge movement. In the deeper channel, no variation in turbidity was recorded.

A total of 207 fish species belonging to 61 families and 17 orders were recorded from the study stretch, of which, 27 fish species have been listed as threatened as per the IUCN criteria. Lower stretch (Zone–I) harbours the lowest number of fish species with conservation significance (11 species) which might be attributed to stressed habitat conditions owing to its proximity with Kolkata metropolitan area, industrial establishments and highly intensive fishing activities. Though a rapid change in fish assemblage structure has been observed in the seine net catches during passing of barge, it is difficult to arrive at any conclusions regarding the change in fish assemblage structure due to barge movement in this short term study. Impacts of barge movement on fish community composition can only be assessed by studying the fish community composition over a longer period of time as the shift in species composition is a slow and gradual process which requires continuous monitoring. A temporal and seasonal fluctuation in fish catch and catch per unit effort (CPUE) including that of the migratory fish hilsa has been recorded. The variation in the abundance of fish larvae was insignificant during barge movement.

Phytoplankton community consisted of 68 species distributed in 5 phylum, 9 class, 27 orders and 39 families; major groups being diatoms followed by green, blue green and yellow green algae. Among zooplankton, 12 taxa were reported mostly comprise rotifers and copepods. The impact of barge movement on plankton abundance and quality in terms of damaged cell structure was studied. Impact study of barge traffic on plankton abundance revealed that there was a 16% decrease in total plankton abundance (2772 nos/l) in comparison to the status prior to the barge movement (3275 nos/l). Quantitative study in terms of cell damage due to barge movement also revealed that there was 15% increase in the cell structure damage immediately after passage of barge, which was reduced to 10 % after 30 min of barge movement with respect to the normal condition (before barge movement). The observation of reduction in cell structure damage is due to flowing of damaged cell along the river flow. However, continuous study may require for assessing fish stock depletion if any and suggesting mitigation measures in the long run.

Macro-benthic community in the entire stretch comprised of 25 species under 10 families and 3 classes. The diversity of these communities was higher in the upper stretch (15 species), followed by middle and lower stretches (9 species each). However, the impact of barge movement on macro-benthic community diversity could not be observed significantly in this short duration study since the variations in diversity itself is very slow and needs years together to observe the differences.

So far, this study has shown no significant changes in water quality, abundance of fish larvae, benthic creatures and fish stock due to the present movement of barges. Further, it is suggested that long term continuous studies may be required to assess the impact of barge movement on ecology of the river, fish assemblage and stock.

The Bhagirathi-Hooghly stretch of the river contains a sizable population of the endangered Gangetic dolphin (*Platanista gangetica gangetica*). The noise exposure behavior disturbance criteria for dolphins is 177 dB. However, the barge plying in NW-1 (1500-2000 DWT) with modern technology and regulated speed in the dolphin populated stretch generate noise of 110-140 dB. Since, the noise generated from the barge is below the noise exposure behavior disturbance criteria for dolphins, no adverse impact on the organisms is anticipated.

The critically erosion prone zones need to be protected through erection of retaining walls, putting gabions with stones, stone pitching, establishing vegetation, etc. However, IWAI reported that it has taken suggestive measures from the Haldia to Farakka stretch.

In addition, IWAI plan to introduce shallow draft vessels, which will reduce any kind of disturbance to the benthic organisms and avoidance of any constrictions of the river flow, which lead to sustainability of environment. Also, maintaining the least available depth of more than 3 m of the navigation channel (or average water depth of 5 m, considering deep pools along the channel) may also reduce the disturbance to benthic habitat, facilitate escapement of fishes including hilsa and dolphins. Further, it is suggested that the barge speed may be reduced to 5 knot in dolphin dominated areas, in hilsa sanctuaries during breeding season and narrow stretches for reducing the wave action and thereby minimizing possibilities of bank erosion.

To assess the impact on livelihood of fishermen, information were collected from 500 fishers along the study stretch through personal interview. The survey results indicated that some constraints have been faced by them due to barge movement. These were forced suspension of fishing operations, dislodging of nets, loss of fishing time and chances of net damage. The problem is more near the river meanders and narrow stretches. The fishers largely depend on the fish catch for their daily livelihoods. Disturbance caused by the movement of barge has direct bearing on the fishing operations. Around 38% of the fishers reported loss in fishing time. The average monetary loss per fishermen was found to be Rs. 0.75, 4.35 and 17.63 per incidence of barge(s) movement in lower, middle and upper stretches, respectively.

The monetary loss of the fishermen is marginal in lower and middle stretches with the frequency of barge movement during the study period and arises mainly due to the reduction in fishing time. However, this loss can be minimised by taking certain measures like prior announcement of barge movement schedule, generation of awareness on barge movement among public, especially the fishers and ferry operators. Stakeholders meetings may be organized periodically for sensitization. Additionally, measures may be taken to enhance the fisherman welfare. Furthermore, navigational aids in the form of night navigation facilities and channel marking, enhancement of existing river information system, improved communication platform and expanded user reach and river monitoring systems will help fishermen to schedule their fishing time.

The analysis of river water and barge sewage samples revealed that the coliform load in river water varied from 1.1 to 1.4 x 10^4 numbers/ml and sewage generated in the barges varied from 1.5 x 10^3 to 4.6 x 10^5 numbers/ml. Thus, with respect to coliform count, both the river water and barge sewage samples exceeded the permissible level for irrigation purpose (<200 numbers/100 ml).

Energy conservation and other perceived benefits in inland water transport *vis-a-vis* road and rail transportation were assessed.The actual average fuel consumption of barges of Jindal ITF Ltd. (present transporter of coal) and accepted norms of fuel consumption for transportation of bulk goods by railways were worked out. It is estimated that there will be savings to the extent of 9.1 million litre per annum of high speed diesel (HSD) for the transportation of 3 MTPA coal between Haldia to Farakka using IWT mode as compared to railways. Transportation of 3 MTPA of coal by road is not a practical proposition since about 800 trucks (of 10 ton capacity) will be required to be moved one way every day between Haldia to Farakka. Therefore, IWT has the potential to substantially reduce the GHG emissions as compared with other mode of transportation. Also, other benefits in the waterways transportation are savings in rail and road maintenance cost, reduction in congestion and accidents on road &rail, minimum pilferage/loss in transit, etc. Therefore, it is concluded that, IWT is a competitive alternative to road and rail transport, offering an economical and environment friendly mode in terms of energy consumption, noise and greenhouse gas emissions.

The above studies indicate that there is marginal impact on aquatic flora & fauna, fishing and livelihood of fishermen and wherever there are impacts, plans are suggested which can be easily implemented. The transportation of coal through covered and moist condition did not show any substantial impact on the river ecology. However, this movement reduces substantial carbon footprint in the form of saving diesel as compared to surface transportation.

Considering the observation of the present study, in case of more water availability i.e. least available depth of more than 3 meters (which will be equivalent to average depth of 5 meter including the deep pools and deeper channel in consideration) the permitted rate of coal movement may be revised to 3.0 MMTPA for NTPC-Farakka STPP having capacity of 2100 MW.

1.0 Introduction

NTPC Limited is operating Farakka Super Thermal Power Project (Farakka STPP, Capacity 2100 MW) in Murshidabad district of West Bengal. Presently, the coal requirement for Farakka STPP, Stage-I, II and III is about 13.31 million ton per annum (about 32,900 ton per day) which is met from domestic coal mines. In order to supplement the shortfall of domestic coal to the Project, it was planned to blend the domestic coal with imported coal. The imported coal is proposed to be sourced from Indonesia/Australia and transported through sea route up to Sandheads/Kanika Sands and is proposed to transport the coal to Farakka STPP through National Waterway No.1 (NW-1). The Sagar to Farakka stretch of river Hooghly, 560 km out of total 1620 km stretch of NW–1, will be utilized for transportation of coal in covered barges. NTPC had approached Ministry of Environment and Forests (MoEF), presently, Ministry of Environment, Forest and Climate Change, for amendment in environmental clearance for Farakka STPP for use of blended coal as well as change in mode of transport of coal, from railways (present) to using Inland Waterways (proposed). The copy of the permission letter received is given in Annexure I.

As per the Ministry of Environment, Forest and Climate Change letter no. J-13011/28/2006 – IA. II (T) dated 31.07.2014, the Expert Appraisal Committee accorded permission for one year for coal transportation as a pilot project, subject to undertake a study on the impact of transportation of coal through NW-1 on aquatic ecology and fisheries of the river for further consideration of MoEF & CC. Accordingly the Jindal ITF Limited, New Delhi, presently involved in transportation of coal through the waterway, approached ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore to undertake a detailed study on “Impact Analysis on Ecology, Flora and Fauna including Fish and Fisheries due to Movement of Barges Carrying Coal through National Waterway No.1 (Sagar to Farakka)”. The study report was presented in the 38th Expert Appraisal Committee Meeting (Thermal Power) on 26.06.2015. The committee recommended that the study should be continued on long term basis and at least for one year. Accordingly, the Inland Waterways Authority of India (IWAI), Ministry of Shipping, Government of India, has sanctioned ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore a consultancy project on “**Impact assessment of coal transportation through barges along the National Waterway No.1 (Sagar to Farakka) along River Ganga”.**

At present the coal is transported through barges (dimension of 72 m x 14 m x 4.25 m) having carrying capacity of about 2,100 ton. The barges move at a speed of about 5 to 6 knots in loaded condition and about 9 to 11 knots while returning from Farakka in ballast [ICAR-CIFRI final report of the project on Impact Analysis on “Ecology, Flora and Fauna including Fish and Fisheries due to Movement of Barges Carrying Coal through National Waterway No.1 (Sagar to Farakka)]. Thus, the average speed is 7-8 knots per hour and it takes about 5 to 6 days to complete its cycle of transportation. Currently, 27 barges are being engaged but during full operation, up to 40 barges will run throughout the year.

The ecology of river system plays the most important role in habitability and abundance of the flora and fauna in different stretches of the river. The aquatic organisms inhabiting in the river system depends upon the interaction of both physical and chemical characteristics. The characteristics originate from the interplay between land form and climate within the basin. Two major factors which govern river ecology are: longitudinal distribution within the system or zonation in space and seasonality which correspond to zonation in time. The flora and fauna of the river is an assemblage of a mixed and widely varied organisms belonging to the plant and animal kingdom. At the primary level, the microscopic algae through photosynthetic activity add to the biotic production chain. Mosses and macrophytes among plants and small crustaceans, larval forms of insects and mites among animals constitute the secondary producers and consumers in the food chain. The animals like fishes and dolphins occupy the higher positions in the tropic level. In principle, the population structure of the organisms is governed by the river characteristics. In majority of cases, rivers have sufficient natural phenomenon to influence the behaviour of the living organisms. In rivers where the parameters vary a little throughout the year, the resident aquatic communities remain relatively stable. Seasonality in such river systems from climatic variability, other than water quality, influences the biota. Any adverse changes in the sensitive parameters result in failure in recruitment leading to a sharp decline in the population. In addition to these, human activities such as the water obstruction, abstraction, pollution, etc. have largely modified most of the rivers. As a result, the plankton, sedentary macrobenthic organisms and young fishes have impacted. A large number of fish species became threatened or endangered and the fish productivity of most riverine ecosystems has declined. Movement of vessels during navigational activities along the riverine waterways has different levels of ecological impact although it is well established that among the inland transport systems, the Inland Water Transport (IWT) is the most economic and safest mode of transportation. It has economy in fuel consumption and release less amount of different harmful gases. Several studies on transportation in water bodies elsewhere in the world have shown that the flora and fauna living in the water bodies are affected. In addition to the aquatic flora and fauna, the livelihood of the fishermen, depending on these open water resources get affected. Hence, it is imperative to estimate the impact of the movement of barges to maintain a sustainable river ecosystem. The ICAR - Central Inland Fisheries Research Institute, Barrackpore conducted the study during 2015-2016 and 2016-17.

This report describes the observations of the present study, including the findings of the study conducted during 2013-14 on "Ecology, Flora and Fauna including Fish and Fisheries due to Movement of Barges Carrying Coal through National Waterway No.1 (Sagar to Farakka)".

Based on the ICAR-CIFRI study conducted during 2014-15, the following recommendations were given by the 38th Expert Appraisal Committee Meeting (Thermal Power) held on 26.06.2015:

POINT NO. 1. ***Long term, and a minimum period of one year continuous study shall be conducted on the impacts of varying traffic loads on aquatic flora and fauna with particular reference to species composition of different communities, abundance of selective species of indicator value, species richness and diversity and productivity.***

POINT NO. 2. ***Impacts of noise generated by the barge movement on Gangetic Dolphin which is declared as a National Aquatic Animal.***

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POINT NO. 9. ***Accordingly, the study should conclusively come out as to what tonnage of coal can be transported through Waterways i.e. in the proposed route of NW-1 in an environmentally sustainable manner.***

The ICAR-CIFRI conducted the study with the following objectives and work plan as per the above recommendations of the EAC.

2.0 Objectives:

- **Assess the impact of varying barge traffic loads on population structure and dynamics of important aquatic flora and fauna.**
- **To document the impact of barge movement on the fish catch and livelihood of fishers.**
- **Estimate optimum barge traffic load without serious eco-biological and social impacts.**

3.0 Plan of work:

The stretch of the Bhagirathi-Hooghly river from Sagar to Farakka has been classified into three zones based on:

i) the intensity of the navigation/shipping
ii) salinity dependent aquatic biodiversity and
iii) intensity of fishing activities / involvement of fishers

The map of the study area and classified three zones is given in Fig. 1.

Zone I: Lower stretch from **Sagar Island to Dakshineswar** (154 km) with characteristics of intensive shipping activities, high tidal effect, higher abundance of euryhaline fish species and high fishing pressure.

Zone II: Middle stretch from **Dakshineswar to Nabadwip** (124 km) with characteristics of moderate shipping activities, low tidal effect, mixed fishes of euryhaline as well as freshwater species and moderate fishing pressure.

Zone III: Upper stretch from **Nabadwip to Farakka** (282 km) with characteristics of least shipping activities, non-tidal zone, complete freshwater fish species and moderate fishing pressure.

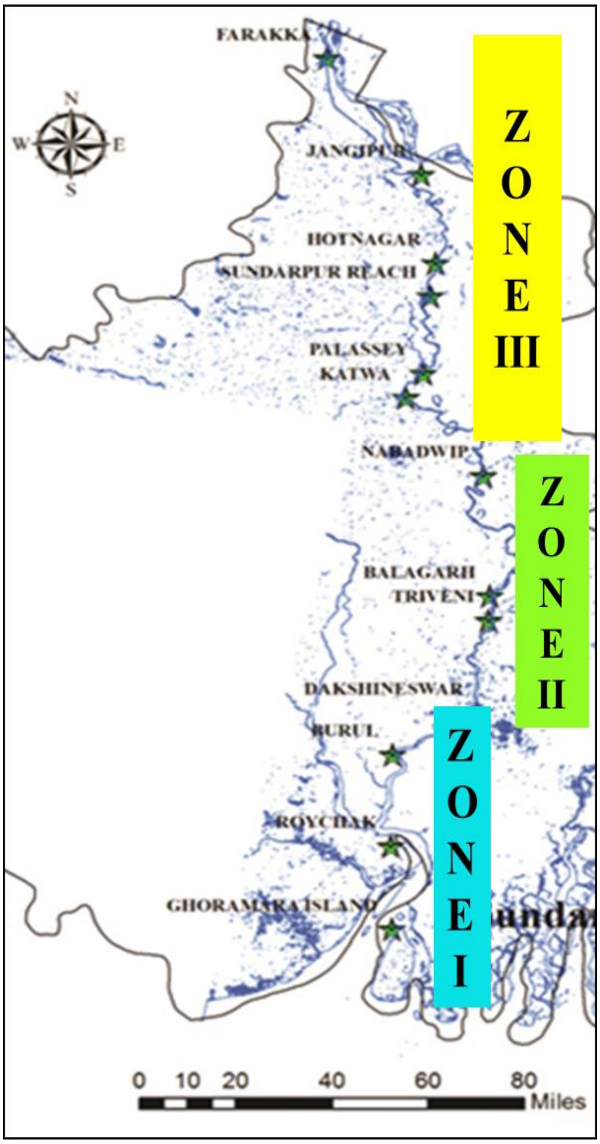


Fig. 1. Map of the study area and classified three zones

The report is divided into general observations and five different but inter-related components (Fig. 2) as given below.

The general observations section includes the description of the National Waterway No.1 and details about the coal loading/unloading and transportation system presently in use and the Standard Operating Procedure of the organisation involved in operation.

The five different components demarcated are:

Component I: Assessment of impact of barge movement on biotic community
Component II: Impact of barge movement on fish catch and livelihood issues of fishers
Component III: Assessment of barge traffic impact on water and sediment qualities
Component IV: Characterisation of sewage generated in the barges
Component V: Estimation of optimum barge traffic load without serious eco-biological and social impacts

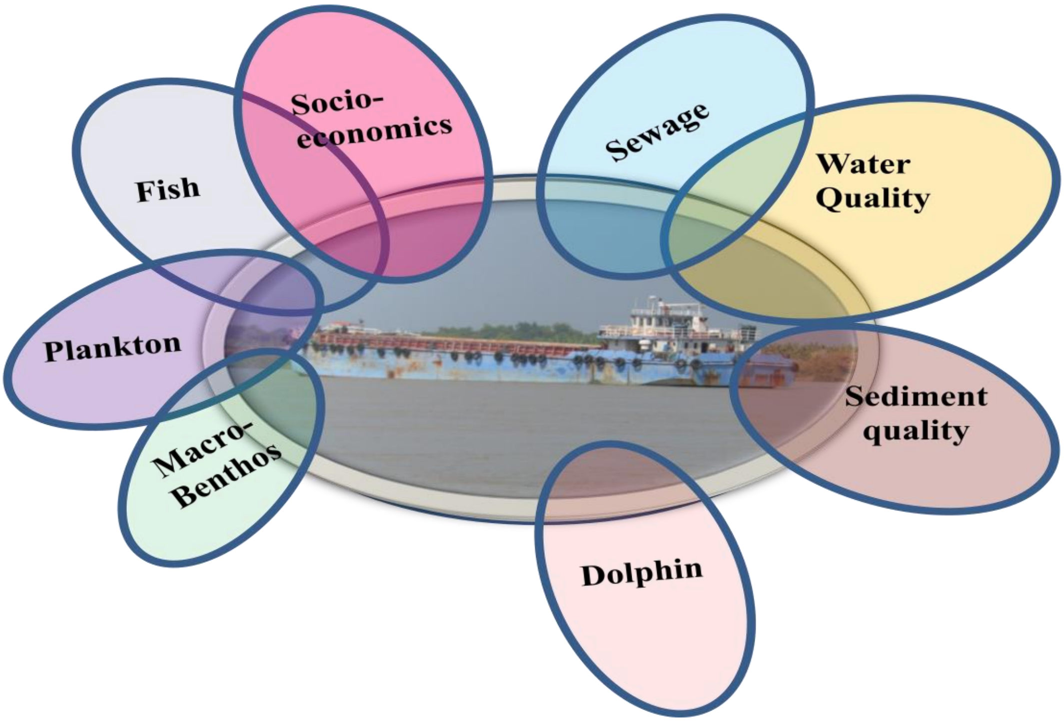


Fig. 2. Diagram showing relation among the components

Description of the sampling methodology of different components is given below:

3.1 Component I: Assessment of impact of barge movement on biotic community:

Aquatic faunal and floral diversity from all the three stretches (Sagar Island to Dakshineswar, Dakshineswar to Nabadwip and Nabadwip to Farakka) were assessed with emphasis on fish, macro-benthos and plankton communities.

3.1.1 Fish communities

3.1.1.1 Fish biodiversity study

Fish sampling surveys were carried out during two distinct seasons, *viz*., pre-monsoon (March – June) and monsoon (July – October) during 2016. Fishing activities along the study area employ a wide variety of gears with several local variants (Ramesan *et al*., 2009). For fish diversity studies, we analyzed the catches of all fishing gears found operational during sampling survey (seine nets, gill nets, bag nets, lift nets, cast nets, hook and line, traps and set barriers) as per Roshith *et al*. (2013). As the changes in fish species composition and abundance in response to barge movement will be rapid, the sampling gear should enable rapid sampling of fish assemblages, cover a large sampling area and capable of capturing a variety of species belonging to different size groups. A seine net possesses all these attributes (Pierce *et al*., 1990) and is ideal for sampling with regard to this specific objective. Seine nets with length: 100 – 150 m and height/breadth: 8 – 8.5 m (Fig. 3) were operated by hiring local fishermen in selected sampling sites (Kuntighat, Kalna and Nabadwip). The seine net operations were carried out at three distinct sampling points within a site:

1) Dredged/deeper channel (used by coal transportation barges)
2) Shallow littoral zone near river banks (between dredged channel and river bank) and
3) Sheltered areas within river islands (with abundant submerged aquatic vegetation)

Fig. 3. Seine net in operation

It has been previously mentioned that different zones within the studied stretch are subjected to stress due to inland navigation, with varying levels of intensity. As the intensity of inland navigation (shipping, recreational boats, fishing boats, etc.) is difficult to quantify with respect to a particular stretch during a given time period, some insights regarding the probable impacts of barge movement of fish communities was made by adopting the methodologies:

1) Comparison of the present data on fish catch structure with historic data (fish catch data collected at various sampling locations on the studied stretch prior to 2013–14, time during which coal transportation by barges started on experimental/trial basis).
2) Sampling of fish assemblages along selected river channel before and after crossing of barges to monitor the direct impacts on fish communities due to barge movement.

The fishes caught were counted, weighed, fixed in 10 % formalin as per APHA (2010) and further analysis were carried out at ICAR-CIFRI laboratory. The fishes were identified up to species level with the help of standard taxonomic literature (Talwar and Kacker, 1984; Talwar and Jhingran, 1991; Talwar, 1991; Talwar et al., 1992; Jayaram, 1999; Chatterjee et al., 2000; Kamala Devi and Rao, 2007; Raje et al., 2007). The fish species were listed according to the classification scheme by Nelson (2006). The scientific name of each fish species were ascertained as per updated and revised scheme provided in the Eschemeyer Catalog of Fishes. For comparison of fish community structure between the various sampling zones, we relied on c-dominance plot (PRIMER v6 PERMANOVA software package) where cumulative relative abundance/dominance of fish species (Y-axis) from a sampling zone is plotted against the increasing species rank on X-axis. The c-dominance curves for all stretches were compared to determine whether the fish community structure exhibit any signs of ecological stress.

3.1.1.2 Impact on migratory fish species

One indicator species (hilsa *Tenualosa ilisha*) among the migratory fishes in the study area was studied for understanding impacts due to varying levels of barge traffic in its migratory path through monitoring their abundance in the shipping channel and adjacent waters.

3.1.1.3 Impact on fish larvae

In order to identify peak breeding grounds through spawn/ larval availability along the stretch of river, fish spawn sampling was carried out using three types of gears: push net, shooting net and tow net (Fig. 4). Fish larvae collection gears were employed in the shipping channel and adjacent areas/waters to explore the breeding areas in the study stretch. To investigate barge movement associated impact on fish larvae, efforts were made to collect larval fish from the sailing line before and immediately after barge passage.

Fig. 4. Push net (left) and tow net (right) used for hilsa and other fish larvae sampling

3.1.2 Plankton community

Plankton is known to be the most sensitive floating community in an aquatic ecosystem. Any undesirable changes in aquatic ecosystem affect diversity as well as biomass of this community (Summarwar, 2012). High intensity turbulence in water is generated from both anthropogenic and natural causes such as boat propellers, strong winds and breaking waves. Movement of barges cause disturbance like alluviation and loose soil formation especially in shoreline of the rivers that is carried downstream and increase the suspended sediment loads. The unconsolidated soil is also accompanied with the presence of exposed tree roots, clumps of grass from collapsed river banks. Hence, eroded river bank acts as an external force on phytoplankton development. This causes low light permeability in underwater and limit photosynthesis and prevents phytoplankton development (Reynolds, 2006; Baykal *et al.*, 2011; Garrison and Tang, 2014) as well as micro-zooplaktonic growth (VIMS, 2011). Llames *et al*. (2009) have described the light limitation theory through a mesocosm experiment on various degrees of light availability on planktonic community structure and metabolism which shows abundance of most grazers having a negative relationship with light availability and simultaneously an abrupt decrease in density of grazers leads to changes in the nutritional value of the aquatic ecosystem.

Many species of phytoplankton especially diatoms are used as indicator of water pollution. Zoo-planktonic organisms are also known as bio-indicators of water quality and degree of pollution because they are strongly influenced by environmental alterations and respond quickly to changes in quality (Dorak, 2013). In the eutrophic water the zooplankton composition changes; replace the dominance from larger species (e.g. Calanoid copepods) to smaller species (*e.g.* especially rotifers) (Marneffe *et al.* 1996). Zooplankton acts as an important member in the consumer food chain of an aquatic ecosystem in the transformation of energy from primary producers to upper level consumers (Sharma *et al.*, 2010). And thus, they maintain the ecosystem food chain. Micro-zooplanktonic populations are important because they serve as the foundation for food chains supporting vertebrate populations (USEPA, 2011) and are sensitive biological indicators of biological impairment in aquatic ecosystems (Chadwick and Canton, 1983; USEPA, 2011). In the light of maintaining sustainability among the production parameters of an aquatic ecosystem it is imperative to study possible impact of barge movement on riverine phytoplankton and zooplankton occupying lower level in the natural food chain.

3.1.2.1 Sampling design for collection of plankton in the barge route

Water samples were randomly collected in three replications from the subsurface region of the water column in the barge route at three different time interval of barge movement viz., before passage of barge, immediately after passage of barge and thirty minutes after passage of barge for plankton enumeration. The collected samples were processed separately for phytoplankton and zooplankton analysis in laboratory.

3.1.2.2 Plankton sample preservation and enumeration

For taxonomic analysis of phytoplankton, samples were collected from sub-surface photic region of the water column in 1 litre polyethylene bottles and fixed with lugol iodine solution (10 ml/l) and formaldehyde solution with a final concentration of 2% (Baykal et al., 2011). Algal samples were concentrated by sedimentation process by pouring the whole sample into a 1000 ml measuring cylinder and allowing the cylinder to stand on a vibration free surface for more than a period of 24-72 hours (Belliger and Siegee, 2010). The sedimentation unit was maintained in a dark cool condition and kept away from heat. The top algal free water was drained out with intensive care. To minimize cell disturbance, the remaining top clear water was siphoned out using a 1000 µl pipette. The concentrated biovolume was subjected to microscopy for qualitative analysis. For quantitative analysis, water samples for zooplankton sieved by deploying 30 micron bolting silk mesh for a specific time period following standard protocol (APHA, 2012) and preserved in 4% formaldehyde solution for further analysis. The density and abundance were estimated by using a compound microscope. Density and quantum of abundance was measured by employing a Sedge Wick rafter counting chamber using a strip count method (APHA, 2012). The schematic diagram of the sampling methodology is given in Fig. 5.

3.1.2.3 Plankton sample identification

Phytoplankton species were identified with a Carl Zeiss Microscope with 100x, 400x, 630x magnifications and in 1000x magnification under oil immersion. Photographic data were recorded using a photo capture unit (Moticam 2300) digital microscopy. The phytoplankton were identified upto species level wherever possible following Prescott, 1899; Edmondson, 1959; Ramanathan, 1964; Philipose, 1967; Hustedt, 1976; Cox, 1996; Anand, 1998; Biggs and Kilroy, 2000. Phyla were arranged following algaebase website (Guiry and Guiry, 2016). Quantum of abundance was measured using Neubauer- improved haemocytometer (marienfeld, Germany) (Schoen, 1988; LeGresley and McDermott, 2010). Zooplankton community were identified at genus level using various source (Battish, 1992; Edmondson, 1959; Witty, 2004).

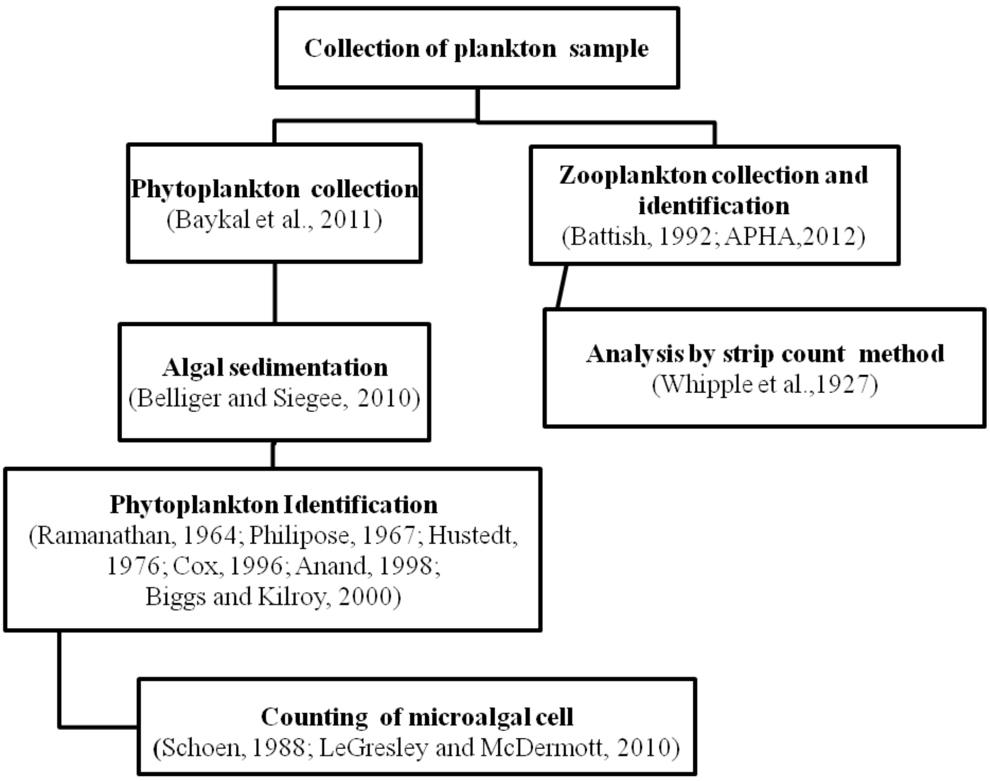


Fig.5. Schematic diagram of sampling methodology for plankton

3.1.3 Macro-benthic community

Macro-benthic community refer to the living organisms that inhabit the bottom substrates of aquatic habitats, for at least part of their life cycle. It has been well studied that the community structure and their distribution depends upon several parameters such as habitat characteristics, sediment quality, stream flow, and depth (Peeters and Gardeniers, 1998; Bhatet al., 2011). These organisms are mostly favoured in environmental monitoring programme because of their sessile nature or limited in their range of movement and therefore cannot avoid pollution (Gaufin, 1973). In addition, a long term exposure to the transport systems like barge and other pollution, these organisms may play a significant role in signalling the ecosystem status. The present investigation was performed to understand benthic diversity and possible impact on them due to barge movements in the study stretches. The result was compared with the study conducted by ICAR-CIFRI, Barrackpore during 2009.

3.1.3.1 Sampling methodology:

The selected stretch, from Sagar to Farakka was classified into three zones (Zone I: Lower stretch from Sagar Island to Dakshineswar; Zone II: Middle stretch from Dakshineswar to Nabadwip; Zone III: Upper stretch from Nabadwip to Farakka) and from each zone two sites were selected. Samples were collected throughout the width of the river, representing two bank sides and middle channel of the river. Random sampling was done in relatively homogenous areas in three zones by using grab (Fig.6, 7).Three samples were collected from each sites and mixed them to make one sample. The sample collection was made as per standard protocol (APHA, 2010). The collected samples were segregated based on different species, genera or groups. Quantitative estimation was made for each individual as well as for groups. The number of macrobenthos per square meter were calculated and presented below.

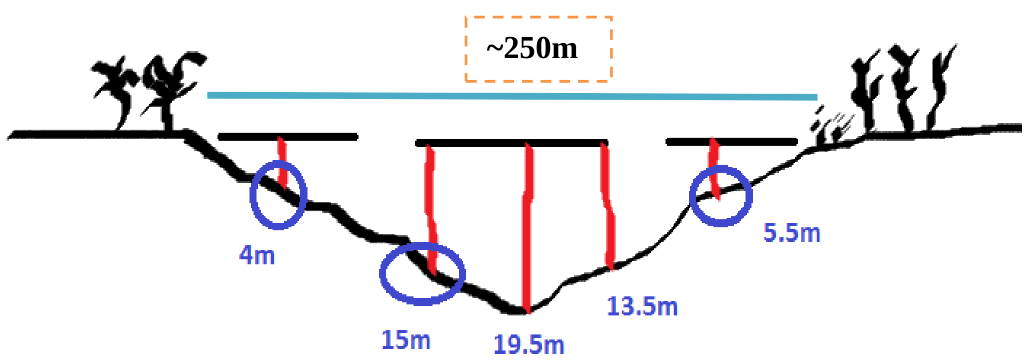


Fig.6. Schematic sketch of river cross section at Balagarh with sampling spots

Fig. 7. Collection of macrobenthos sample from the river bed

3.2 Component II: Impact of barge movement on fish catch and livelihood issues of fishers

River plays an important role in supporting the livelihood of millions of impoverished communities. In the Bhagirathi-Hooghly stretch of the Ganga river, a sizeable population of fishers depend on fishing for their livelihood and daily sustenance. Any disturbance including movement of vessels in the river will have direct bearing on fishing operations which may result into obstruction of the fishing activities and thereby affecting the daily livelihood of the fishermen. The present study is an attempt to assess the socio-economic conditions of the fishermen and to analyse their opinion regarding impact of barge movement on livelihood.

3.2.1 Methodology

To document the impact of barge movement on the fish catch and livelihoods of fishers, data were collected by personally interviewing the fishermen using survey schedules (Annexure II). The study was conducted during the month of March-May, 2016 and September-October, 2016. A total of 500 fishers were covered under this study.

3.2.2 Sampling design

Multi-stage stratified random sampling design was adopted to select the fishermen from all the three classified zones (Fig. 1 and 8). Then, 32 sampling sites (fishing areas) were selected randomly covering all the 3 zones (Table 1); 8 from lower zone; 10 from middle zone and 14 from upper zone. At third stage, fishermen's household were randomly selected from the selected sampling sites. A total number of 500 fisher families (100 from lower stretch, 200 each from middle and upper stretches) were interviewed for the socio-economic study.

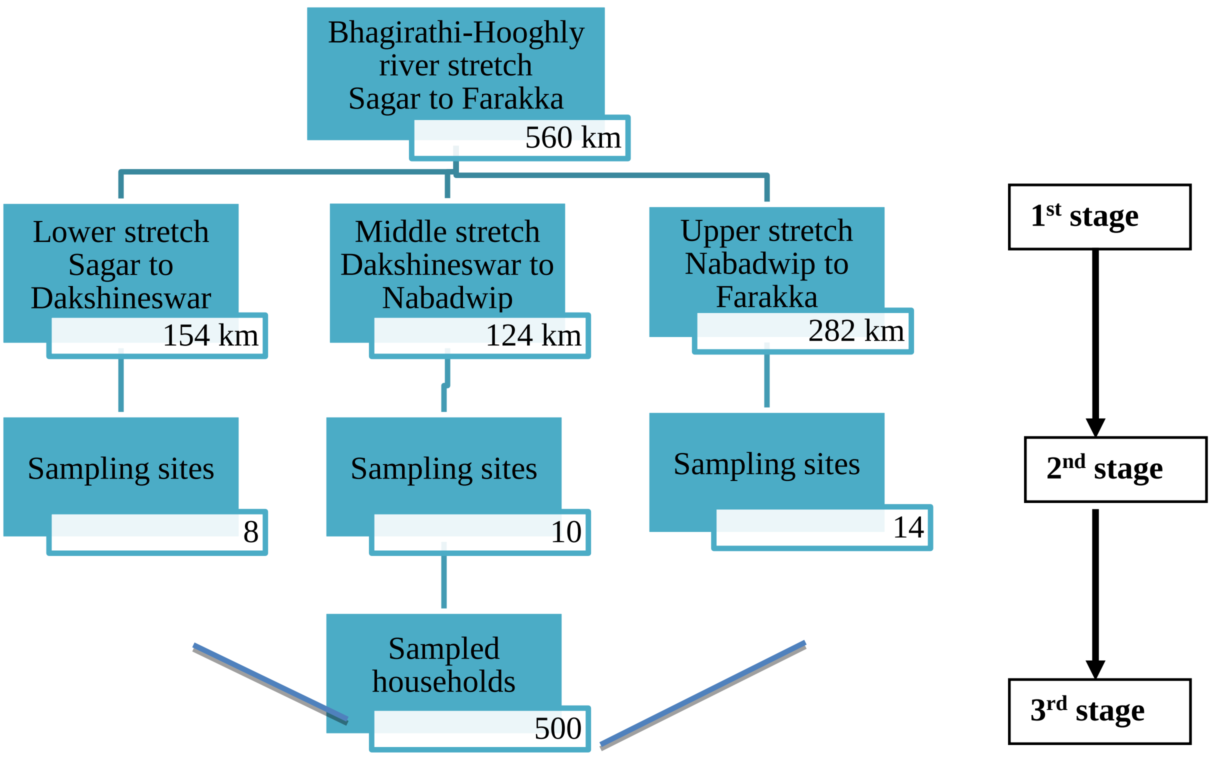


Fig. 8. Multi-stage stratified random sampling design for selecting respondents

Table 1. Sampling sites in the three designated zones

Zone/Stretch	Distance (km)	No. of sampling sites	Name of the sites	Number of households
Zone I: Lower Stretch	0 – 154	8	Sagar light house, Diamond Harbour, Hanrar Khal, Noorpur/ Roy Chak, Burul, Godakhali, Jagannathpur 11 No. Lockgate (Uluberia), Baranagar / Bally / Barendrapara	**100**
Zone II: Middle Stretch	154 – 278	10	Barrackpore/ Nawabganj / Debitala, Halisahar (Acharjeepally, Lalkuthi, Sarkarpara), Sannyalchar, Medgachi, Hatathpally (Kalyani), Shamsundarighat, Khasbati, Hooghly ghat, Tribeni, Balagarh	**200**
Zone III: Upper Stretch	278 - 560	14	Katwa / Moraghat, Rajachar, Palassey (Ramnagar), Sundarpur Reach, Hotnagar, Chowrigachha, Lalbagh, Jiaganj, Jangipur, Raghunathganj, Sarala Kishorepur, Hasipur, Putimari, Farakka	**200**
Total		**32**		**500**

3.2.3 Data collection

Primary data were collected by personally interviewing the respondent fishers. The data were collected on structured survey schedules. Various socio-economic components *viz*. fisherman's personal data, household information, income sources and occupation details, information on fishing operation, fishing gears and crafts, fish catch data, expenditure pattern, constraints in fishing, etc were collected. Data were also collected for both pre-barge and post-barge periods based on the opinion of the fishers. In some cases, the fish catch data were verified with the actual catch of the day.

3.2.4 Process of the survey

The interview schedule was tested during pre-survey at Balagarh (middle stretch) and was revised as per the requirements. The survey teams were trained for establishing solid understanding of the survey schedules. They visited the fishermen villages and randomly interviewed the fishers' respondent. In many places Primary Fishermen Cooperative Societies and block level fishery extension officers helped in identification of active fishermen. Validity of the answers was screened by the team leader. Any absurd answers were either discarded or corrected through additional interview.

3.2.5 Variables and analysis

All data collected were entered into the MS EXCEL spreadsheet. The mathematical and statistical analysis of socioeconomic data were carried out by applying standard methodology.

3.3 Component III: Assessment of Barge traffic impact on water and sediment qualities

Rivers like Ganga have been the cradle of ancient civilizations of India where river banks were mostly preferred for human settlement. Even today population density is much higher around the river and that too is increasing day by day. Unfortunately, this population growth leads to increased anthropogenic pressure on the river, resulting in severe degradation of the ecosystem. River became the ultimate sink of anything and everything coming through surface run off and in the bargain it is losing its utility functions at a faster pace. Water quality parameters have their direct influence on aquatic organism present therein. Biodiversity of rivers are modified as per the changes in habitat which is related to water quality parameters. So, continuous monitoring of water quality is necessary to formulate suitable management norms to prevent any unwanted modification of aquatic biodiversity.

To assess the water and sediment quality parameters, the samples were collected from boat using water sampler and Petersen grab sediment sampler. Samples were collected across the river as well as from the two banks and also from the sub surface layer of the middle of the river to obtain composite water and soil sample during 10-11 AM. The analysis was carried out following standard methods (APHA, 1998) and as per the methods modified at ICAR-CIFRI based upon the field situations for water and as per the methods of Piper (1966) and Jackson (1964) for sediment samples. The parameters analysed are given in Table 2.

Table 2. Water and sediment parameters evaluated in the study stretch

Water parameters	Sediment parameters
Temperature	Texture
Depth	pH
Transparency	Specific conductance
Dissolved oxygen	Free $CaCO_3$ content
pH	Organic carbon
Total alkalinity	Nitrogen
Total hardness	Total nitrogen
Specific conductance	Available phosphorous
Salinity	
Biochemical oxygen demand	
Chemical oxygen demand	
Soluble reactive phosphate phosphorus	
Total nitrogen	
Silicate-silicon	

3.4 Component IV: Characterisation of sewage generated in the barges

Sewage generated in the coal carrying barges were analysed for pollution related study through following parameters

- Estimation of faecal coliform
- Analysis of physico-chemical parameters - pH, conductivity, dissolved oxygen, biochemical oxygen demand.

To characterize the sewage generated in the barges, sampling was conducted on 27.06.2016 and 19.09.2016 at Nurpur, South 24 Parganas. Water samples were collected from (i) river - away from the docking site at Nurpur, South 24 Parganas and (ii) Sewage Treatment Plant of barges, in order to understand the quality of water that is discharged for irrigation purpose and also which has possibility of entry into the river system. Sampling and analysis were done from one barge in June and from seven barges in November, 2016.

Fig. 9. Sampling site at Nurpur

Fig. 10. Unloaded barge

Fig. 11. Sample collection from STP of Barge 1

Fig. 12. Sample collection from STP of Barge 2

3.4.1 Bacteriological analysis

In order to estimate the faecal coliform count the following standard method was followed

1) Presumptive test

Presumptive test involves the primary presumption for the presence of Gram negative coliform bacteria in the samples demonstrated by the appearance of gas in the lactose fermentation broth. Bacteriological analysis was carried out for indicator organisms i.e. total and faecal coliform (*E. coli*) by most probable number (MPN) method as per APHA, 1998. The water and sewage sample was 10-fold serially diluted up to 10^{-4} and 10^{-9}, respectively and then 1 ml sample of each dilution (10^{-2}, 10^{-3} and 10^{-4} for water and 10^{-7}, 10^{-8} and 10^{-9} for sewage) were inoculated into triplicate in test tube containing 10 ml of Lactose broth (HiMedia, India) with andrade indicator and Durhams' tube and incubated at 44.5°C for 48 h. After incubation, the number of bottles in which lactose fermentation with acid (change of the colour of media from yellow to pink) and gas production (a bubble filling the concavity of Durham's tube) were considered presumptive positive growths of coliforms and counted. Finally, by referring to probability table (Macrady table 2) the MPN of coliform in water sample was estimated (Cheesbrough, 2006).

2) Confirmative test

Inoculum was taken from tubes showing positive for acid and gas and streaked on petriplate containing 20 ml of Eosine-methylene-blue agar and incubated at 44.5°C for 48 h. Dark colour colonies with metallic green sheen indicated positive for faecal coliforms.

3.4.2 Analysis of physicochemical parameters

The analysis methodology was similar to the techniques described in section 3.3.

3.5 Component V: Estimation of optimum barge traffic load without serious eco-biological and social impacts

Converging components I to IV, component V- the barge movement model in relation to eco-biological and social impacts could be assessed.

Efforts were made to understand the concept followed in other countries in relation to movement of vessels in the inland transport systems.

The studies were carried out in two spells: March to August, 2014 in first phase and January to October, 2016 in the second phase.

4.0 Description of study area:

National Waterway No. 1

Ganga-Bhagirathi-Hooghly river system from Allahabad to Sagar was declared as NW-1 *vide*. National Waterways Act 1982 (49 of 1982). It became operative from 27th October 1986. The map of the NW-1 is given in Fig. 13. Only a part of this waterway (Sagar to Farakka of about 560 km out of total length of 1620 km NW-1) is intended to be used for the proposed coal transportation (Fig. 14). The Hooghly river portion of the waterways from Sagar to Nabadwip is a tidal stretch. The vessels coming through sea navigate up to Kolkata (140 Km) and the fair way up to Kolkata is maintained by the Kolkata Port Trust. From Kolkata to Triveni, there is no restriction for navigation by inland vessels of a loaded draft up to 4 m. From Nabadwip to Jangipur the waterway is formed by Bhagirathi river, which is a regulated river from the Barrages at Farakka and Jangipur. With the controlled discharge from Farakka Barrage and limited river conservancy work, a navigable depth of 2.5 m is maintained by IWAI in this route throughout the year (Source : IWAI)

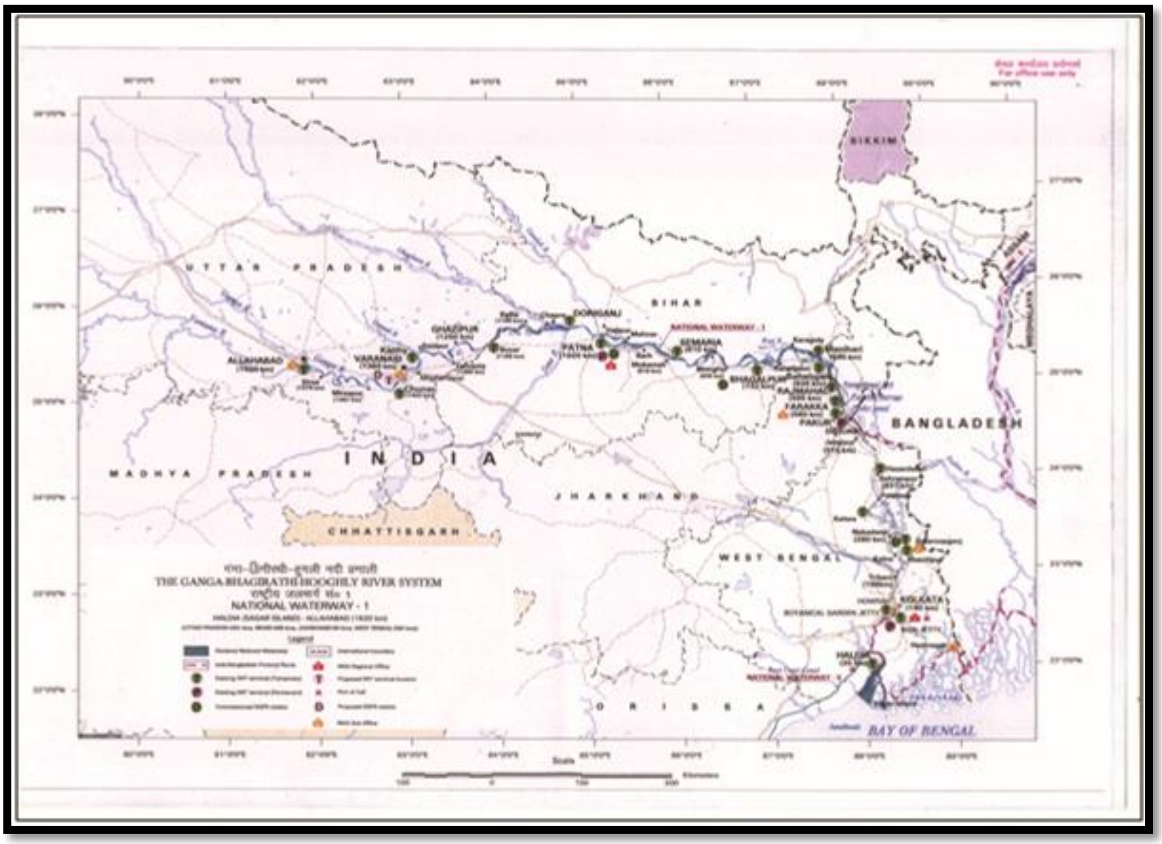


Fig.13. National Waterway No. 1

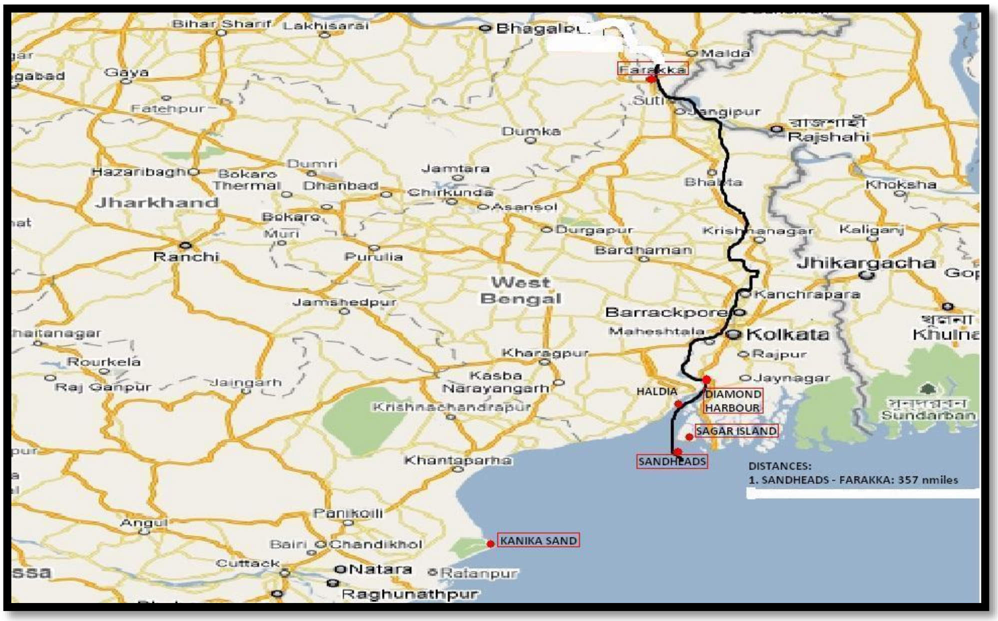


Fig. 14. Sagar Island to Farakka stretch of National Waterway No.1 with location of Sand heads and Kanika Sands

5.0 Coal loading/unloading and transportation system

The related information has been provided by Jindal ITF regarding the coal handling at loading and unloading points and transportation as well as the facilities in place for waste management. A transshipper has been positioned at high seas at Sand heads under the jurisdiction of Kolkata Port during fair weather conditions and at Kanika Sands under jurisdiction of Paradip Port during rough weather conditions of monsoon months. Coal is unloaded into barges using transshipper and transported through NW-1 to NTPC, Farakka where a service platform equipped with cranes and conveyor system has been constructed for unloading and delivery to the NTPC stack yard. The Jindal ITF has elaborated that the Company has Standard Operating Procedures (SOPs) with regard to action required to be taken to prevent spillage and pollution during the operation and also in emergencies. The facilities, infrastructure and equipment involved in the process of transportation and handling used are given below.

5.1 Transshipment points

Transshipper is used (holding capacity of 66,000 ton and loading/unloading capacity 12,500 ton/day) to unload coal from Ocean Going Vessels (OGV) and loading onto the barges at Sand heads (Sagar) or Kanika Sands. Mechanical grabs available on the transshipper are used for trans-loading of coal into barges. These grabs are kept in perfect order so that they are locked face to face to avoid any spillage while discharging (Fig. 15). These mechanical grabs are so made that they cannot be lifted unless closed properly. Crane operators and signal men perform the task and ensure no draining of cargo while loading and no leakage from grab takes place outside the cargo holds. Additionally, cargo slings used are made of very strong canvas placed between the ships and the barges. Spillage, if any, is collected in the canvas. Cleaning gang cleans cargo spilled on the deck and puts it back in the cargo hold. Rubber sheets have been provided at the end of conveyor and boom so that even when cargo drops from a height, cargo will not fly into air. Immediately after loading the cargo in the barges, they are fully covered with tarpaulins before the barge sails out.

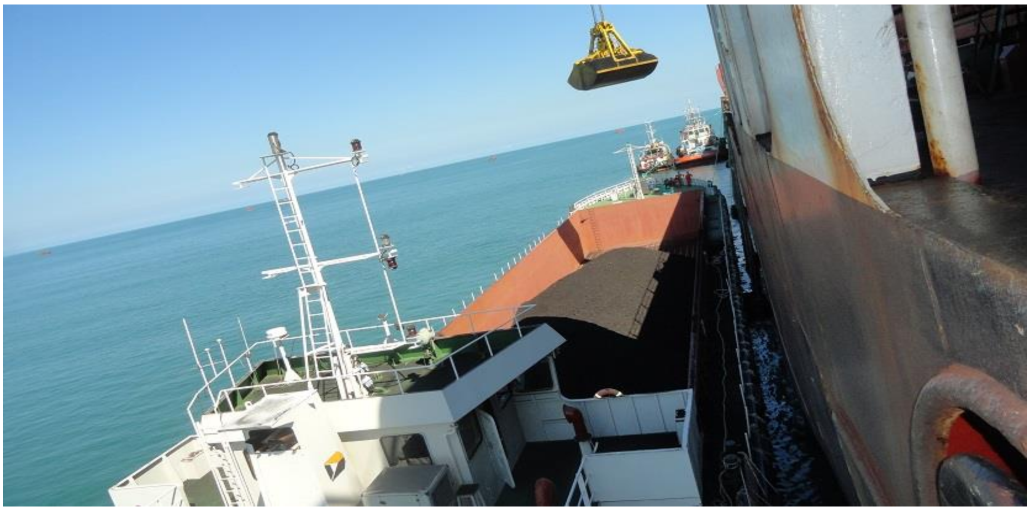


Fig. 15. Unloading of coal from ship to barge at Sand heads

5.2 The barges

The imported coal is trans-loaded into barges with carrying capacity of about 2,100 tons, but the actual quantity being carried depends on draft available. Presently a total of 27 barges are being engaged. The barges have dimension of 72 x 14 x 4.25 m (Fig. 16). They move at a speed of about 5 to 6 knots in loaded condition and about 9 to 11 knots while returning from Farakka in ballast. Thus, the average speed is 7-8 knots per hour and it takes about 5 to 6 days to complete its cycle of transportation. All barges are IRS (Indian Register of Shipping) class. The cargo is covered and secured properly with tarpaulin to ensure no spillage, as mentioned. Regarding the management of the pollutants generated in the barges, the disposable pollutants as listed below are disposed through work order issued to third party for collection of sludge at Coal Handling Plant (CHP) at Farakka.

Fig. 16. Coal laden barge on its way

5.2.1 Used oil management

The waste oil used during servicing of the vessel machinery is stored in the bilge holding tanks. As per orders no pollutants or oils contained within bilges are to be pumped overboard into the river /sea. When the tank is nearing filling, the same is communicated to the control room for its disposal at Farakka.

5.2.2 Sewage management

Sewage Treatment Plant (STP), on the barges, is operational and running continuously. As per instructions, no direct discharge to the river / sea is undertaken. The disposable sewage is stored in sewage tank and discharged to shore support base at Nurpur. When the tank is nearing filling, the same is communicated to Operations Centre for arrangement of its disposal.

5.2.3 Garbage management

The galley /accommodation garbage is kept in disposable bags and stored in garbage bins. When the vessel reaches Nurpur, the garbage is disposed.

5.2.4 Bunkering of barges

Jindal ITF Ltd. has a dedicated High Speed Diesel (HSD) tanker unloading point along with a pump for transferring HSD from tanker to the barges (Fig. 17). Two flexible hose are used at two end points of a steel pipe fitted permanently for transfer. No leakages and spillage are ensured during transfer. Bunkering is done simultaneously at the time of unloading.

Fig. 17. Bunkering arrangements at Farakka

5.3 Coal Handling Plant (CHP) at Farakka

Jindal ITF Ltd, Farakka, as explained, has two service platforms (Fig. 18) at Farakka waterfront for unloading coal from barges and has invested in state of art CHP consisting of two grab un-loaders and dedicated coal conveying system (Fig. 19; 2.2 km with rated capacity of 800 ton per hour). The system is designed for environment friendly zero spillage/ zero dust emission while discharging/ unloading coal from barges.

Fig. 18. Coal unloading point at Farakka

Fig. 19. Coal stack yard at Farakka

5.3.1 Grab un-loaders

Two grabs of Verstaggen make and each having 24 cbm capacity are used for unloading the coal from barges into the conveyor system (Fig. 20). Two barges can be unloaded at a time and it takes about 5 hours to unload using grabs. The coal grabs are calibrated in auto mode prior commencement of operation ensuring its 100% closing in the process of continuous operations. The grabs close water tight during lifting of coal from the barge hold ensuring no spillage of coal into the river channel. The gap between Barge and Shore / Service Platform is covered by Tarpaulin to avoid any minor spillage as precautionary measure.

Fig. 20. Coal being unloaded from barge and loaded on to the conveyer system

5.3.2 Hoppers

Plain water dust suppression system of F Harley Ltd make are installed on both the hoppers (Coal Feeding Point) which consists of 36 sprinklers installed on each hopper (Fig. 21). By sprinkling water through nozzles from all four sides of hopper dust generation is prevented and the same settles into the hopper.

Fig. 21. Sprinkling water to suppress coal dust

5.3.3 Junction houses

Dry Fog Dust Suppression system, F Harley Ltd. make is installed on all junction Houses. Plain water is mixed with compressed air, in the ratio 60:30, to create a dry fog. Droplets of water are atomized with the help of pressurized air and sprayed on the escaping dust to settle them on the conveyor belts.

5.3.4 Coal slurry management system

Concrete Drains are laid alongside the Conveyors to collect the slurry which transfers the slurry to coal settlement tank. After settlement and recirculation of the slurry, the clear water is collected and further pumped ahead to NTPC Sewage Treatment Plant. This ensures no slurry being discharged into the river (Fig. 22).

Fig. 22. Collection system for coal slurry

5.3.5 Pollution aspects of the environment in Coal Handling Plant

As per the guidelines received from the State Pollution Control Board, Jindal ITF Ltd will have to generate data at half yearly interval on ambient air quality and liquid discharge systems. The analysis report is submitted to the Pollution Control Board office for inspection.

5.4 Disaster Management

Emergency situation may arise during transshipment, operation of the barges or in the Coal Handling Plant. These may be dangerous to human life, environment, flora & fauna. To prevent such situation the following steps are to be taken:

- Minimize risk occurrence (Prevention)
- Rapid control (Emergency Response)
- Effectively Rehabilitate Damaged Areas (Restoration)

The major hazards may include Fire, Flood and Oil Spill. The safety measures covered under the Manual IWAI ; SOPs (Environment, health and safety manual of Jindal ITF Ltd.; Technical SOP of Jindal ITF Limited) are to be strictly followed.

The following conditions may arise in river operations

- Grounding of vessel
- Collision of vessel with cargo vessel
- Collision of vessel with country boat carrying cargo
- Collision of vessel with ferry boat carrying passengers
- Collision of vessel with small country crafts
- Collision of vessel against river/canal bank
- Collision of vessel with shore structures like bridges, HT line,
- Fire Hazard
- Spillage of oil in the river

Mitigation Measures

Facilities available and activities of IWAI: IWAI Nodal officers are available for day to day operation for the stretches: Sagar-Kolkata; Kolkata-Triveni; Triveni-Berhampore and Berhampore-Farakka. On receiving intimation of any distress the nodal officer of concerned area would alert the Distress Management Unit of IWAI, nearest Police Station, local administration, and would visit the site and coordinate deployment of multi-purpose tugs equipped with fire fighting facilities, first aid kit and life saving equipment immediately. The nodal officer of IWAI will alert the police.

A coordinating cum monitoring office at IWAI Regional Office, Kolkata, is being maintained for round the clock monitoring of the Inland Waterways.

Rescue Stations have been sited at Kolkata, Berhampore/Swaroopganj and Farakka which are equipped with high speed launches/boat fitted with additional life saving gears, fire fighting and first aid facilities.

Multipurpose tug (MPT) has been positioned at rescue stations for rescue/salvage operation including control/removal/arresting oil spillage.

Kolkata Port Trust /State Government agencies are sensitized for assistance in salvage/rescue operation.

Sensitization of users of the waterway including fishermen, passenger ferry operation, and country craft and general public of the area are also done.

Facilities available and activities of Jindal ITF Ltd.:

Quick reporting system through hand-held VHF Radio sets or walkie talkies are available in all barges.

Control Room is being manned 24x7 & for barge movement tracking and monitoring at Kolkata and at Farakka.

Emergency contact details to include district administration officials, police, hospitals, fire stations are available in all barges and Control Room.

Designated Person Ashore (DPA) has been nominated to monitor and act in case of emergency.

Barge crew has been trained to handle emergency situations such as fire, grounding, and collision with ferry boat.

In case of an accident the same to be informed by barge Master to nodal officer of the concerned stretch and Control Room either on mobile or through internet.

Incident Reporting/Near Miss Reporting & root cause analysis for the same is being carried out and circulated for awareness of the entire fleet.

Vessel movement is being done on designated Electronic Navigational Charts (ENC) track developed by IWAI containing information on general, topography, hydrography and navigational aids for safe navigation.

River notices issued by IWAI fortnightly are being incorporated to ensure updation of track.

Dredging is being done by IWAI for maintaining 'Least Available Depth' (LAD) of 2.5 meters.

All vessels are being equipped with standard firefighting equipment.

SOP of the barge: In case of disaster incident while moving through water ways the SOPs complied with are:

Technical SOP of Jindal ITF Ltd: Laid down safety procedures for compliance keeping in mind the safety of men and equipment. It also defines the various procedures to ensure environmental protection and maintaining highest standards of discipline in connection to pollution management. It also quantifies the various emergency procedures and drills to void such situation.

SOP of IWAI: An SOP has been formulated by IWAI to ensure safe navigation through channel and for assistance during disaster management.

SOP of Coal Handling Plant at Farakka: In case of disaster at plant site, it deals with Employee Health & Safety (EHS) SOP.

5.5 Supervisory Control and Data Acquisition (SCADA)

To monitor and control the Coal Handling Plant at Farakka, SCADA has been installed. The system is used to mission critical industrial processes with reliability. It gathers and analyzes real time data.

SCADA system provides graphical representation of entire system, automatic control, and continuous information. It also makes modifications to the system, auto-generate reports, create alarms and trouble-shoot.

The graphical presentation of coal handling plant at Farakka is presented in Fig. 23 and the data recorded at the Control Room is presented in Fig. 24.

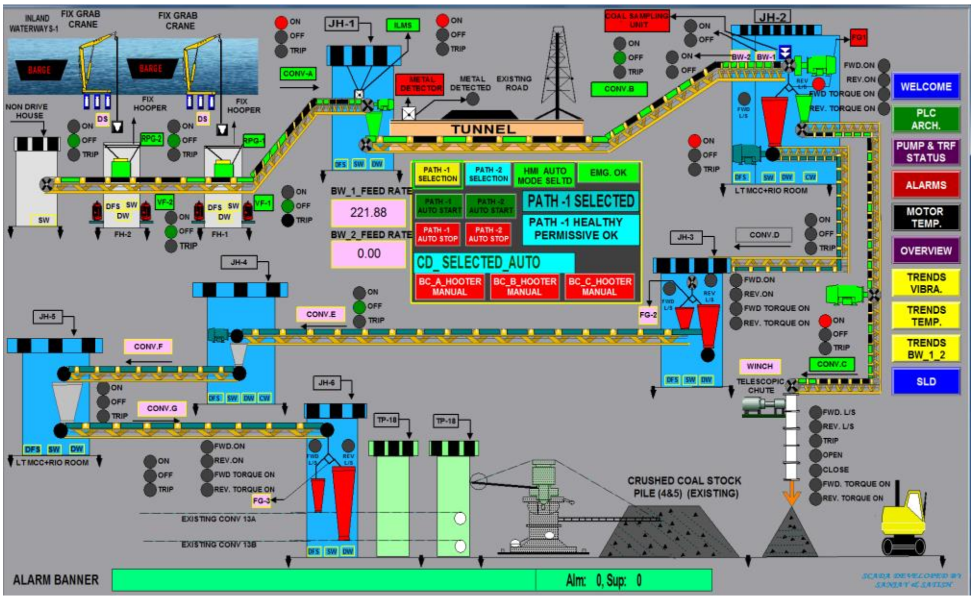


Fig. 23. Overall graphical representation of coal handling plant at Farakka

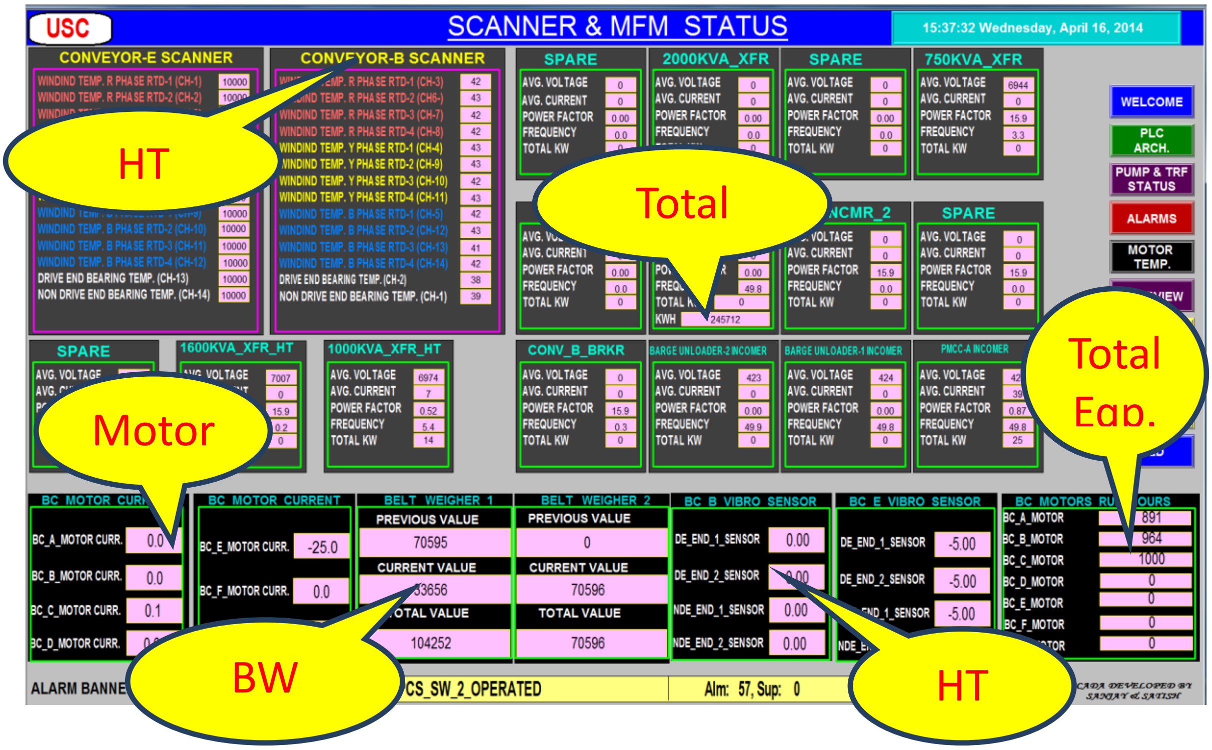


Fig. 24. Continuous equipment or process parameter information at control room

6.0 Establishment of field laboratory at Farakka

ICAR-CIFRI has established a laboratory within the NTPC plant area (Fig. 25). The facility helps in field studies and provided a base to ICAR-CIFRI in the Farakka region.

Fig. 25. ICAR-CIFRI laboratory at Farakka

Findings of ICAR-CIFRI

7.0 Component I: Impact of varying traffic loads on aquatic flora and fauna

7.1 Fish community

7.1.1 Status of fish diversity

A total of 207 fish species belonging to 17 orders and 61 families (Table 3) were recorded from the stretch (pre-monsoon and monsoon surveys). More than 3/4th (77 %) of the fish diversity is distributed among four main orders (Fig. 26), *viz*., Perciformes (75 species), Siluriformes (32 species), Cypriniformes (30 species) and Clupeiformes (23 species). As major part of the study area (about 89.6 %; 502 km) comprise of freshwater habitats, Cyprinidae was the dominant family in terms of species richness (25 species). The other major families include, Gobiidae (15 species), Sciaenidae (13 species) and Engraulidae (12 species).

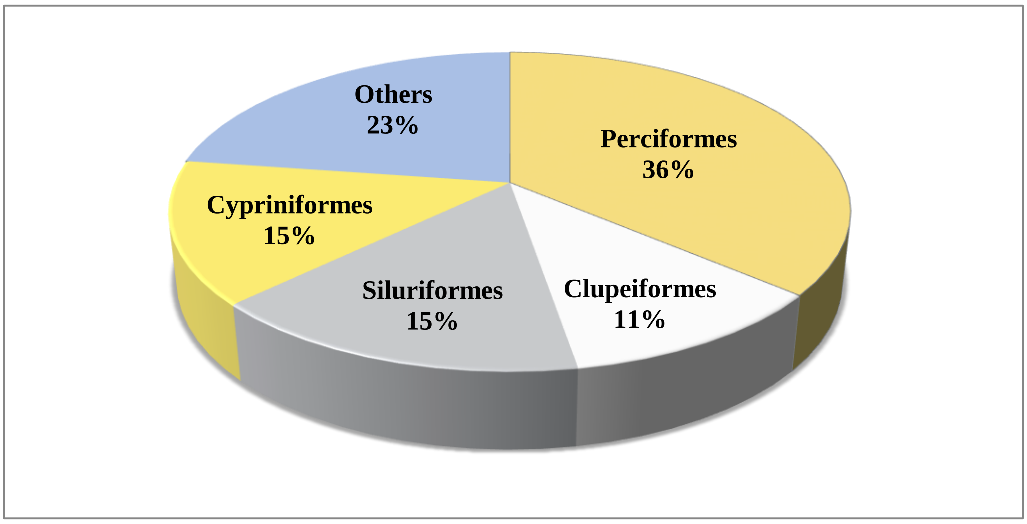


Fig. 26. Dominant orders based on their contribution to fish diversity

As zone – I (Fig. 1) represented the true estuarine zone, the species diversity was maximum (157 species) in this zone due to predominance of marine migrants (76 species) and estuarine/brackish water species (42 species). Zone – III represents the non-tidal riverine freshwater stretch of Bhagirathi (Nabadwip to Farakka) where the river water is regulated by discharge from Farakka barrage. The perches (Order: Perciformes) were poorly represented in this stretch with only 9 species. Cyprinidae formed the major component of fish communities with 24 species. A total of 75 fish species were recorded from this zone during the study period.

Table 3. List of fish species recorded from the studied stretch (Sagar – Farakka)

Family	Fish species	Zone I	Zone II	Zone III
Dasyatidae	*Dasyatis zugei*	+		
	Himantura walga	+		
	Himantura imbricata	+		
	Pastinachus sephen	+	+	+
Notopteridae	*Chitala chitala*		+	+
	Notopterus notopterus		+	+
Anguillidae	*Anguilla bengalensis*		+	
Moringuidae	*Moringua raitaborua*	+	+	
Muraenidae	*Gymnothorax tile*	+		
Muraenesocidae	*Muraenesox bagio*	+		
Ophichthidae	*Pisodonophis boro*	+	+	
Pristigasteridae	*Ilisha megaloptera*	+		
	Ilisha elongata	+		
	Pellona ditchela	+		
	Raconda russeliana	+		
Engraulidae	*Setipinna phasa*	+	+	+
	Setipinna brevifilis			+
	Setipinna taty	+		
	Setipinna tenuifilis	+		
	Thryssa purava	+		
	Thryssa dussumieri	+		
	Coilia dussumieri	+		
	Coilia reynaldi	+		
	Coilia neglecta	+		
	Coilia ramcarti	+		
	Stolephorus commersonii	+		
	Stolephorus baganensis	+		
Clupeidae	*Gudusia chapra*	+	+	+
	Gonialosa manmina		+	+
	Corica soborna	+	+	+
	Tenualosa ilisha	+	+	+
	Escualosa thoracata	+		
	Sardinella gibbosa	+		
	Anodontostoma chacunda	+		
Cyprinidae	*Aspidoparia morar*		+	+
	Aspidoparia jaya		+	+
	Amblypharyngodon mola	+	+	+

['+' indicates presence of a species. Classification scheme followed is Nelson (2006)]

Table 3. *Continued.*

Family	Fish species	Zone I	Zone II	Zone III
Cyprinidae	*Catla catla*		+	+
	Chela cachius		+	+
	Cirrhinus mrigala		+	+
	Cirrhinus reba		+	+
	Crossocheilus latius		+	+
	Devario devario			+
	Esomus danricus		+	
	Labeo bata		+	+
	Labeo calbasu	+	+	+
	Labeo rohita		+	+
	Labeo gonius		+	+
	Laubuca laubuca			+
	Osteobrama cotio		+	+
	Pethia phutunio		+	
	Pethia ticto		+	
	Pethia conchonius	+	+	+
	Puntius terio			+
	Puntius sophore	+	+	+
	Systomus sarana		+	+
	Securicula gora		+	+
	Salmophasia bacaila	+	+	+
	Salmophasia phulo	+	+	+
Psilorhynchidae	*Psilorhynchus sucatio*		+	+
Cobitidae	*Lepidocephalichtys guntea*		+	+
	Acanthocobitis botia		+	+
Balitoridae	*Botia dario*		+	
	Botia lohachata		+	
Bagridae	*Sperata aor*	+	+	+
	Sperata seenghala	+	+	+
	Mystus tengara	+	+	+
	Mystus bleekeri			+
	Mystus vittatus		+	+
	Mystus cavasius	+	+	+
	Mystus gulio	+		
	Rita rita		+	+
Siluridae	*Ompok bimaculatus*		+	+
	Ompok pabda	+	+	+
	Wallago attu		+	+
Pangasiidae	*Pangasius pangasius*	+	+	+
Erethistidae	*Erethistes pussilus*		+	
Clariidae	*Clarias magur*		+	
Heteropneustidae	*Heteropneustes fossilis*	+	+	+

['+' indicates presence of a species. Classification scheme followed is Nelson (2006)]

Table 3. *Continued.*

Family	Fish species	Zone I	Zone II	Zone III
Schilbeidae	*Clupisoma garua*	+	+	+
	Eutropiichthys vacha	+	+	+
	Eutropiichthys murius		+	+
	Ailia coila		+	+
	Silonia silondia	+	+	+
	Neotropius atherinoides		+	+
Sisoridae	*Bagarius*		+	+
	Bagarius bagarius		+	+
	Gagata gagata	+	+	+
	Gagata cenia	+	+	+
	Gagata sexualis			+
Ariidae	*Arius gagora*	+		
	Osteogeneiosus militaris	+		
	Arius arius	+		
	Cephalocassis jatia	+	+	
	Netuma thalassina	+		
	Nemapteryx caelata	+		
Synodontidae	*Harpadon nehereus*	+		
Bregmacerotidae	*Bregmaceros mcclellandi*	+		
Mugilidae	*Rhinomugil corsula*	+	+	+
	Sicamugil cascasia	+	+	+
	Chelon planiceps	+		
	Moolgarda cunnesius	+	+	
	Valamugil speigleri	+		
	Chelon parsia	+		
Adrianichthyidae	*Oryzias dancena*	+		
Hemiramphidae	*Hyporhamphus limbatus*	+		
	Rhynchorhamphus georgii	+		
	Zenarchopterus striga	+		
Belonidae	*Xenentodon cancila*		+	
	Strongylura strongylura	+		
Aplocheilidae	*Aplocheilus panchax*	+	+	+
Sygnathidae	*Microphis cuncalus*	+	+	
Synbranchidae	*Monopterus cuchia*		+	
Mastacembelidae	*Mastacembelus armatus*	+	+	+
	Macrognathus pancalus		+	+
	Macrognathus aral	+	+	+
Platycephalidae	*Platycephalus indicus*	+	+	
	Grammoplites scaber	+		
Ambassidae	*Pseudambassis ranga*	+	+	+
	Chanda nama	+	+	+
	Parambassis lala	+	+	+
	Ambassis nalua	+		

['+' indicates presence of a species. Classification scheme followed is Nelson (2006)]

Table 3. *Continued*

Family	Fish species	Zone I	Zone II	Zone III
Sillaginidae	*Sillaginopsis panijus*	+	+	
	Sillago sihama	+		
Carangidae	*Alepes kleineii*	+		
	Atule mate	+		
	Alectis indicus	+		
	Scomberoides commersonnianus	+		
	Scomberoides lysan	+		
	Gnathanodon speciosus	+		
	Megalaspis cordyla	+		
	Atropus atropos	+		
Leiognathidae	*Secutor ruconis*	+		
	Secutor insidiator	+		
	Nuchequula blochii	+		
Lutjanidae	*Lutjanus johnii*	+		
Gerreidae	*Gerres filamentosus*	+		
Haemulidae	*Pomadasys argenteus*	+		
	Pomadasys maculatus	+		
Polynemidae	*Eleutheronema tetradactylum*	+		
	Polynemus paradiseus	+	+	
Sciaenidae	*Johnius gangeticus*	+	+	
	Johnius coitor	+	+	
	Otolithoides pama	+	+	
	Otolithoides biauritus	+		
	Johnius sina	+		
	Johnius carutta	+		
	Johnius borneensis	+		
	Macrospinosa cuja	+		
	Chrysochir aureus	+		
	Pterotolithus maculatus	+		
	Panna microdon	+		
	Protonibea diacanthus	+		
	Johnius belangerii	+		
Mullidae	*Upeneus sulphureus*	+		
Toxotidae	*Toxotes chatareus*	+		
Callionymidae	*Callionymus fluviatilis*	+		
Nandidae	*Nandus nandus*		+	+
	Badis badis	+	+	
Terapontidae	*Terapon jarbua*	+		
	Terapon theraps	+		
Gobiidae	*Glossogobius giuris*	+	+	+
	Odontamblyopus rubicundus	+	+	
	Apocryptes bato	+	+	
	Scartelaos histophorus	+		
	Trypauchen vagina	+		

['+' indicates presence of a species. Classification scheme followed is Nelson (2006)]

Table 3. *Continued.*

Family	Fish species	Zone I	Zone II	Zone III
Gobiidae	*Acentrogobius viridipunctatus*	+		
	Pseudapocryptes elongatus	+		
	Boleophthalmus boddarti	+		
	Oxuderces dentatus	+		
	Taenioides buchanani	+		
	Taenioides anguillaris	+		
	Taenioides cirratus	+		
	Parachaeturichthys polynema	+		
	Oligolepis acutipennis	+		
	Brachygobius nunus	+	+	
Eleotridae	*Eleotris fusca*		+	
	Butis butis	+		
	Butis melanostigma	+		
	Odonteleotris macrodon	+		
Scatophagidae	*Scatophagus argus*	+		
Trichiuridae	*Lepturacanthus savala*	+		
	Trichiurus lepturus	+		
Scombridae	*Scomberomorus guttatus*	+		
Stromateidae	*Pampus argenteus*	+		
	Pampus chinensis	+		
Anabantidae	*Anabas testudineus*		+	
Osphronemidae	*Trichogaster fasciata*	+	+	
	Trichogaster lalius		+	
Channidae	*Channa striata*	+	+	+
	Channa marulius		+	+
	Channa orientalis	+		
	Channa punctata	+	+	+
Soleidae	*Brachirus pan*	+	+	
	Brachirus orientalis	+	+	
	Synaptura commersoniana	+		
Cynoglossidae	*Cynoglossus cynoglossus*	+	+	
	Cynoglossus lingua	+	+	
	Cynoglossus macrostomus	+		
	Cynoglossus arel	+		
	Paraplagusia bilineata	+		
	Cynoglossus puncticeps	+		
Tetraodontidae	*Tetraodon cutcutia*	+	+	+
	Chelonodon fluviatilis	+		
	Chelonodon patoca	+		
	Lagocephalus lunaris	+		

['+' indicates presence of a species. Classification scheme followed is Nelson (2006)]

The cumulative dominance (c-dominance) plot of fish community composition (Fig. 27) based on cumulative relative abundances (derived from PRIMER v6 package) across three zones (I, II and III), revealed a more accurate picture of the status of fish community in these areas. The curve for Zone – I is elevated (J – shaped) which clearly reflects the stressed condition of the habitat in the area. In zone – I, the habitat is stressed due to anthropogenic activities resulting in higher dominance of abundant species. But, the curve for zone – II and III is sigmoid (S – shaped) which is typical to that of a relatively undisturbed site.

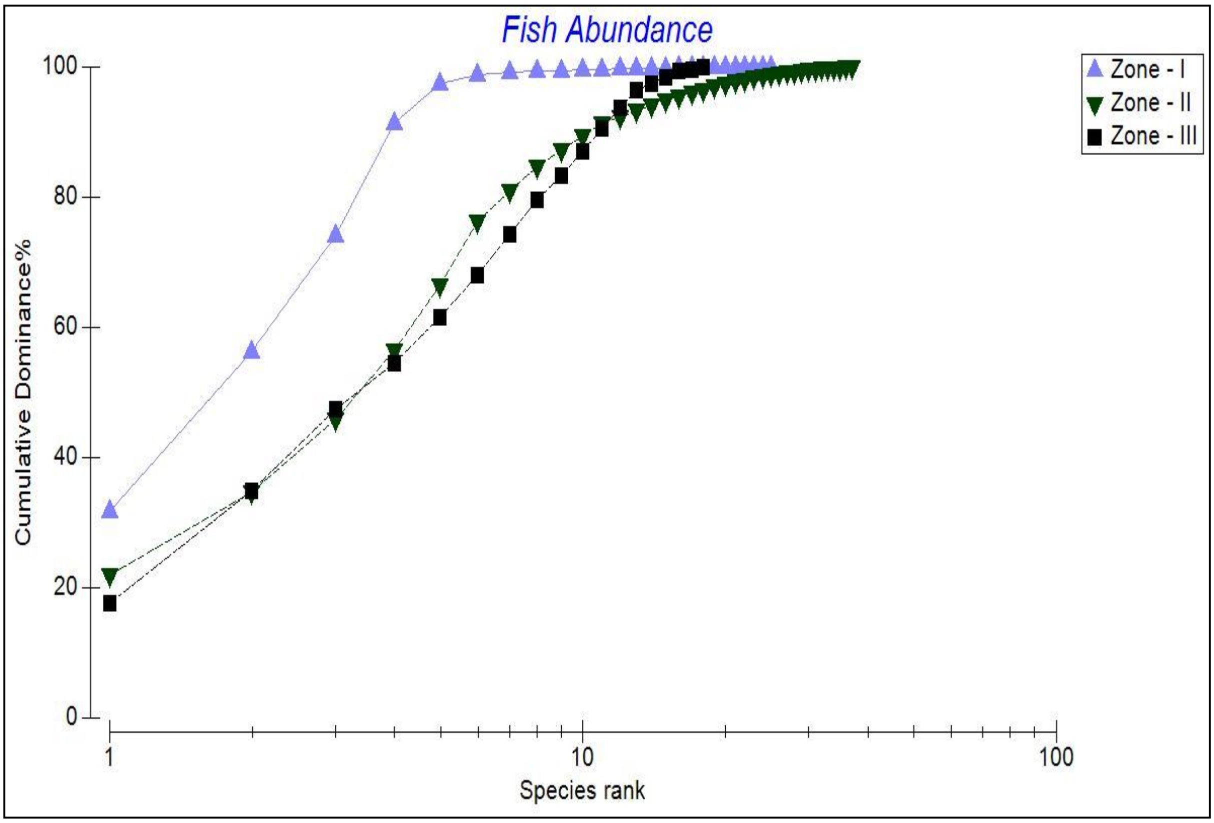


Fig 27. Cumulative dominance plot for various sampling zones

7.1.2 Conservation status of fish species recorded from the studied stretch

The river Ganga supports one of the largest and most diverse fish populations in the world; comprising around 20% of all of the freshwater species found in India (Sarkar *et al.*, 2012). However, the fish resources of Ganga are heavily threatened by multitude of natural as well as anthropogenic factors (habitat degradation, water abstraction, pollution, sand mining, climate change related factors, etc.), owing to which many of the fish species in Ganga are now being categorized among threatened fishes of India (Table 4).

Table 4. List of threatened fish species reported from various zones in studied stretch

FISH SPECIES	Conservation Status CAMP (1998)	Zone		
		I	II	III
Pangasius pangasius	CR	+	+	+
Anguilla bengalensis	EN		+	
Botia lohachata	EN		+	
Chitala chitala	EN		+	+
Eutropiichthys vacha	EN	+	+	+
Johnius gangeticus	EN	+	+	
Neotropius atherinoides	EN		+	+
Ompok bimaculatus	EN		+	+
Ompok pabda	EN	+	+	+
Psilorhynchus sucatio	EN		+	+
Ailia coila	VU		+	+
Anabas testudineus	VU		+	
Aspidoparia jaya	VU		+	+
Catla catla	VU		+	+
Channa orientalis	VU	+		
Cirrhinus reba	VU		+	+
Clarias batrachus (now C. magur)	VU		+	
Clupisoma garua	VU	+	+	+
Gonialosa manmina	VU		+	+
Heteropneustes fossilis	VU	+	+	+
Mystus bleekeri	VU			+
Mystus vittatus	VU		+	+
Pethia conchonius	VU	+	+	+
Rhinomugil corsula	VU	+	+	+
Sicamugil cascasia	VU	+	+	+
Systomus sarana	VU		+	+
Tenualosa ilisha	VU	+	+	+

CR = critically threatened; EN = endangered and VU = vulnerable;

\+ indicates availability / presence

It is evident from the table that zone – I harbours the lowest number of fish species with conservation significance (11 species) which can be attributed to the heavily stressed habitat condition owing to their proximity to Kolkata metropolitan area, industrial establishments and highly intensive fishing activities. The highest diversity of threatened freshwater fish species in zone – II (25 species) signifies the ecological value of this zone as refuges for threatened fish species owing to the availability of sheltered areas along the river stretch. Zone – III recorded second highest diversity with 21 species indicating that both zones II and III areas are relatively less threatened by inland navigation and other anthropogenic disturbances.

7.1.3 Impacts of varying traffic loads on fish assemblage

7.1.3.1 Species composition of fish communities, species richness and diversity

Literatures are available which describe the adverse impacts of inland navigation (barge/boat movement, dredging, recreational boat traffic, etc.) on aquatic communities inhabiting rivers and estuaries of countries in Europe and South America (Lightfoot and Jones, 1996; Desperez, 2000; Wolter and Arlinghaus, 2003; Perez – Rufaza *et al*., 2006; Whitfield and Becker, 2014). Some of these studies (Wolter and Arlinghaus, 2003) were carried out under simulated conditions in laboratories or in those protected channels that are not used for inland water transport. The study becomes more challenging when it is conducted in such a dynamic environment as estuaries where ichthyofaunal assemblage is influenced by seasonal variability (Demarques Ribeiro *et al*., 2012).

Experimental seine netting operations carried out at Kuntighat (193 channel km) during monsoon revealed that the fish assemblage structure varies at different points within the riverine stretch. The fish assemblage of the dredged/deeper channel (used by barges for navigation) was dominated by gobiids such as *Odontamblyopus rubicundus* (22.47 %) and *Apocryptes bato* (17.98 %). The fish diversity was lowest in the dredged channel (21 species). The diversity was higher (31 species) in the shallow littoral area between the dredged/deeper channel and bank. The fish assemblage along this area was dominated by *Ailia coila* (28.89 %), *Salmophasia bacaila* (26.63 %) and *Rhinomugil corsula* (17.92 %). The site is characterized by river islands (formed by siltation and locally known as 'char lands') which serve as ideal refuge areas as well as nursery grounds for several species of fishes that has been categorized as threatened (Endangered – EN and Vulnerable – VU) as per IUCN criteria (CAMP, 1998). The sheltered areas recorded the highest fish diversity with 45 species, with the assemblage being dominated by *Rhinomugil corsula* (23.84 %), *S. bacaila* (16.47 %) and *Aspidoparia morar* (11.61 %). It is evident that the fish abundance is lowest in the dredged/deeper channel (178 individuals/haul), moderately high in shallow littoral area (597 nos. /haul) and highest in sheltered areas of river islands (1275 nos. /haul).

Though the dredged/deeper channel supported less diverse fish assemblages, juveniles of two species of fishes, *viz*., *Silonia silondia* (4.5 - 4.9 cm) and *Bagarius bagarius* (both listed as Vulnerable) have been recorded only from dredged/deeper channel which indicates the preference of these fishes to deeper channels.

It has already been proved that high intensity barge movement across regulated river channel results in shift in fish species composition, resulting in low diversity and dominance of certain fish species (Lightfoot and Jones, 1996). But it may take years for this shift in fish species composition to get manifested in the fish catch. The comparison of seine net catch composition (monsoon period) at Kuntighat area during two different time periods, *viz*., 2011 – 12 (no movement of coal barges) and 2016 (after commencement of coal transportation) also established this fact. Though there were minor changes in relative abundance (% of total numbers caught) and abundance (1400 nos. /haul in

2011-12 and 1280 nos. /haul – 2016), the general catch structure (Fig. 28) remained the same with dominance of species such as *R. corsula*, *S. bacaila*, *S. phulo*, *A. morar* and *Sicamugil cascasia*.

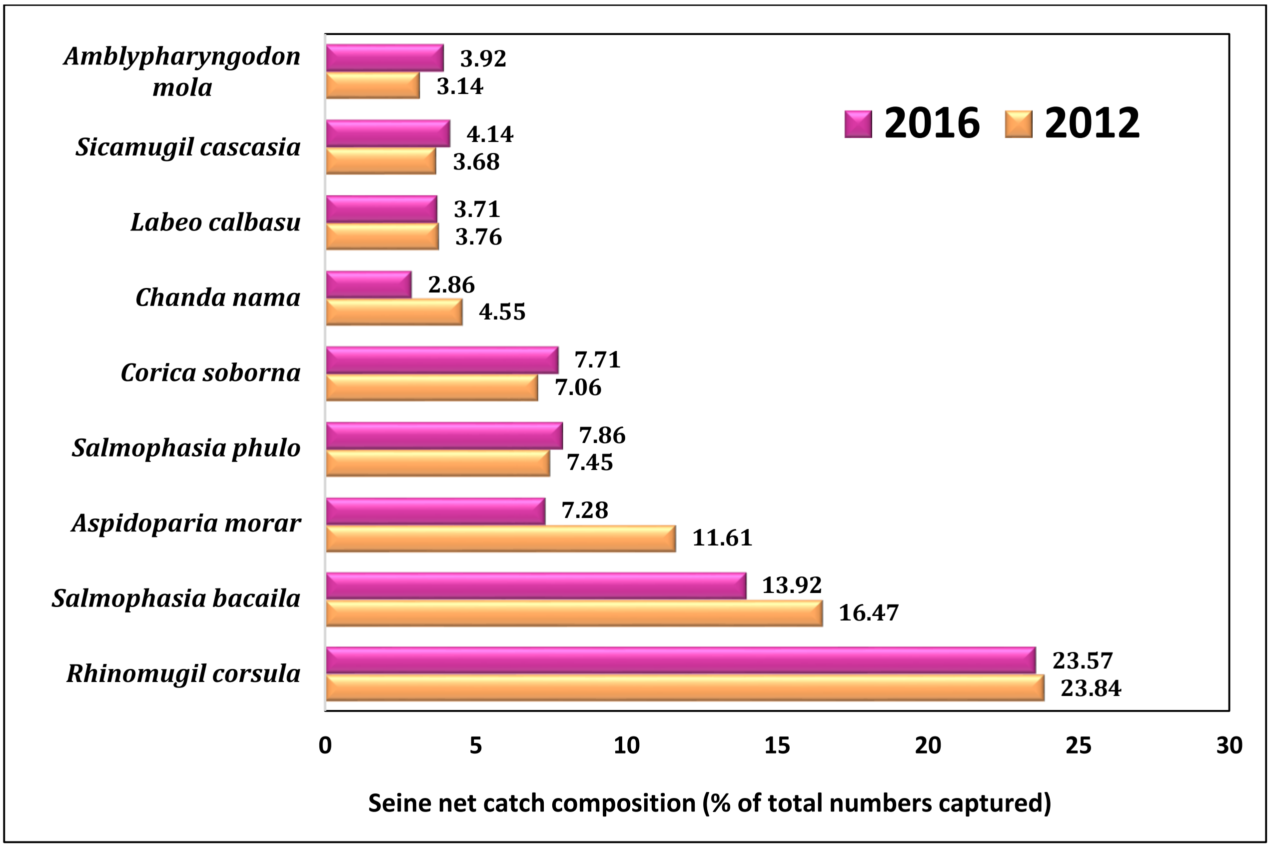


Fig. 28. Seine net catch composition during 2011 (pre-coal movement period) and 2016 (after commencement of coal movement) at Kuntighat, Tribeni

Even though, the relative abundance of some fish species (*Amblypharyngodon mola*, *Sicamugil cascasia*, *Corica soborna* and *Salmophasia phulo*) have been increased in the catch of seine net, it is difficult to make conclusions regarding the change in fish assemblage structure due to barge movement in this short term study. Impacts of barge movement on fish community composition can only be assessed by studying it over a long period of time as the shift in species composition is a slow and gradual process which requires continuous monitoring of fish populations.

7.1.3.2 Variation in fish catch per unit effort (CPUE) with barge traffic

Majority of the studies carried out abroad highlights the fact that it is practically difficult to identify the effects of inland navigation on fishes (especially teleosts) due to their ability to avoid disturbance by migrating to adjacent areas. Studies were carried out at Bhagirathi channel north of Nabadwip by experimental seine netting (along dredged channel) before barge movement and immediately after the passing of barge for monitoring fish community dynamics in a regulated channel during barge movement. The observed CPUE (number of individuals/ haul) before barge movement (95 individuals/haul) got reduced to more than half (38 nos. /haul) immediately after the passing of barge. The overall fish diversity observed in the catches was also different in both occasions, *i.e.*, higher before barge movement (15 species) which got reduced after the passing of barge (10 species). This rapid change in fish community can be attributed to the natural fish behaviour to avoid any disturbance (barge movement and the navigation induced currents in this case) in the water body.

This change in assemblage is not permanent as the fishes will re-occupy the same habitat after certain period of time once the impact of physical disturbance gets nullified.

7.1.3.3 Impact on migratory fish species

Many fishes have evolved a life history that includes coordinated movement from one habitat to another. This synchronous, directed movement of part or all of a population between discrete habitats is called ‘migration’. Approximately 2.5% of all fish species undertake migrations. Fish migrations are grouped into different categories such as anadromous, catadromous, oceanodromous, and potamodromous etc., based on their relationship to the seawater /freshwater boundary.

Anadromous fishes

Anadromy occurs when most feeding and growth occurs in saltwater and fully grown adults move back into freshwater to spawn. Among the fishes distributed in the studied stretch, the most important and well studied migratory species is *Tenualosa ilisha*, commonly called as *hilsa* shad. Belonging to family Clupeidae, the species inhabits rivers, estuaries and coastal waters. Hilsa spends its adult life in the marine environment and migrates to riverine habitats for breeding. The young ones migrate back to marine environment for growth. Due to its nutritional value and taste, the fish is considered a delicacy and provides direct or indirect livelihood to millions of fishers along the coastal and riverine stretches in its range of distribution. It is most abundant in the Ganga-Brahmaputra-Meghna river systems of India, Bangladesh and Myanmar, forming one of the most important commercial fisheries in these countries.

The species was earlier found to migrate up to Agra, Kanpur and Delhi in the years of excessive abundance, and up to Allahabad in normal years in the Ganga river system in the past (pre-Farakka barrage period). But after the commissioning of Farakka Barrage, the major population of the species was confined downstream of Farakka barrage. Hence the studied river stretch is the major area where the hilsa population migrate for breeding and the juveniles are grown till they return to the marine environment for reproductive growth. Recently, the Government of West Bengal, based on the recommendations provided by CIFRI, has issued gazette notification on 9th April 2013, attempting to conserve hilsa to facilitate their migration, breeding and growth; in which three hilsa sanctuaries are mentioned in the Bhagirathi-Hooghly river stretch, *viz*., from Nischintapur to Diamond Harbour (in between sampling sites Ghoramara Island and Roychak, channel chainage 40 to 70 km), Hooghly Ghat to Kalna (in between sampling sites Tribeni and Nabadwip, chainage 184 to 246 km) and Lalbagh to Farakka (in between sampling sites Hotnagar and Farakka, chainage 442 to 540 km). These three suggested sanctuaries fall in the barge route under study. Hilsa have significant ecological, economic and cultural importance, and are currently the focus of conservation efforts to preserve the sustainability of the fisheries.

There are many others among the recorded species which shows anadromous migration, though not in a huge scale of distance as in case of *T. ilisha*. *Stolephorus* spp, the whitebaits are said to undergo anadromous migration from coastal waters to estuarine areas of rivers. Apart from fishes, there are many species of prawns distributed in the river Ganga which are migratory. *Macrobrachium* *rosenbergii,* the giant freshwater prawn, requires estuarine conditions for hatching and larval metamorphosis prior to upstream migration to freshwaters.

Catadromous fishes

Catadromous fishes are ones that migrate from fresh water into the sea to spawn; or, ones that stay entirely in fresh water and migrate downstream to spawn. The species *Anguilla bengalensis,* commonly called as Indian mottled eel, is a semelparous, catadromous species. It is migratory, breeding in the ocean (Seegers *et al*. 2003) and migrating into freshwaters and estuaries, including large rivers, as juveniles (glass eels/elvers). Elvers can migrate high up rivers into streams where they inhabit pools until they mature although like many anguillids some individuals will remain in coastal waters. Like other migratory species, its numbers and range have been reduced by dam building and other obstructions in their habitat. The species has been assessed as Near Threatened by IUCN; although there are no data available to determine actual rate of decline, it is suspected that a reduction of close to 30% is likely to have occurred over the last 3 decades, based on reports of declines across its range.

Amphidromous and potamodromous fishes

There are many amphidromous species among the ichthyofauna, which move from coastal to freshwater habitat and vice versa for feeding and other (not breeding) purposes. Amphidromous fishes are- that spawn in freshwater migrate downstream to the sea and then go upstream at a juvenile stage for further growth and reproduction. There are a large number of amphidromous species in the recorded ichthyofauna of the river stretch, the majority being recorded from the Zone-I and Zone-II (lower stretches) as the influence of the coastal waters is more dominant in these zones. The species such as *Eleutheronema tetradactylum, Polynemus paradiseus, Scatophagus argus, Liza* spp etc. are significant among the amphidromous species distributed in the lower Ganga.

When fishes migrate from one freshwater habitat to another in search of food or for spawning, it is called potamodromous migration. There are about 8,000 known species that migrate within lakes and rivers, generally for food on daily basis as the availability of food differs from place to place and from season to season. Many species of fishes are potamodromous, which migrate within the river system. Potamodromous fish species are abundant in the River Ganga as the river has good flow and water availability throughout the year, the significant ones among the recorded ichthyofaunal of the river being *Bagarius* spp, *Gagata* spp, *Eutropiichthys* spp, *Notopterus notopterus, Labeo* spp, *Catla catla* etc.

Conserving the ecological potential of fish communities in waterways or its sustainable management requires minimizing of navigation impacts through various methods such as by enhancing shoreline structures, ecotone diversity and enlargement or by revitalizing submerged and emerged macrophytes (Wolter and Arlinghaus, 2003).

The studies of ICAR-CIFRI demarcated three breeding grounds of hilsa in the Bhagirathi-Hooghly river stretch (Fig. 29; Bhaumik and Sharma, 2012). The Fisheries Department, Government of West Bengal has given importance to protect these areas as Hilsa Sanctuaries by way of its administrative protection and release of Gazette notification (Notification No 719, The Kolkata Gazette Extraordinary, 2013; Annexure III, however, it has not been covered under Wildlife Protection Act, 1972). In order to facilitate hilsa brooders spawning in these areas, all types of catching are banned in the hilsa sanctuaries during June to August and October to December every year. Fishing hilsa is prohibited within 5 square kilometre of Farakka Barrage round the year. To conserve hilsa juveniles, use of bag net, scoop net, lift net and small meshed gill nets (<1 inch, equivalent to catching hilsa less than 23 cm) is totally prohibited during February to April every year.

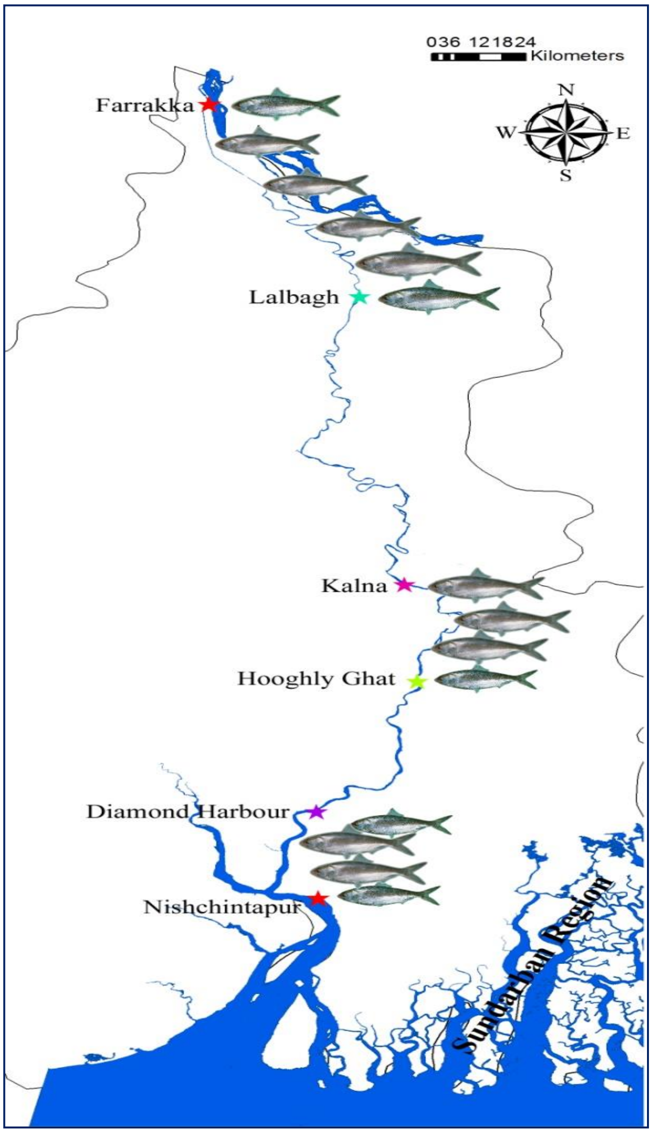


Fig 29. Designated sanctuary sites for *Tenualosa ilisha*

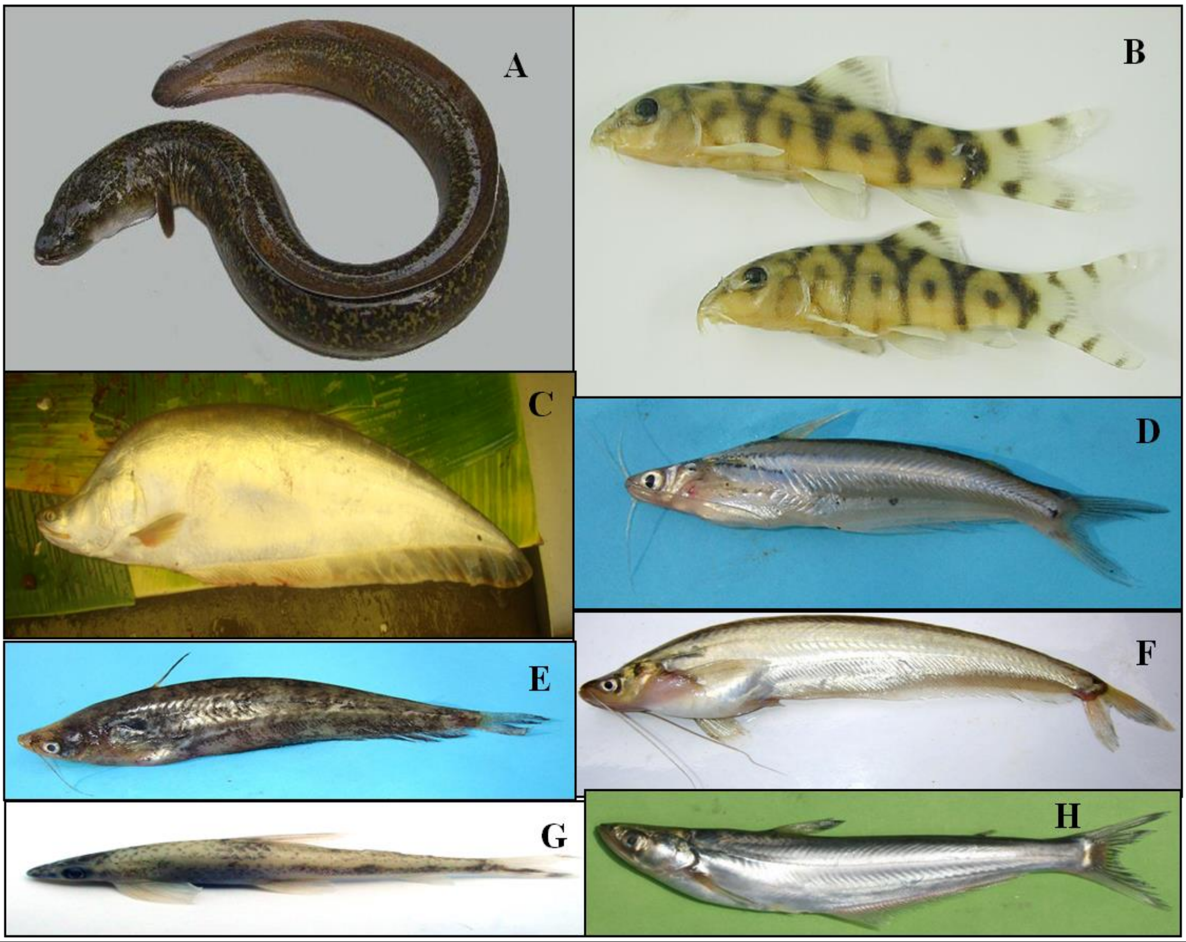


Fig. 30. Threatened fish species from study area as per IUCN criteria (CAMP, 1998)
A) *Anguilla bengalensis* B) *Botia lohachata* C) *Chitala chitala* D) *Neotropius atherinoides* E) *Ompok pabda* F) *Ompok bimaculatus* G) *Psilorhynchus sucatio* H) *Eutropiichthys vacha*

7.1.4 Fish breeding ground surveys

Many workers suggested a bimodal annual spawning cycle of hilsa in River Hooghly, one during monsoon (July to September) and another in the end of winter, i.e. January to March (Motwani *et al.*, 1957; Pillay, 1958; Bhaumik, 2012). The present observation corroborates the same.

A huge mass of gobid fish larvae was observed in Balagarh stretch indicating the stretch as preferred breeding ground for these fishes. The most common and abundant gobid species distributed in this stretch are *Glossogobius giuris* and *Apocryptes bato.*

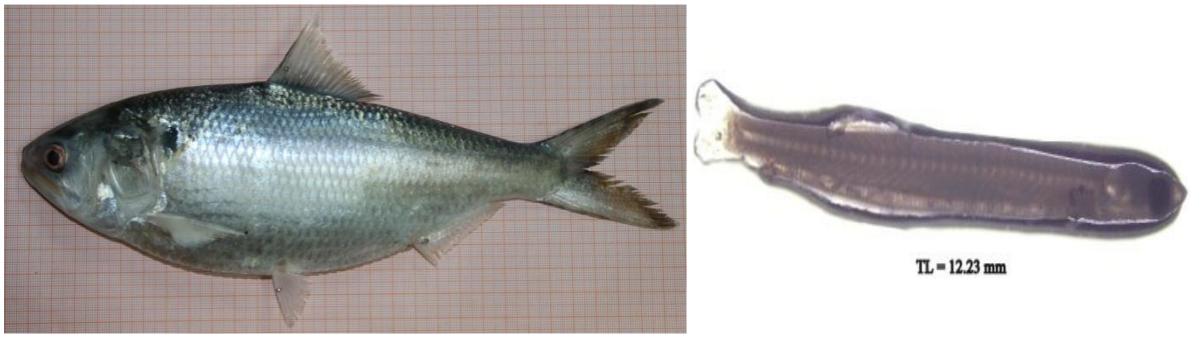


Fig. 31. Hilsa (*Tenualosa ilisha*) adult and post larva

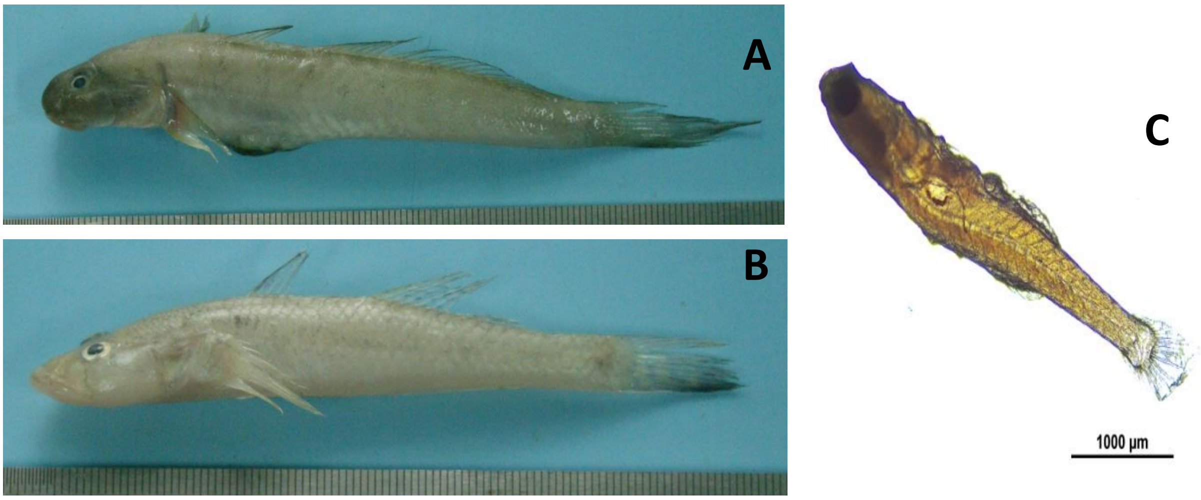


Fig. 32. *Apocryptes bato* (A) *Glossogobius giuris* (B) and Gobid larvae (C) collected from Balagarh

7.1.5 Impact on fish larvae

Field studies carried out at Balagarh (Zone – II) to study the impact of barge movement on fish spawn/larvae showed that the relative abundance (% of total numbers) and composition of larvae in samples taken before and after barge passage did not differ significantly. High sampling mortality and less abundance of larvae in the sailing line masked any barge effects.

7.1.6 Information on catch of hilsa

A steady decline in the catch of hilsa has taken place in the Bhagirathi-Hooghly river stretch. The trend in last 10 years is presented in Fig. 33. A number of factors including intensive fishing pressure, capture of the fish in its young stage, juvenile fishery, sandification of the river bed, low water availability in the river, pollution, etc are responsible for its decline. The situation has farther deteriorated in last 5-6 years. About 20 years back hilsa fishery was the most important and remunerative in the Bhagirathi-Hooghly river stretch. But now a days, obtaining mature hilsa has become a rare occasion. The catch in three locations representing 3 classified zones of the river stretch is presented in Fig. 34 which also indicates its rare availability.

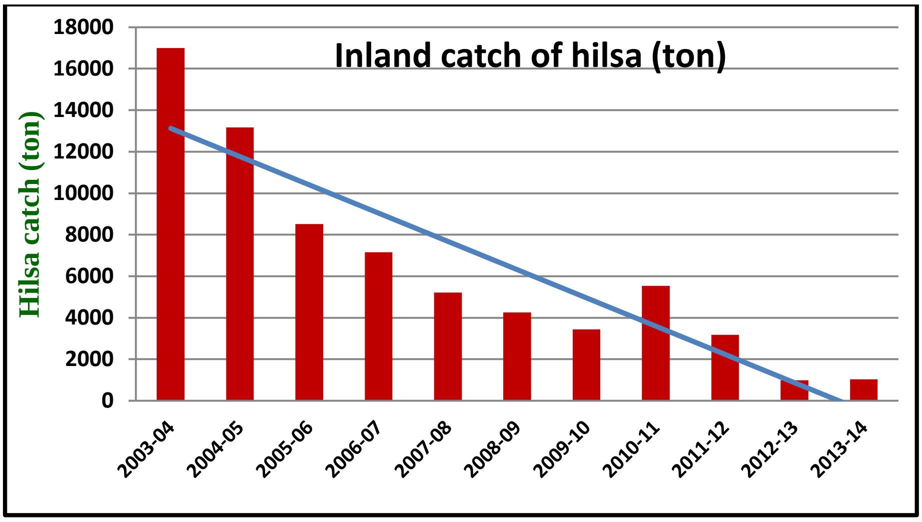


Fig. 33. Inland catch of hilsa

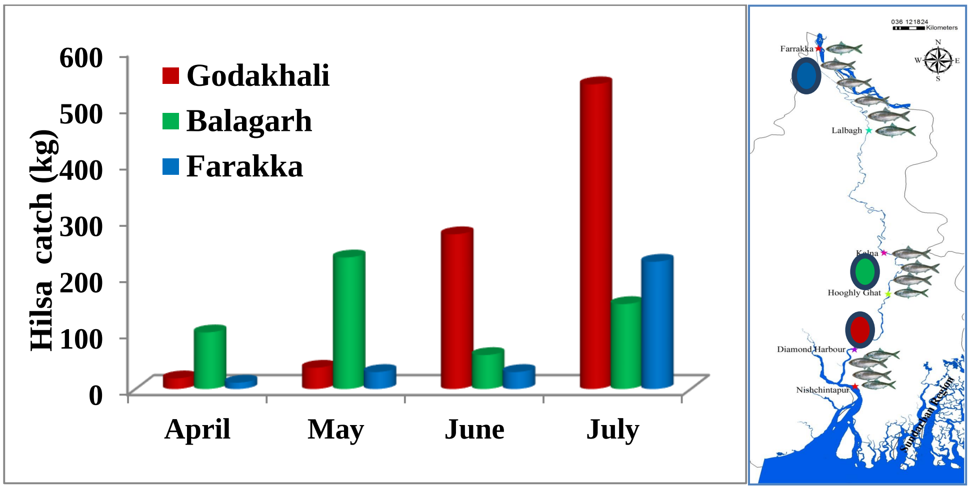


Fig. 34. Hilsa catch from three sites representing three classified zones during 2016

7.2 Study of impact of barge traffic on plankton dynamics

7.2.1 Plankton diversity

Phytoplankton community consisted of 68 taxa distributed in 5 phylum, 9 class, 27 orders and 39 families. Of these, diatoms were found to be more diverse followed by green, blue green and yellow green group of algae (Fig. 35). Among zooplankton, 12 taxa were reported mostly comprising rotifers and copepods (Fig. 36). Protozoans and ciliates are also mentioned in Fig. 37. The plankton taxa distribution is computed before and after barge movement and has been represented in Table 5. Study showed that density of total plankton was more in zone - I (lower stretch) followed by zone III (upper stretch) and the zone II (middle stretch) of the river. Among phytoplankton diatoms were predominant followed by green and blue green algae in all the three zones. Present study indicates higher abundance of diatoms in upper stretch followed by middle and lower stretches. Similar result was also reflected in previous study by CIFRI (ICAR-CIFRI, 2014). Present study also depicts that bacillariophytes are rare in the freshwater (upper stretch) which is evident in ecological study report by IIT (IIT report, 2012). Yellow green algae and euglenophytes were also recorded in small quantity in the present study. There was also a decrease in total plankton abundance by 16% after barge movement, which was 2772 nos./l with respect to 3275 nos./l before barge movement. Abundance of the total plankton has decreased after passage of barge in the present stretch of river.

Table 5. Zone wise Plankton diversity

Phytoplankton	**Zone I**		**Zone II**		**Zone III**	
Phylum: Bacillariophyta	Before barge	After barge	Before barge	After barge	Before barge	After barge
Aulacoseira granulata	+	-	+	+	-	-
Aulacoseira sp.	++	+	++	++	++	+
Cocconeis sp.	-	-	-	+	-	-
Coscinodiscus sp.	+	-	++	-	+	-
Cyclotella sp.	+	+	+	+	+	+
Cymbella sp.	+	+	+	-	+	-
Diatoma sp.	-	+	-	-	-	+
Diatomella sp.	-	-	-	+	-	-
Eunotia sp.	+	-	-	-	+	-
Fragilaria sp.	+	-	+	+	++	-
Gomphonema sp.	+	+	-	+	-	-
Gyrosigma sp.	+	-	-	-	-	-
Hantzschia sp.	-	-	-	+	+	-
Melosira sp.	+	-	++	+	+	-
Meridion sp.	-	-	-	+	-	-
Navicula sp.	++	+	+	+	+	-
Nitzschiaacicularis	+	-	+	-	-	-
Nitzschiareversa	-	-	+	-	-	-
Nitzschia sp.	+	+	+	+	++	+
Pinnularia sp.	-	+	-	+	-	-
Surirella sp.	-	+	-	-	-	+
Synedra sp.	+	-	+	-	++	-
Synedraulna	+	+	+	-	+	+
Thalassiosira sp.	++	-	-	-	-	-

	Zone I		Zone II		Zone III	
Phylum: Chlorophyta	Before barge	After barge	Before barge	After barge	Before barge	After barge
Actinastrum sp.	+	-	+	-	-	-
Ankistrodesmus sp.	+	-	-	+	+	-
Closteriopsis sp.	-	-	+	-	-	-
Coelastrum sp.	+	-	+	-	+	-
Crucigenia sp.	-	-	-	+	-	-
Microspora sp.	-	-	+	+	-	-
Mougeotia sp.	-	+	-	-	-	-
Pediastrum duplex	+	-	++	+	++	+
Pediastrum simplex	+	-	++	+	++	+
Scenedesmus quadricauda	+	-	-	-	+	-
Scenedesmus sp.	+	-	+	-	-	-
Schizogonium sp.	+	+	-	-	-	-
Spirogyra sp.	+	+	+	+	+	-
Volvox sp.	-	-	-	-	+	-
Phylum: Cyanobacteria						
Anabaena sp.	+	-	+	+	++	+
Aphanocapsa sp.	-	+	++	-	-	+
Arthrospira sp.	-	-	-	+	-	-
Coelosphaeruim sp.	-	-	+	+	-	-
Merismopedia sp.	+	-	+	-	+	-
Microcystis sp.	+	-	++	+	+	+
Oscillatoriasimplissima	-	-	+	-	-	-
Oscillatoria sp.	+	+	+	+	++	+
Phormidium sp.	+	-	-	-	+	+
Phylum: Ochrophyta						
Centritractus sp.	-	-	-	+	-	-
Gloeobotrys sp.	-	-	+	-	-	-
Tribonema sp.	-	-	-	+	-	+
Phylum: Euglenophyta						
Euglena sp.	-	-	+	+	+	-
Phacus sp.	-	-	-	+	-	-

'+' indicates presence; '-' indicates absence; '++' indicates dominance

Table 5 continued

Zooplankton	Zone I		Zone II		Zone III	
Phylum: Rotifera	Before barge	After barge	Before barge	After barge	Before barge	After barge
Brachionus anguilaris	-	-	-	-	-	+
Brachionus caudatus	-	-	-	-	-	+
***Brachionus* sp.**	-	+	-	-	++	-
***Filinia* sp.**	+	-	+	-	-	-
Keratella sp.	+	-	-	-	+	+
***Lecane* sp.**	-	+	-	-	-	-
Phylum: Arthropoda						
***Bosmina* sp.**	+	-	+	-	+	-
***Cyclops* sp.**	+	-	+	+	++	+
***Ceriodaphnia* sp.**	+	-	-	-		-
***Daphnia* sp.**	+	-	-	-	+	-
***Diaptomus* sp.**	+	+	+	-	+	+
***Moina* sp.**	+	-	+	-	+	-
Nauplius larva	+	-	-	-	++	+
Phylum: Amoebozoa						
***Arcella* sp.**	-	+	-	-	-	+
Phylum: Chordata						
***Ciliata* sp.**	-	+	-	-	-	-
Phylum: Ciliophora						
***Thecacineta* sp.**	-	+	-	-	-	-
***Vorticella* sp.**	-	+	+	+	++	+

'+' indicates presence; '-' indicates absence; '++' indicates dominance

7.2.2 Impact of barge movement on plankton cell

For assessment of the possible impact of barge movement on existing plankton cell structure, water samples were collected in triplicates from barge route of all the three zones with a schedule of before barge, immediately after passage of barge and thirty minutes after passage of barge. Impacts on plankton cell structure are represented in the form of percentage of damaged cell in the samples. The data was analysed using Analysis of Variance (ANOVA) in R software. Percentage of ruptured and damaged cell variation was found statistically significant at 5% level between different time interval of sample collection *viz*. before passage of barge, immediately after passage of barge and 30 minutes after passage of barge. Ruptured cell variation was also found statistically significant at 5% level in three stretches showing a total of 21% damaged cell immediately after passage of barge and 10% damaged cell thirty minutes after passage of barge with respect to the natural condition (6%) i.e. before barge movement in the entire study stretch (Table 6). The interaction (time of sampling x zone) was also found significant. The fragmented cells are shown in Fig. 38.

Mean of fragmented cell percentage in middle zone (10.34) was found to be significantly higher at 5% level of significance ($p<0.05$) than upper (4.45) and lower (2.87) zone, but no significant difference was observed between lower and upper zones before barge movement (Table 6).

Immediately after passage of barge, the fragmented cell percentage in middle zone was found to be significantly higher (26.25%; $p<0.05$) than the lower (15.86) and upper (20.92) zone, here again no significance difference between lower and upper zones was recorded. Thirty minutes after passage of barge, the fragmented cell percentage in middle zone (14.11) again was found to be higher than lower (7.95) and upper zone (8.61) at 5% level of significance.

Table 6. Percentage of ruptured or damaged cell (Mean ± SD) in three zones at different time interval of barge passage

Barge movement	Lower stretch	Middle stretch	Upper stretch	Average
Before	2.87±0.593	10.34±0.083	4.45±1.107	5.90
Immediate	15.86±2.937	26.25±1.624	20.92±1.647	21.01
30 minutes later	7.95±0.054	14.11±1.684	8.61±0.290	10.22

Study on the cell destruction and aggregation of dead cell of algae due to turbulent flow in laboratory experiment showed algal collision and cell destruction of *Scenedesmus quadricauda* with increase of level of turbulence in the water column (Hondzo and Lyn, 1999). Further, strong turbulence also act as causative agent for diatom mortality in terms of increase in number of dead cell (Garrison and Tang, 2014). Present study also reported 15% increase in percentage of damaged cell of phytoplankton immediately after passage of barge due to higher turbulence. The percentage of damaged cell was reduced by 11% thirty minutes after passage of barge with respect to the immediate barge movement data. Present study showed higher percentage (26%) of damaged cells in the water samples of middle stretch immediate after passage of barge. More concentration of damaged cell in this stretch can be attributed to the disruption of intracellular osmoregulatory mechanism of those marine/brackish species that are being transported to this zone by tidal ingress (Mitra et al., 2014).

Barge movement affected the plankton quality by 21% in the form of damaged cells in the water samples collected from barge route immediately after its movement which shows 15% increase with respect to the natural condition. The percentage of damaged cell 10 % was also recorded in the barge route thirty minutes after passage of barge. The percentage was reduced by 11 % from the immediate barge movement which may be due to ingress of undamaged plankton community along with water current. The record of increase percentage (15%) of damaged cell immediate after passage of barge might be attributed to heavy turbulence generated by barge propeller. This situation gets intensified with more barge traffic. Intensive barge movement along with several natural events such as strong wind and heavy waves also give rise to increase in sediment load in the ecosystem. It causes low light permeability in the water column which limits photosynthesis and prevent phytoplankton development and hence forth causing damage to the primary producers which has significant contribution in the aquatic food chain.

In general, phytoplankton species have a regeneration period of 2-4 days for increase of the population in a lentic ecosystem (Rojo *et al.*, 1994) and this doubling time is long in a lotic water (Reynolds, 1994) which allows increase of quickly growing population with an exclusion of slow regenerating species due to horizontal flow movement. This condition may be intensified with frequent barge traffic. Several worldwide studies have highlighted decreased phytoplankton growth rate owing to irregular and sporadic turbulence generated by boat propeller (Reynolds, 2006). Since the negative growth of phytoplankton can also be attributed to anthropogenic pollution and natural stressors such as strong winds and wave breakings, more intensive studies in relation to the impact of varying barge traffic on plankton is advocated to underline the mechanism in such a complex ecosystem.

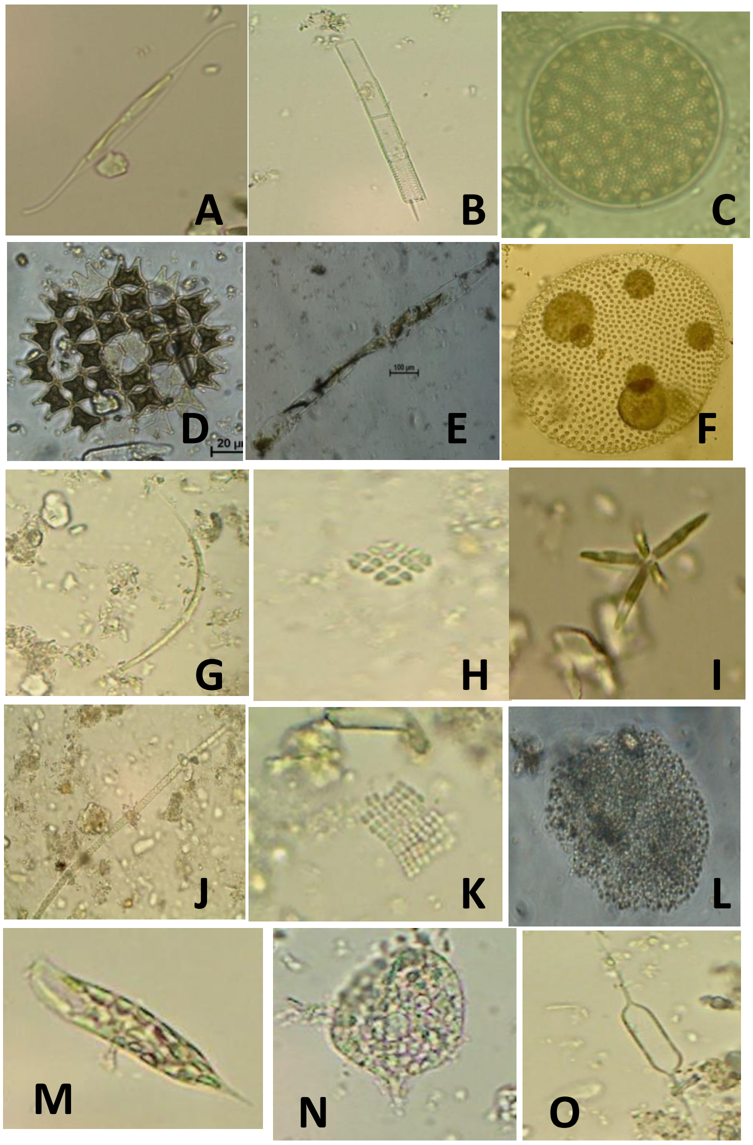


Fig. 35. Phytoplankton diversity: Bacillariophyta (A-C); Chlorophyta (D-I); Cyanobacteria (J-L); Euglenophyta (M-N); Ochrophyta (O).
Species in details: A. *Nitzschia reversa* B. *Aulacoseira granulata* C. *Thalassiosira* sp. D. *Pediastrum duplex* E. *Mougeotia* sp. F. *Volvox* sp. G. *Closteriopsis* sp. H. *Crucigenia* sp. I. *Actinastrum* sp. J. *Anabaena* sp. K. *Merismopedia* sp. L. *Microcystis* sp. M. *Euglena* sp. N. *Phacus* sp. O. *Centritractus* sp.

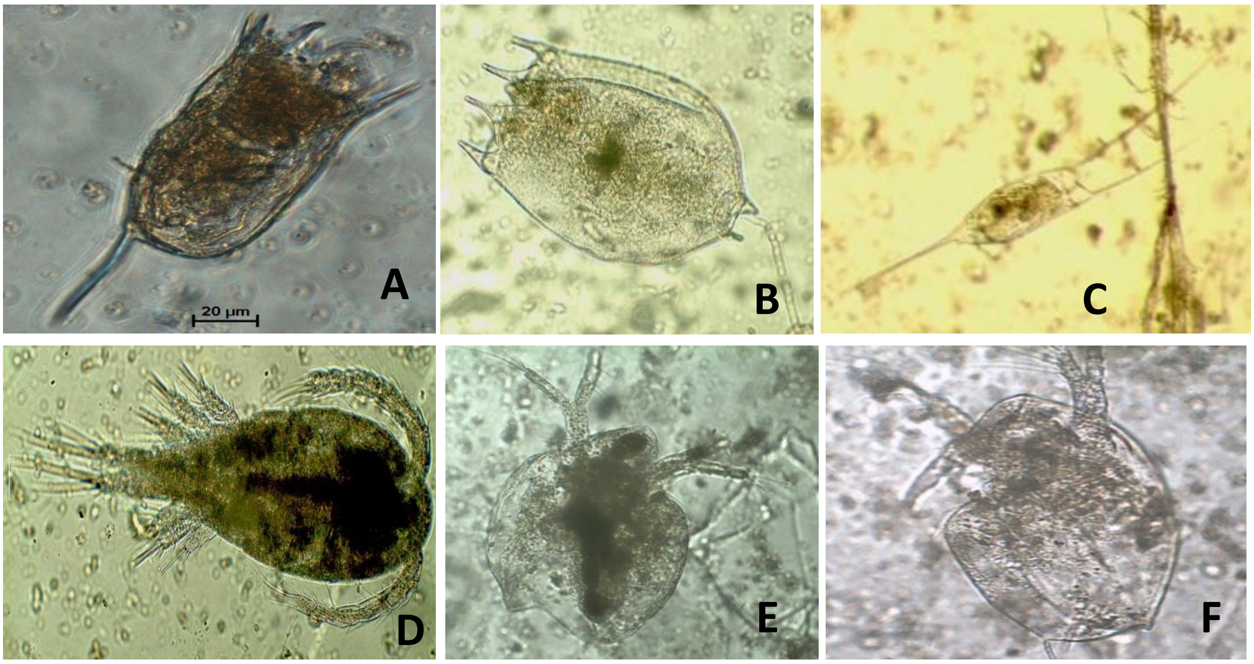


Fig. 36. Diversity of zooplankton

A. *Keratella* sp. B. *Brachionus* sp. C. *Filinia* sp. D. *Cyclops* sp. E. *Moina* sp. F. *Ceriodaphnia* sp.

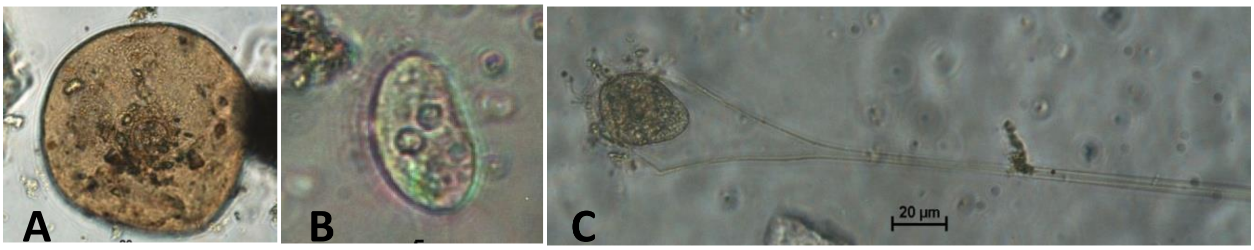


Fig. 37. A. *Arcella* sp. B. *Ciliata* sp. C. *Thecacineta* sp.

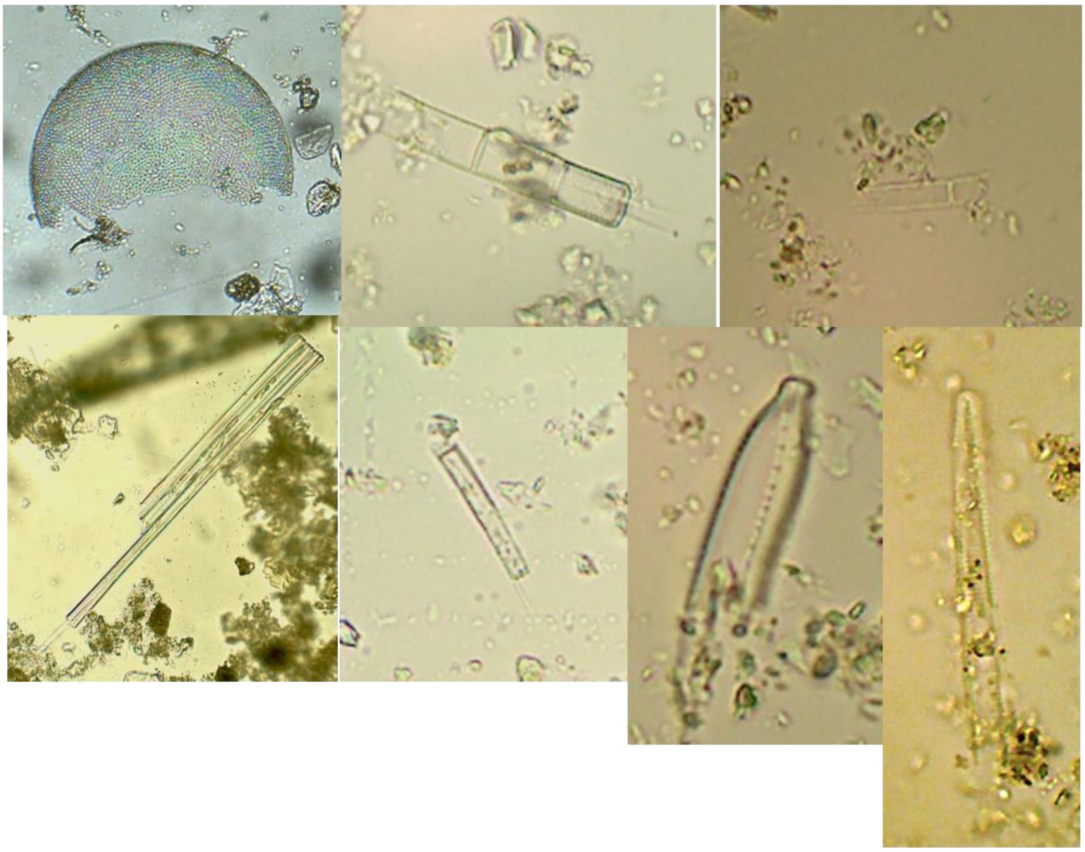


Fig. 38. Fragmented cell of Phytoplankton

7.2.3 Impact on epipelic algae

There is dense infestation of filamentous periphytic algae on soft sediment of river bank as observed in some sections of the studied river stretch (Fig. 39). Those algae proliferate on the water accumulated on small shallow stagnant water bays along the river bank. The waves generated by barge movement were observed to dislodge those periphytic algae and dragged them in the main river channel (Fig. 40). Further study is required to understand the impact of the phenomenon.

	
Fig. 39. Filamentous periphytic algae on the soft sediment of river bank	Fig. 40. Filamentous algae dislodged by the barge movement and dragged to the river water

7.2.4 Salient observation on plankton diversity and impact study

Study showed that density of total plankton was more in zone - I (lower stretch) followed by zone III (upper stretch) and the zone II (middle stretch) of the river. Among phytoplankton diatoms were predominant followed by green and blue green algae in all the three zones. Yellow green algae and Euglenophytes are also recorded in small quantity. There was also a decrease in total plankton abundance by 16% after barge movement, which was 2772 nos./l with respect to 3275 nos./l before barge movement. Barge movement affected the phytoplankton cell structure in the form of damaged cells to 21 % in the water samples collected from barge route immediately after its movement which shows 15% increase with respect to the natural condition i.e. before barge movement.

7.3 Impact of barge movement on macro-benthic community

7.3.1 Diversity of macro-benthic community:

A total of 25 species under 10 families and 3 classes were recorded in the study stretch. Zone wise distribution is presented in Table 7. Different gastropods and bivalves recorded in three zones are given in Table below.

Table 7. Macro-benthos recorded in studied zone (Bhagirathi–Hooghly river)

Zone I: lower stretch	Zone II: middle stretch	Zone III : upper stretch
Neritina smithi	*Assiminea francessiae*	*Bellamya bengalensis*
Telescopium telescopium	*Bellamya bengalensis*	*Bellamya crassa*
Pila globosa	*Corbicula stratella*	*Brotia costula*
Bellamya bengalensis	*Indoplanorbis exotus*	*Corbicula bensoni*
Cerithidea singulata	*Lymnea acuminata*	*Corbicula striatella*
Stenothyra deltae	*Lymnea luteola*	*Gabbia orcula*
Nerita articulata	*Thiara granifera*	*Gyraulus convexiuscula*
Thiara granifera	*Thiara lineata*	*Gyraulus labiatus*
Thiara lineata	*Thiara tuberculata*	*Lymnea acuminata*
		Novaculina gangetica
		Parreysia favidens
		Thiara granifera
		Thiara lineata
		Thiara scabra
		Thiara tuberculata

The diversity of macrobenthic community varied with season. Gastropods were dominating throughout the river stretch except in zone III during pre-monsoon season. Cephalopods were present only in the zone III during monsoon season. The detailed abundance of different macrobenthic communities in percentages are given in Table 8.

Table 8. Percentage distribution of macrobenthic communities

	Zone I: Lower stretch		**Zone II: Middle stretch**		**Zone III: Upper stretch**	
	Pre-monsoon	Monsoon	Pre-monsoon	Monsoon	Pre-monsoon	Monsoon
Gastropods	100	100	99	100	60	98
Bivalves	0	0	1	0	40	0
Cephalopods	0	0	0	0	0	2

Percentage of bivalve gradually decreased from zone III to zone I during pre-monsoon season. Gastropod shared almost 98% during monsoon as compared to 60% during pre-monsoon in upper stretch. Appearance of bivalve during pre-monsoon and negligible during monsoon in the zone III might indicate change in some parameters which is species specific.

7.3.2 Species wise macro-benthic diversity in different zones

7.3.2.1 Zone I (Lower stretch)

Macrobenthos collected from different sampling stations located in Zone I (Sagar to Dakhineswar) was analysed and given below (Fig. 41).The zone was completely dominated by *Thiara granifera*, *Thiara lineata*and *Neritina smithi* (Fig. 42).

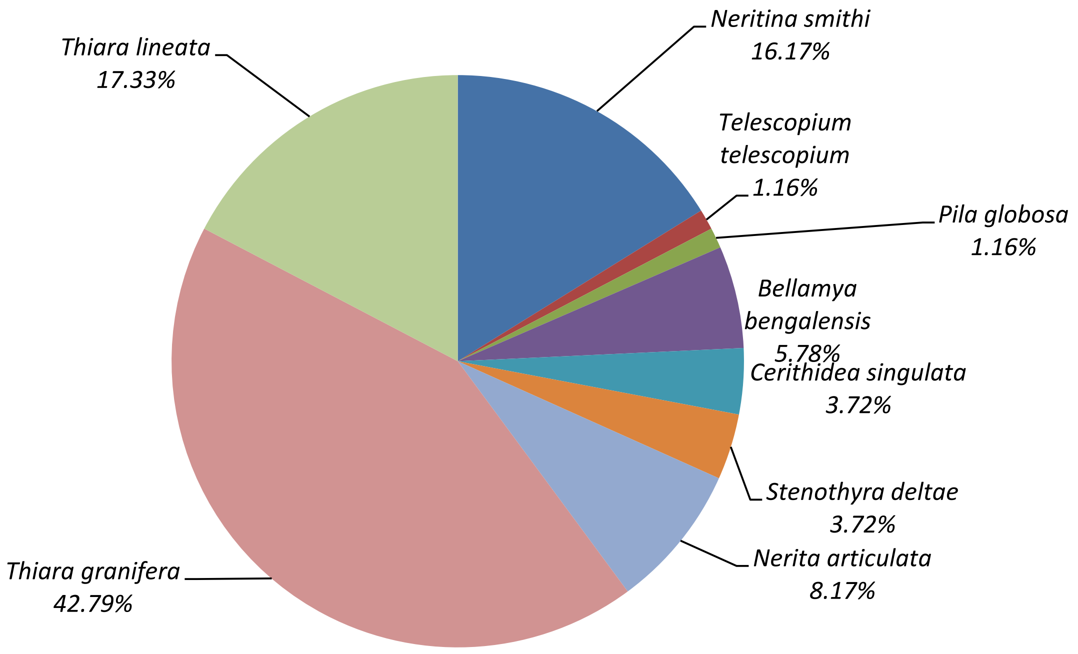


Fig. 41. Species wise macro-benthic diversity in Zone I (Lower stretch)

Fig. 42. Macrobenthos from zone I: *Thiara granifera* (left) and *Neritina smithi* (right)

7.3.2.2 Zone II (Middle stretch)

Macrobenthos collected from different sampling stations located in zone II (Dakhineswar to Nabadwip) was analysed and given below (Fig. 43). Zone II i.e. middle stretch was dominated by *Bellamya bengalensis* (44.5%) (Fig. 43). *Corbicula striatella* is the major bivalve observed in this stretch (Fig. 44).

Fig. 43. Species wise macro-benthic diversity in Zone II (Middle stretch)

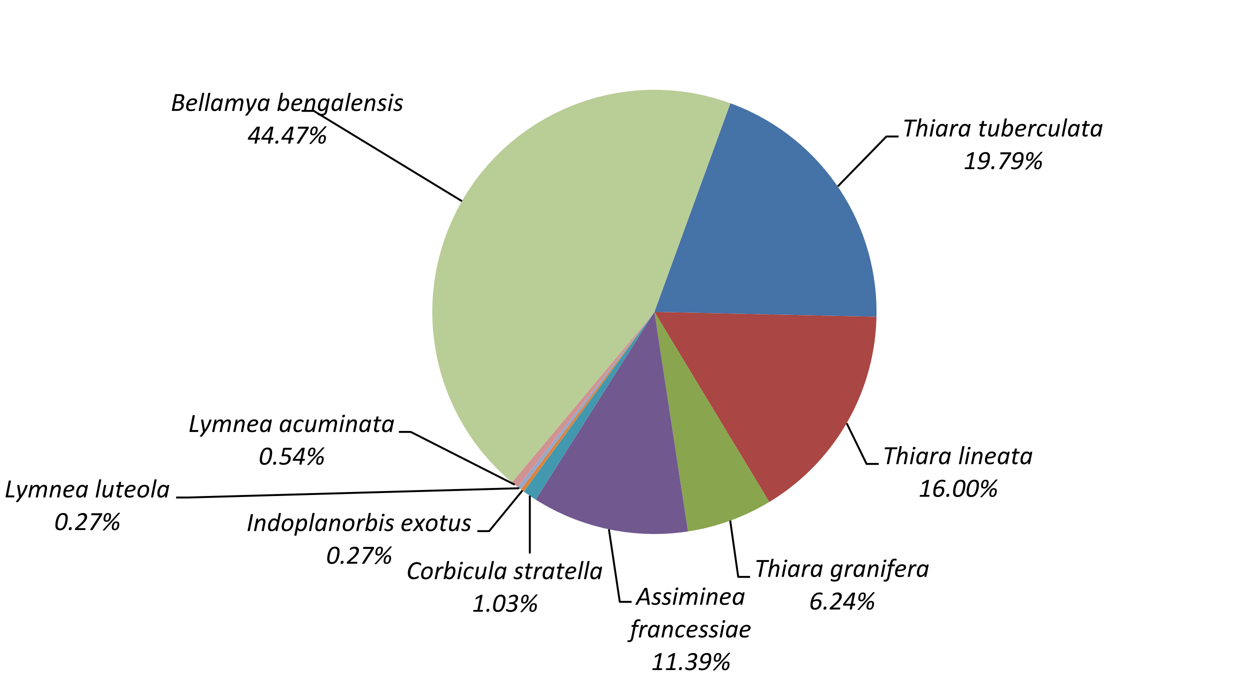


Fig.44. Macrobenthos from zone II: *Bellamya bengalensis* (left) and *Corbicula striatella* (right)

7.3.2.3 Zone III (Upper stretch)

Benthos collected from different sampling stations located in Zone III (Farakka to Nabadwip) was analysed and given below (Fig. 45). The most dominant species in Zone III are *Brotia costula* (30.38%), *Novaculina gangetica* (18.51%) and *Bellamya bengalensis* (11.87%) (Fig. 46).

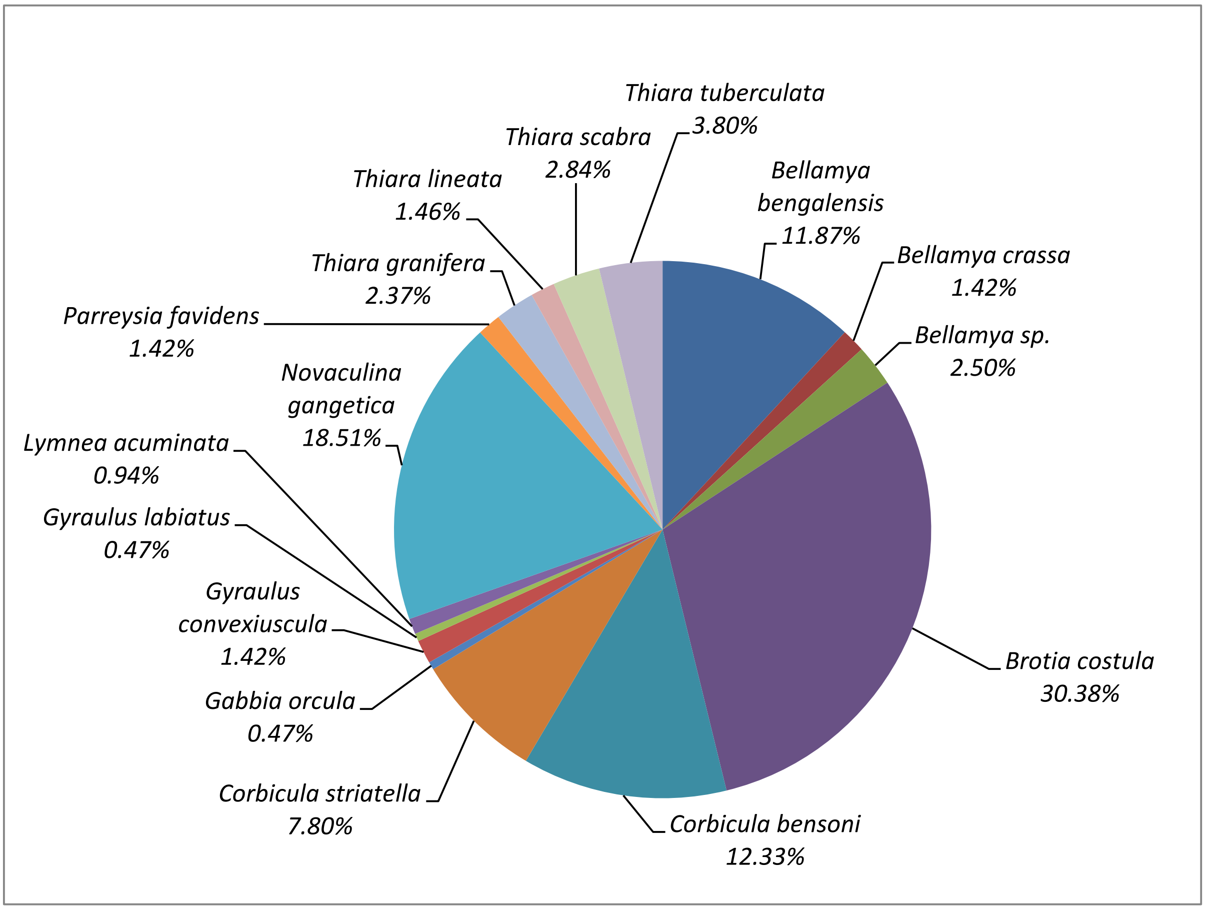


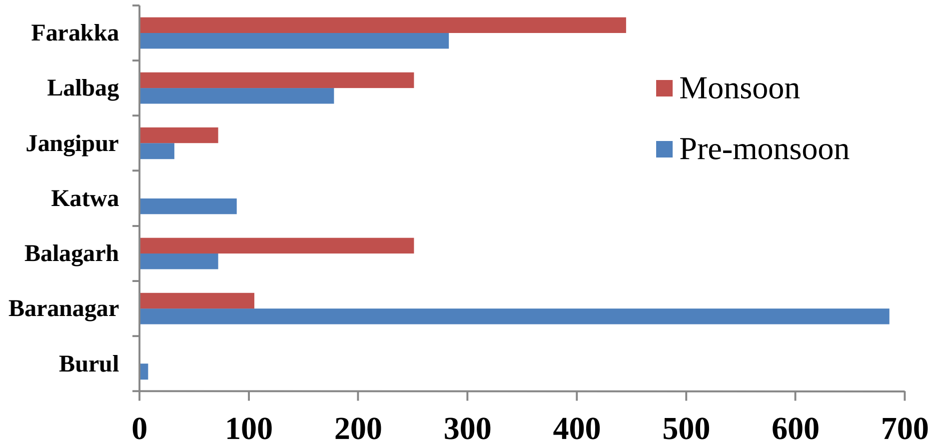
Fig. 45. Species wise macro-benthic population diversity in Zone III (upper stretch)

Fig.46. Dominant macro-benthos in Zone III: *Brotia costula* (left) and *Novaculina gangetica* (right)

7.3.3 Station-wise seasonal distribution of gastropods

The gastropod population was recorded high at Farakka followed by Lalbagh and Jangipur in the zone III irrespective of season. Baranagar stretch showed highest number of gastropods (Fig. 47).

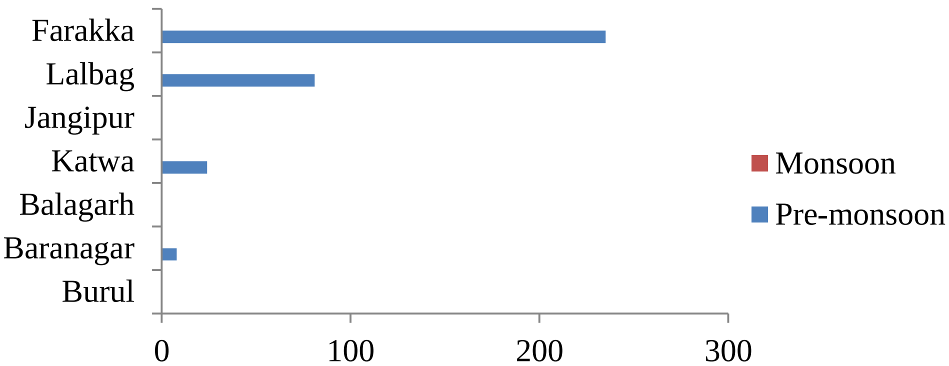
Fig.47. Station wise distribution (number/m^2) of gastropods



7.3.4 Station-wise seasonal distribution of bivalves

Three species of bivalve viz. *Novaculina gangetica, Corbicula striatella* and *Parreysia favidensi* were mostly dominating in zone III and zone II of the sampling sites during pre-monsoon. It was interesting to note that Lalbagh and Farakka are most suitable sites for these species to establish which is evident from their dominance by number (Fig.48). This result underlines the importance of future study on the impact of frequent barge movement on these species both at population level and micro-tissue level.

Fig.48. Station wise distribution (number/m^2) of bivalves



A large number dead shell of bivalves was recorded from the banks of the Feeder canal at the Farakka sampling site during pre-monsoon period (Fig.49). This was probably due to change in water level in the channel due to recent sharing of water and aerial exposure of the banks and also dead shells got accumulated after carrying from upstream. The benthos samples from mid-channel also exhibited significant number of dead gastropods.

Fig.49. Dead bivalves from bank of feeder canal (Left) and from mid-channel (Right)

7.3.5 Observation on impact of barge movement on macro-benthos

During our study it was observe that macro-benthic community especially gastropods are more distributed on soft sediments [Clay (60%), Silt (32%) and Sand (8%)] (Fig. 50, 51). Wave action caused by barge movement, could possibly dislodge the gastropods. Further long term and in-depth analysis is required to understand the impact of barge movement on these organisms.

Fig. 50. Soft sediment on river bank is densely infested with gastropods

Fig. 51. Sampling for benthos on the shoreline for impact assessment of barge movement

During our present investigation, it is observed that the diversity of benthic population varied with seasons. Gastropods, bivalves and cephalopods were dominating organisms throughout the river stretch. Zone III (Nabadwip to Farraka) showed more macro-benthic diversity than Zone II and Zone I. It indicates that the zone III is relatively less disturbed in terms of anthropogenic activities including navigational activities. Comparing with the studies conducted at CIFRI during 2008-09 indicated that the same sites were dominated by gastropods, followed by polychaetes, oligochaetes, decapods and bivalves. The present study indicated dominance of gastropod followed by bivalve. However, we could not able to record polychaetes and other macro-invertebrates in the present study. To conclude on the impact of the barge movement a long term study is required at macro as well as at micro or cellular level.

7.4 Gangetic Dolphin

The Gangetic dolphin *Platanista gangetica gangetica* is an indicator species for the river ecosystem and is at the apex of the food chain. It is an endemic and rare aquatic mammal found only in the Indian subcontinent and is a part of our natural aquatic heritage. Conservation of dolphins in Ganga river system is required for the following reasons:

- India is the last stronghold with extant populations in the Ganges-Brahmaputra river system. The species is in peril in Nepal and Bangladesh.
- It is an excellent indicator of riverine ecosystem health.
- As a signatory to numerous international conventions, India must fulfill its treaty obligations to aid in the conservation of this species.
- It is a unique charismatic mega-fauna.
- The species has recently been declared the 'National Aquatic Animal' by the Government of India, and is part of our national heritage.

7.4.1 Distribution in the study stretch

Gangetic dolphin (*Platanista gangetica gangetica*) falls under Schedule I of the Indian Wildlife Protection Act, 1972 and in the endangered category of IUCN red list species. It inhabits in the main channel of river Ganga and also in the tributaries and distributaries. The Sultangaj Pahar to Kahalgaon stretch of river Ganga is declared as the Vikramshila Dolphin Sanctuary (VGDS) under Wild Life Protection act 1972 via SO dated 7th August 1991. The West Bengal State Office of World Wide Fund for Nature -India, has undertaken in-depth study on the distribution of dolphins under the ongoing river watch programme along the river stretch from Ganga Sagar to Farakka. A list of those identified stations (Table 9) is given in Fig. 52. The numbers of individuals noticed from these stations are mentioned. The numbers are based upon the direct observations in the rivers by standard methods with sighting frequency in that stretch in various seasons.

Table 9. Distribution of Gangetic dolphin in Sagar to Farakka stretch of NW-1

District	Location	River	Sighting Record (numbers)
Howrah	Gadiara	Confluence of Roopnarayan and Hooghly	9
	Garchumukh	Confluence of Diamond and Hooghly	4
South 24-Paragnas	Raichak	Hooghly	3
	Diamond Harbour	Hooghly	3
	Beguakhali (Sagar)	Hooghly	1
	Budge Budge	Hooghly	5
	Bata Nagar	Hooghly	3
	Namkhana-Narayanpur	Hatania-Duania	4
Kolkata	Millenium Park	Hooghly	2
Hooghly	Khamargachi Char	Hooghly	5-6
	Swabuj Dwip	Hooghly	12-14
	Tribeni	Hooghly	2-3
Nadia	Payradanga (Close to Ranaghat)	Confluence of Churni and Hooghly	2-4
	Nabadwip	Confluence of Jalangi and Bhagirathi	3
Murshidabad	Farakka	Bhagirathi	6
	CISF Ghat	Feeder Canal	2
	Dhuliyan	Bhagirathi	1
	Suti	Bhagirathi	2

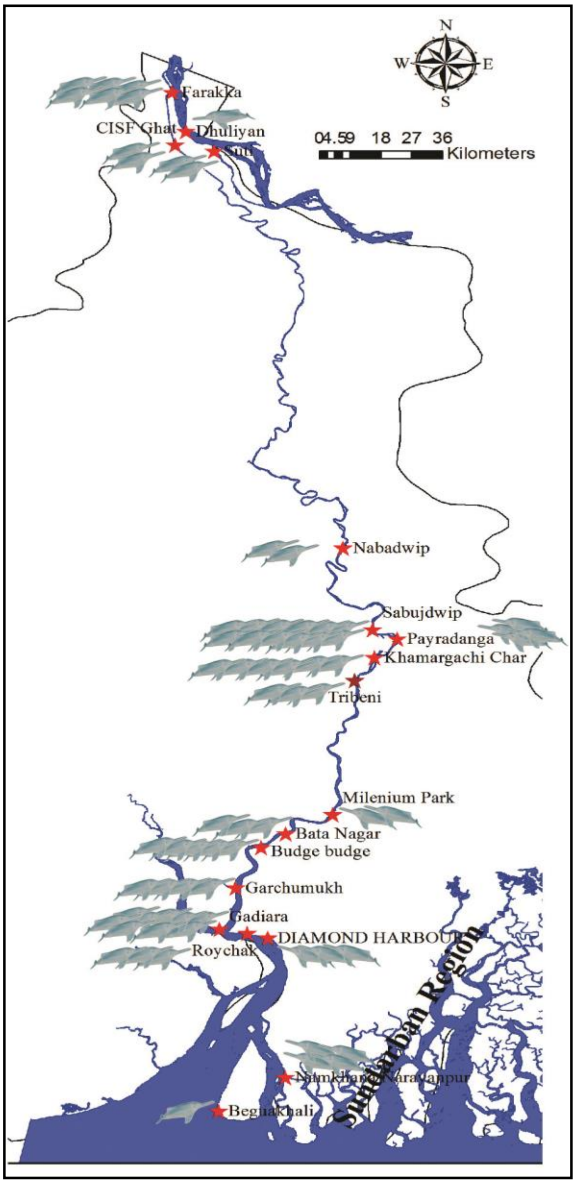


Fig. 52. Distribution of Gangetic dolphin in Sagar to Farakka stretch of NW-1

(Source: WWF-India, West Bengal State Office. Records noted from study undertaken during 2011 to September 2014)

7.4.2 Underwater sound

Like many stressors, under water sound has potentiality to harm the aquatic community. Underwater sound is an acoustic pressure wave that travels through water and occurs as a backward and forward motion of the water particles driven by a vibrating source. The magnitude of the water particle motion determines the intensity of the sound. The rate at which the water particles oscillate backward and forward determines its frequency given in cycles per second or Hertz (Hz).

The basic principles of sound propagation in air and in water are the same, but there are a number of features peculiar to underwater acoustics. Water is an excellent medium for sound transmission because of its high molecular density than air. Sound travels about five times faster in water than in air (about 1500 vs. 300 m/s), and this means that wavelengths are about five times longer in water than in air (e.g. for a 100 Hz signal: 3 m in air, 15 m in water). Sound also attenuates less over the same distance in water than in air. As a consequence, sound travels much greater distances at higher amplitude levels in water compared to air, thereby enabling long distance communication, but also a long-distance impact of noise on aquatic animals.

Sound also travels about four-and-a-half times faster in water than in air. In general, the anthropogenic noise is less in water than in air. But it is typically audible over much greater ranges in water than in air. Most sources of noise generate acoustic energy over a broad range of frequencies. Screeching or whistling noises are composed mainly of high frequency sounds while rumbles or booms are composed mainly of low frequency sounds. Sounds are usually characterised according to whether they are continuous or impulsive in character. Continuous sounds occur without pauses and examples include ship traffic, pumps and the ambient noise environment. Impulsive sounds are of short duration and occur singly, irregularly, or as part of a repeating pattern. Blasting represents a single impulsive event whereas the periodic impacts from a pile driving rig results in a patterned impulsive sequence. Impulsive signals typically sound like bangs and generally include a broad range of frequencies.

Sound pressures are measured underwater with a hydrophone. The international standard unit of sound pressure is the Pascal (Pa). Sound pressures encountered underwater range from levels just detectable by the mammal ear (hundreds of μPa) to much greater levels causing hearing damage (billions of Pa). Because this range is so enormous, sound pressure is normally described in terms of a sound pressure level (SPL) with units of decible (dB) referenced to a standard pressure of 1 μPa.

Underwater noise descriptors commonly used for presenting source, measured or received underwater noise levels include the following:
Sound pressure level (SPL) – Sound pressure averaged over the measurement period expressed in dB re 1 μPa. Continuous sources such as vibro-piling and dredging are commonly characterised in terms of an SPL.
Sound exposure level (SEL) – Sound energy over the measurement period expressed in dB re 1 μPa^2s. The SEL is commonly used for impulsive sources such as impact pile driving because it allows a comparison of the energy contained in impulsive signals of different duration and peak levels. The measurement period for impulsive signals is usually defined as the time period containing 90% of the sound energy.

Peak level – Highest sound pressure over the measurement period expressed in dB re 1 μPa. The peak level is commonly used for impulsive sources.
Source level – The intensity of underwater noise sources is compared by their source level (SL) expressed in dB re 1 μPa at 1 m. The source level is defined as the sound pressure, exposure or peak level that would be measured at 1 m from an ideal point source radiating the same amount of sound as the actual source being measured.

SPLs and SELs can be presented either as overall levels or as frequency dependent spectral or third-octave band levels indicating the frequency content of a source. Overall SPLs and SELs present the total average noise and energy level, respectively, within a given frequency bandwidth – usually the band that contains most of the energy. Spectral density levels are expressed in units of dB re 1 μPa²/Hz and provide a greater frequency resolution than third-octave band levels, which are expressed in units of dB re 1 μPa.

The techniques and sensors for measuring noise, vibration and particle velocity (in the water column) are currently relatively immature, and there is a lack of calibration standards also. There is also a lack of knowledge of what levels of these parameters would cause an effect. Secondary data were referred and analyzed for the study. The Sound source levels of various vessel types are listed in Table 10.

Table 10. Vessel noise at different speeds

Vessel, speed	**SL (0.2–40 kHz)**	**SL (2–12.5 kHz)**
	dB re 1 μ Pa RMS at 1 m	dB re 1 μ Pa RMS at 1 m
2-stroke, 2.5 knots	112 ± 1.0	108 ± 3.0
4-stroke, 2.5 knots	110 ± 2.6	106 ± 2.2
2-stroke, 5 knots	139 ± 1.0	132 ± 3.0
4-stroke, 5 knots	138 ± 2.6	134 ± 2.2
2-stroke, 10 knots	149 ± 0.6	146 ± 0.6
4-stroke, 10 knots	152 ± 0.3	144 ± 0.5

Source: Acoustics in marine ecology' (Vessel noise effects on delphinid communication -Vol. 395: 161–175, 2009doi: 10.3354/meps08204)(1 μ Pa RMS at 1 m = one μ Pa root mean squire at 1 meter)

As per the another study done by Plon, S, Koper, R.P., Endangered Wildlife Trust[1] the noise level from different types of ships is given in Table 11.

Table 11. Noise Level from different type of vessels

Sound sources	**Types of sound**	**Main frequency (KHZ)**	**Source sound level (dB)**
Cargo vessels	Continuous	0.0-0.5	195
Small vessels	Continuous	1.0-10.0	160-170

7.4.3 Noise Impact and Mitigation Measures

Inland water navigation facilitate transportation more cost effective and environmental friendly but the noise generated from the shipping activity may have some adverse environmental impacts on the aquatic fauna. The noise impact assessment due to vessel movement has been carried out considering the outputs of various studies done earlier vs noise to assess the expected noise from vessel movement.

[1]The potential impacts of anthropogenic noise on marine animals and recommendations for Research in South Africa.

7.4.4 Noise impacts due to vessel movement

The Source of Noise of River Vessel: Vessels generate underwater noise from mechanical vibrations of the engine or hull, but most of the medium- and high-frequency components of vessel noise stem from cavitations, a phenomenon whereby air bubbles form and collapse on the edge of fast-moving propeller blades (Ross 1976). The level of cavitation noise increases with the speed of vessels as well as propeller movement (Arveson & Vendittis 2000).

The aquatic organisms are exposed to water pollutants, including increasing levels of anthropogenic noise. As reported the dolphins and other aquatic fauna have evolved auditory and sound production systems that allow them to use sound for aseries of vital processes, including communication, navigation and detection of predators or prey. For example as reported, the most aquatic vertebrates exploit the low absorption of sound underwater to acquire information about their environment and to communicate (Tyack & Miller 2002, Popper 2003, Montgomery et al. 2006). This makes aquatic fauna susceptible to the negative effects of man-made noise if the exposures cause behavioural or physical changes or impede the process of conveying or acquiring information acoustically (Richardson et al. 1995).

Very few studies have been conducted on the impact of sound on dolphins and their subsequent behavioural response. The potential impact of anthropogenic (man-made) noise on fresh water animals depends on the level of noise exposure. At low to moderate exposure levels under water noise may cause a change in the behaviour of aquatic animal. At high exposure levels, underwater noise can induce hearing loss or physical injury to aquatic animals. Noise levels <177dB re 1 µPa or equal are very unlikely to induce any hearing loss or physical injury (injury criteria) in dolphins over the long exposure periods (Table 11). Due to vessel movement activity the aquatic habitat in Sagar to Farakka stretch is subjected to low intensity of continuous nature of underwater noise.

7.4.5 Exposure behaviour disturbance criteria for injury

Exposure behaviour criteria relate to injury to certain marine/freshwater animal groups and are based on received sound levels that meet the definition of Permanent Threshold Shift (PTS) onset. However, due to the lack of data in regard to PTS, criteria have been derived from measure assumed Temporary Threshold Shift (TTS) onset thresholds and growth rate estimates for each marine/fresh water animal group. The injury criteria for individual animals exposed to 'discrete' noise events are presented in Table 12.

Table 12. Exposure Criteria

Species group	Multiple pulse behavior Disturbance Criteria (Sound Pressure, dB re 1µPa)	Non-Pulse behavior Disturbance Criteria (Sound Pressure, dB re 1µPa)
Bryde's Whale	165	135
Dolphins and Dugong	177	177
Marine Turtle	175	150
Sawfish	215	185
Speartooth Shark	202	180

Source: EIA study of South of EMBLEY project

It is pertinent to mention that the vessel/barge movements generate low intensity of continuous nature of noise. As the expected vessel size plying within Farakka-Ganga Sagar stretch will be of medium size and playing at medium speed the underwater noise generated will be of low intensity.

7.4.6 Auditory system of dolphins and noise generation from moving barges

When the dolphin's auditory system is exposed to a high level of sound for a specific duration, the sensory hair cells begin to fatigue and do not immediately return to their normal shape (NRC 2005)[2]. This causes a reduction in the hearing sensitivity, or an increase in hearing threshold. If the noise exposure is below some critical sound energy level, the hair cells will eventually return to their normal shape. This effect is called a temporary threshold shift (TTS) as the hearing loss is temporary. If the noise exposure exceeds the critical sound energy level, the hair cells become permanently damaged and the effect is called permanent threshold shift (PTS). Table 13 summaries the noise exposure criteria adopted for assessing hearing damage (PTS or TTS) and behavioral effects on the river dolphin from vessel noise. The noise exposure criteria are based on the review presented by Southall et al. (2007) and also adopted by NOAA (US National Oceanic and Atmospheric Administration) in 2011.

Table 13. Noise exposure criteria for physiological injury (PTS and TTS)

Impact	Noise exposure criteria
Permanent threshold shift (PTS)	SEL 215 dB(M) re 1μPa^{2}s
Temporary threshold shift (TTS)	SEL 195 dB(M) re 1μPa^{2}s

Source: NOAA & Bangladesh Regional Waterway Transport Project 1-ESIA Report, BIWTA

7.4.7 Vessels noise and relation with speed

Surface shipping remains the most widespread source of low frequency (<1000 Hz) anthropogenic noise (Popper et al. 1998). Vessels generate substantial broad band noise from their propellers, motors, auxiliary machinery, gear boxes and shafts, plus their hull wake and turbulence. Diesel motors produce more noise than steam or gas turbines, but most long distance (low frequency) noise is generated by the 'hissing' cavitations of spinning propellers. Other source of noise due to ship movement is noise from propulsion machinery which reached water via ship hull. However this contributes to very less fraction as compared to bubble cavitations. Noise generation from the ship movement is continuous type. Vessel noise generation and its relation with speed has been studied based on the secondary available data and is discussed below:

As per the study "Acoustics in marine ecology-Vessel noise effects on delphinid (dolphin) communication -Vol. 395: 161–175, 2009 doi: 10.3354/meps08204" Sound source levels of various vessel types at different speeds are measured and listed in following Table 14. The vessels which will ply in the Farakka to Ganga Sagar stretch will be 4 stroke engine vessels and will move with

[2]NRC. (2005). Marine Mammal Populations and Ocean Noise - Determining When Noise Causes Biologically Significant Effects. National Research Council, National Academies Press

speed of 7 knots (12-13 kmph) in the Farakka to Ganga Sagar stretch. Thus based upon the study it can be conclude that the source noise level that can be generated from the vessels (four stroke vessels moving at 10 knot speed) moving at a speed of 10 knot (which is more than 7 knot) will be in range of 144-153 dB.

Table 14. Vessel noise at different speeds

Vessel, speed	SL (0.2–40 kHz) dB re 1 µPaRMS at 1 m	SL (2–12.5 kHz) dB re 1 µPaRMS at 1 m
2-stroke, 2.5 knots	112 ± 1.0	108 ± 3.0
4-stroke, 2.5 knots	110 ± 2.6	106 ± 2.2
2-stroke, 5 knots	139 ± 1.0	132 ± 3.0
4-stroke, 5 knots	138 ± 2.6	134 ± 2.2
2-stroke, 10 knots	149 ± 0.6	146 ± 0.6
4-stroke, 10 knots	152 ± 0.3	144 ± 0.5

Source: Acoustics in marine ecology' (Vessel noise effects on delphinid communication -Vol. 395: 161–175, 2009 doi: 10.3354/meps08204)

7.4.8 Specific observation

It can be concluded from the above study that the noise generation from vessel that ply in NW-1 (1500-2000 DWT) will be between 110-140 dB. This is far below the noise exposure criteria to cause PTS/TTS in dolphins. Thus impact on auditory systems of dolphins is not anticipated due to noise generation from barge movement.

As per above estimations following mitigation measures are recommended for eco-friendly navigation :

- Barge/vessel movement should be restricted to the designated pathway over the river stretch to minimize disturbance on riverine habitants.
- Vessel may be fitted with the dolphin reflectors.
- Average barge speed in Farakka-Ganga Sagar stretch will be 10-13 km/h (<7 knot). So the source noise level to be generated from the vessels will be in range of 110-140 dB.
- Further reducing barge speed when crossing areas of high dolphin density would allow cetaceans more time to avoid the area of oncoming vessel and give the operator more time to react to the dolphin's presence.
- The barge speed can further be reduce to less than <5 knot in narrow stretches as well as in the areas of dolphin movement for minimizing possibilities of any injury to dolphins.
- Modern best / better technology vessels or with retrofits / quieting techniques can further reduce the noise emissions (specifically cavitations noise).
- Regular maintenance of vessels engine and propellers.
- Other operational noise mitigation procedures for vessels are engine power reduction and planning of routes and schedules to avoid areas of high use by dolphins.
- Condition monitoring: a condition monitoring plan may be followed to ensure proper condition of propellers, motors, auxiliary machinery, gear boxes and shafts so that defects can be detected and resolved in time.

7.5 Impact on abundance of economically important fish species (including Dolphin), fish growth and production at varying traffic load.

Under the project, the vessels of 72 m x 14 m x 4.25 m are in operation with carrying capacity of 2100 ton. The speed of these vessels are in the range of 5-12 knots. Although water transport is the most environment friendly mode of transportation as compared to other modes like rail & road but still it has some impact on aquatic flora and fauna.

The tributaries and distributaries of river Ganga support rich biodiversity and offers livelihood and nutritional security to millions of riparian population. The river system harbours rich and diverse freshwater ichthyofauna and many estuarine fishes in the lower reaches. About commercial importance, almost all fish landed fetch a market price and are utilized for the badly needed protein in a developing country like India, especially in West Bengal, a state with majority of fish eaters. Among the landed fishes, hilsa shad commonly called as 'ilish' fetch the highest price.
The hilsa shad or Indian shad, *Tenualosa ilisha*, belongs to the sub-family Alosinae of Family Clupeidae. The river stretch is also the migratory route of many other important species. Hilsa fishery has faced a tremendous fishing pressure and its irresponsible exploitation has resulted in decline in its population. In order to rejuvenate the fishery, three hilsa sanctuaries have been identified under the gazette notification by Government of West Bengal on 9th April 2013. These are Nishchintapur to Diamond Harbour (chainage 40 to 70 km, starting at Sagar Island), between Hooghly Ghat to Kalna (chainage 184 to 246 km) and between Lalbagh to Farakka (chainage 442 to 540 km). These are located in the barge route. Restriction under this sanctuary is in the form of ban on catching all types of hilsa during June to August and October to December.

Studies indicated rich and diverse ichthyofauna of River Bhagirathi–Hooghly with unique and endemic species as well as species of high conservation needs. There are many species, which are listed in threatened and rare categories of IUCN (International Union for Conservation of Nature) red list. As the IUCN Red List Index measures overall trends in extinction risk for groups of species based on genuine changes in their status over time, it provides a good indication of their conservation importance. Species such as *Ailia coila, Wallago attu, Ompok bimaculatus, O. pabda, O. pabo, Bagarius bagarius* and *B. yarrelli* are distributed well in the river stretch, they currently belong to the Near Threatened category in the IUCN red list.

As a vessel or barge navigates through a waterway, it generates hydraulic disturbances in the form of waves and currents, mainly drawdown, return current, slope supply currents, wash waves, and propeller jet. Thus, in addition to the indirect effects of "navigation" on fish assemblages, direct negative effects on fish caused by navigation induced shear stress, ship waves, drawdown, dewatering, backwash, and return currents have been commonly reported. In general, it is often observed that commercial vessel traffic is negatively affecting native fish populations associated with channel bank habitats. Following ecological impacts has been anticipated due to the transshipment.

7.5.1 Impact due to settling of dust from materials handling:

Dust may settle on the surface of river during loading, transportation and unloading operations if appropriate preventive measures are not taken. This dust will increase water turbidity, and may impact the water quality and aquatic fauna including fishes.

Mitigation measures

Coal should be transported under covered conditions to minimize dust generation and its settlement on river surface. The terminals should have facility to control dust pollution during barge loading and unloading.

7.5.2 Impact due to vessel speed and movements: Dolphins, fishes moving in river can collide with the moving vessels which may cause them injury and even mortality.

Mitigation measures

To minimize the chances of collision, restricted vessel speed of <5 knots is proposed in areas of dolphin movement and areas identified for hilsa sanctuary. Thus, vessel would allow dolphins more time to avoid the area of oncoming vessel and give the operator more time to react to the Dolphin's presence. Vessels should move through the designated channels only which are in the deeper zones. Thus, may cause less harm to the fish habitats associated to the shallower regions. The vessels should be fitted with propeller guards to avoid any unwanted injury and associated mortality.

7.5.3 Impact of ballast water discharges: Ballast water discharges by vessel can have a negative impact on the aquatic environment. Bulk cargo carriers huge amount of ballast water. Such ballast water typically contains a variety of biological materials, including plants, animals, viruses and bacteria from the water intake location. As blast water may have various non-native, invasive, exotic species that can cause ecological imbalance and economic damage to the receiving aquatic ecosystems.

Mitigation measures

Under present situation, ballast water is taken from the same river (near Farakka) and shall be discharged into same river and no impacts due to ballast water discharges are anticipated.

7.5.4 Impact due to discharge of waste/sewage and solid from vessels:

Wastes generated in the vessels may pollute the waterway.

Mitigation Measures

In this project majorly freight vessel are expected to ply. Thus the quantity of sewage to be generated will not be large. However, vessels should not be allowed to discharge wastes in river during navigation or berthing. All wastes should be disposed at the designated barge maintenance facility only.

7.5.5 Impact due to usage of anti-fouling paints:

Antifouling paints with toxic content can affect the aquatic life.

Mitigation measure

Use of non-toxic and non-tetrabutyltin containing anti-fouling paints.

7.5.6 Impact due to underwater noise generated from vessels:

Cargo vessels generate substantial underwater noise from their propellers, motors, auxiliary machinery, gear boxes and shafts, plus their hull wake and turbulence. Diesel motors produce more noise than steam or gas turbines, but most long distance (low frequency) noise is generated by the 'hissing' cavitation of spinning propellers. Noise generation from the ship movement is continuous type. Noise generation from vessel movement (1500-2000 DWT) vary from 110-140 dB. This order of noise generation may have impact on behaviour of various aquatic organisms and may also lead to other injuries like tissue injury, temporary and permanent hearing loss.

7.5.7 To reduce the above mentioned impacts, the following general mitigation measures are suggested:

- Barge/vessel movement should be restricted to the designated pathway to minimize disturbance to aquatic life.
- Vessel to be fitted with the dolphin reflectors.
- In the sensitive areas, barges speed to be maintained <7 knot to reduce the impact.
- The barge speed may further be reduced to less than <5 knot in narrow stretches as well as in the identified hilsa sanctuary area and dolphin movement areas to minimizing possibilities of injury.
- Modern / better technology vessels with retrofits / quieting techniques can further reduce the noise.
- Regular maintenance of vessel engine and propeller.

Other measures

- Waste materials should be disposed at the designated barge maintenance facility only.
- Coal should be transported under covered conditions to minimize dust generation and its settlement on river surface. Terminals should have facility to control dust pollution during barge loading and unloading.
- Provision of oil water interceptors in the bilge tank to separate oil prior to discharge of bilge water into river.
- Usage of non-toxic and non TBT containing anti-fouling paints for painting vessels.
- Immediate/quick clean-up of oil/other spills to be undertaken in case of accidents.
- Enhancing fish productivity by river ranching under National program, as has been taken in *Nabami Gange* program. Required training programs may be supported.
- Research programs on sensitive species may be supported.
- IWAI should develop the stringent norms for vessel operators and develop the system of penalization based on polluters pay principle in case the standards are not met or violated.
- The vessels should be fitted with propeller guards to avoid any unwanted injury and associated mortality.

8.0 Component II : Impact of barge movement on fish catch and livelihood issues of fishers

8.1 Socio-economic condition of fishers

The data collected from 500 fisher families comprising 100 from lower stretch, 200 each from middle and upper stretches were analysed and assessed. Multi-stage stratified random sampling design was followed for selection of fishers. Data were triangulated through focused group discussions at certain sampling points. The detailed methodology is given in section 3.2. Some photographs of socio-economic survey are given in Annexure IV.

Analysis of data indicated that the fishermen households are socio-economically backward. The years of schooling of the respondents is only around 2 and majority of them are illiterate (40 %). The main profession of majority of the respondents is fishing and it is the only source of income to a sizeable number of households. The average size of the family is around 4. Very few of them are office bearer or member of any social organizations like panchayat SHG's, farmer'club.

Fishing is the primary occupation to around 89% of the responded fishers; the percentage is higher in lower stretch (92%). Primary occupation for rest (11%) of the fishermen was found to be fish vending, ferry service, rickshaw/van pulling, petty business and labour. Average number of income generating activities in the households ranged from 1.43 in lower stretch to 1.79 in upper stretch. A small amount of income comes from agriculture, labour wage, service, petty business, etc. In the season of less catch, the youth generally are engaged as labours or rickshaw van pullers to earn their livelihood.

Table 15. Socio-economic characteristics of the respondent fishermen

Parameters	Lower stretch	Middle stretch	Upper stretch	Entire stretch#
Number of family surveyed	100	200	200	500
Age (years)	42.13	50.24	44.77	46.43
Avg. family size (numbers)	4.04	3.91	4.21	4.06
Illiteracy (%)	50.00	36.00	40.00	40.40
Can read and write (%)	9	17	9.5	12.4
Education (read up to the class)	2.39	1.39	1.58	1.66
Primary Occupation (% of respondent fishermen)				
Fishing	92.00	91.00	84.50	88.60
Fish vending	1.00	3.00	1.50	2.00
Ferry service	0.00	0.50	1.00	0.60
Tourism	0.00	0.00	0.50	0.20
Driving	1.00	1.00	2.50	1.60
Labour	3	3.5	7.5	5
Petty business	2	1	3	2
Rickshaw van pulling	1	1.5	15.5	1.8

Weighted average of three stretches.

Table 16 shows non-fishing activities of the fishermen households. The table shows that in upper stretch, more number of fishermen households are involved in non-fishing activities. At this stretch the fishing activities alone could not suffice as a livelihood option , hence, they are engaged in other income generating activities. The contribution from non-fisheries activities in income are also given in Table 16.

Table16. Different non-fishing sources of livelihood of the fishermen household*

Economic diversification (% of household)	Lower stretch	Middle stretch	Upper stretch	Entire stretch#
Number of family surveyed	100	200	200	500
Labour	17.00	24.00	25.00	23.00
Driver	2.00	1.00	2.50	1.80
Self employed	7.00	8.00	20.50	12.80
Service	9.00	4.50	7.50	6.60
Business	3.00	6.00	10.50	7.20
Fish vending	2.00	7.50	3.00	4.60
Rickshaw puller	3.00	2.50	3.00	2.80
Others	0.00	3.50	4.50	3.20
Average number of income generating activities in the households including fishing	1.43	1.57	1.79	1.63

*Taking into account all the family members; # Weighted average of three stretches.

8.2 Income-expenditure pattern

The monthly income of the households ranges from Rs.8,984/- in upper stretch to Rs.10,226/- in lower stretch (Fig. 53 to 55), the average income in the study stretch was found to be Rs.9,391/- (Fig. 56). The income is higher in lower stretch because of higher catch and high value fishes in the catch. Analysis of expenditure pattern shows that the household spent on an average Rs.7,191/- on different items per month. The food constitutes around 70% of the total expenses. Other major items of expenditure are clothing (7%), medical (6%), household items (2%), education (3%) and others (7%). The barge movement does not have any impact on the expenditure pattern of the fisherman household across the stretches.

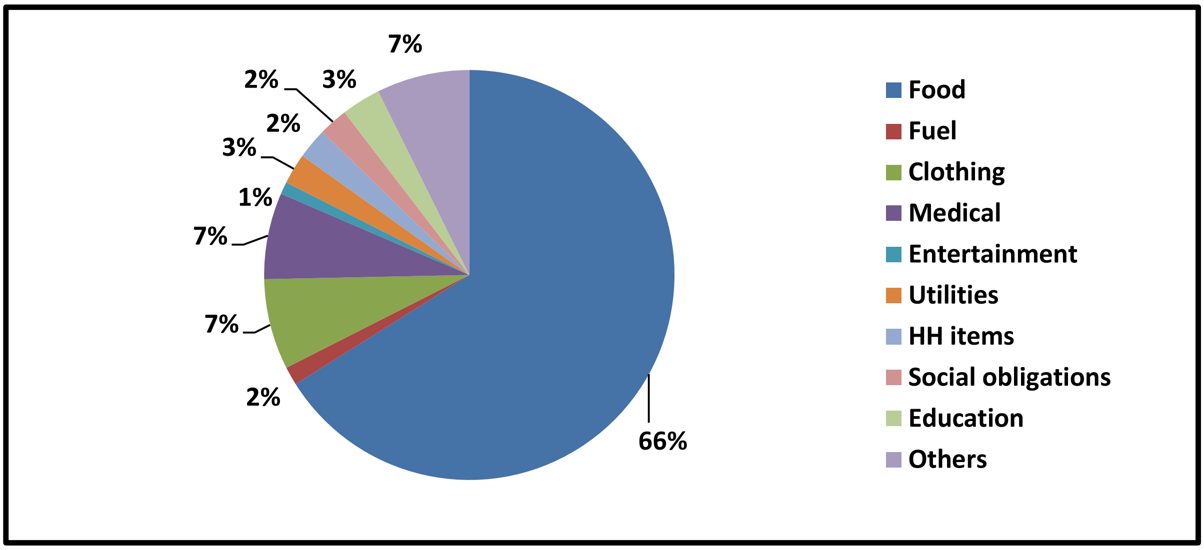


Fig 53. Monthly expenditure pattern of the households (Rs.7,573/-) in lower stretch (Sagar to Dakshineswar). Total Monthly income Rs.10,226/-

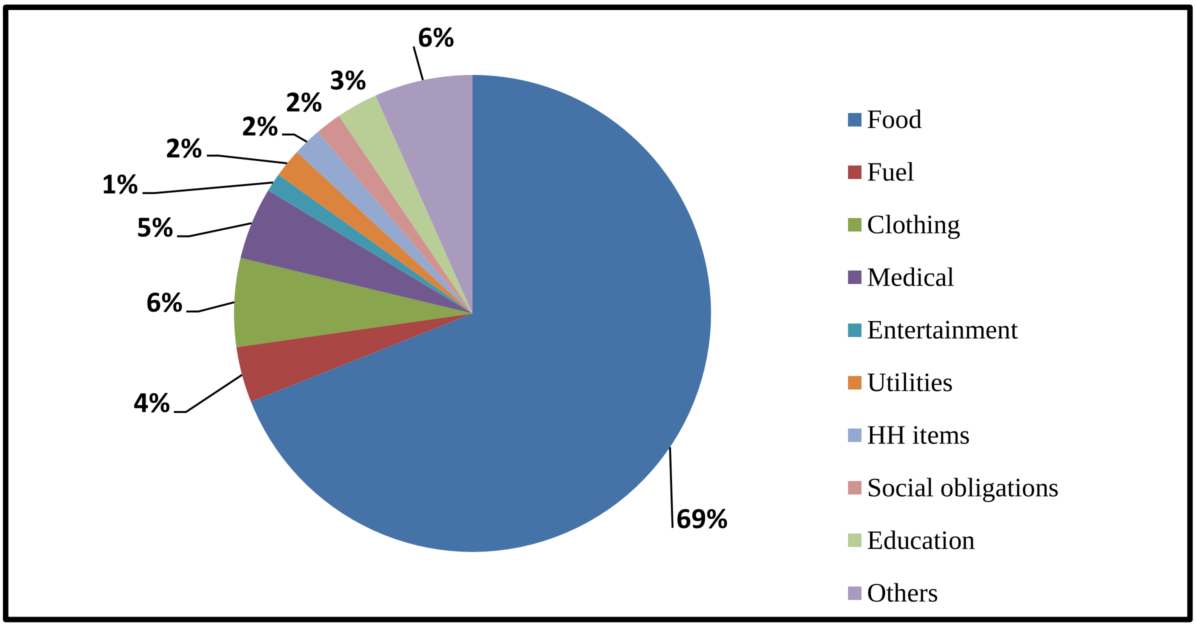


Fig. 54. Monthly expenditure pattern of the households (Rs.6,858/-) in middle stretch (Dakshineswar to Nabadwip). Monthly income Rs.9,380/-

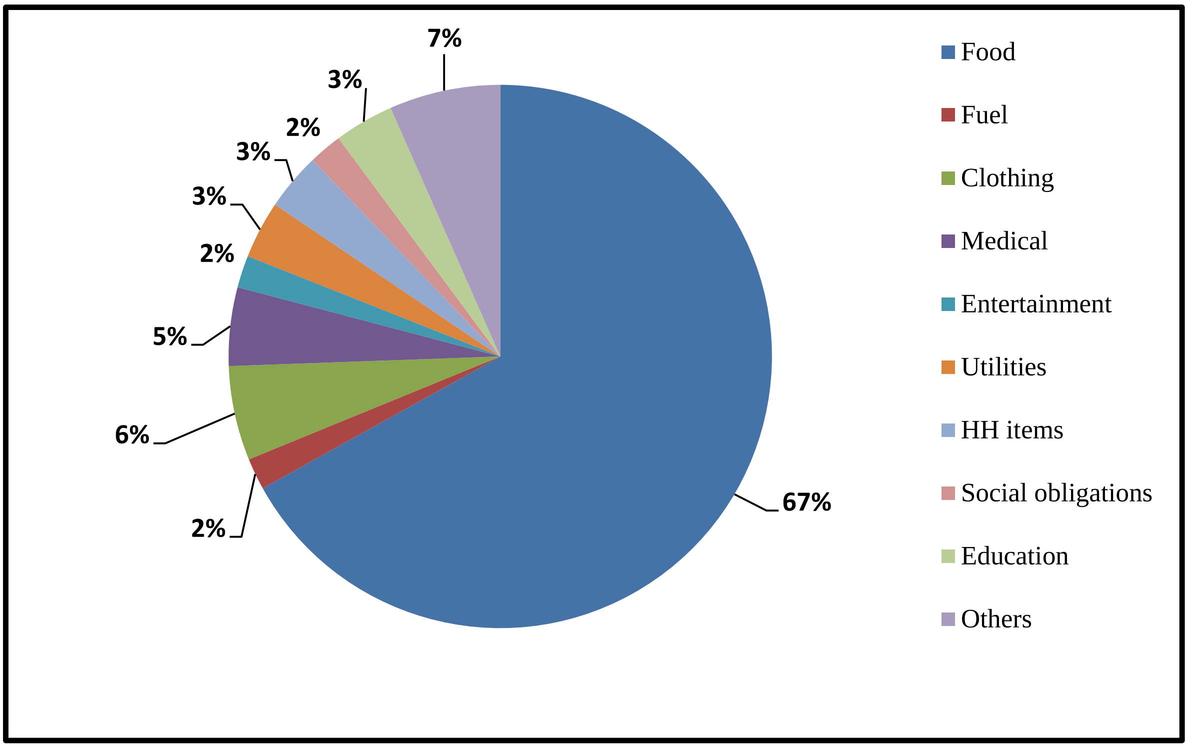


Fig. 55. Monthly expenditure pattern of the households (Rs. 6,855/-) in upper stretch (Nabadwip to Farakka). Total monthly income Rs. 8,984/-

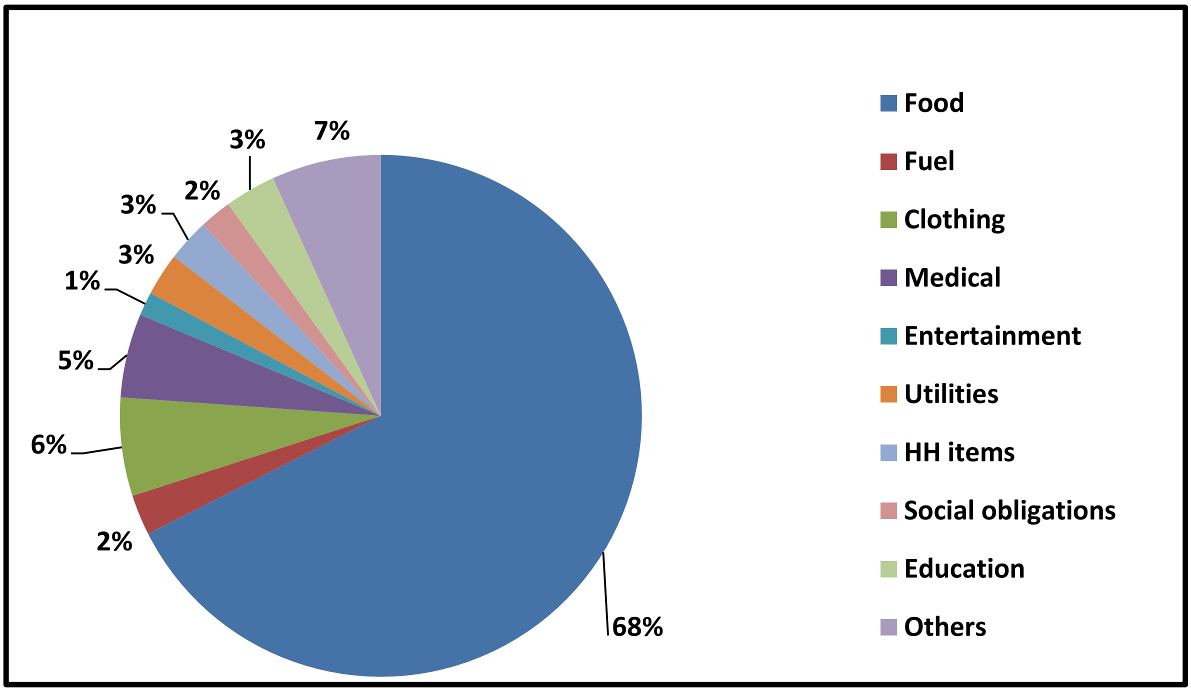


Fig 56. Monthly expenditure pattern of the households (Rs.7,191/-) for entire stretch (Sagar to Farakka). Total monthly income Rs. 9,390/-

8.2.1 Income from fisheries

The contribution of fisheries in household income is given in Table 17. In lower and middle stretches, the contribution of fishing in total income of household was found to be 75.88 % and 72.04 % respectively. In upper stretch, the contribution of fisheries was 65.32%. Overall, in all three stretches the contribution of fishing occupation in total income was estimated to be 70.30 %.

Table 17. Contribution of fisheries in household income*

	Lower stretch	Middle stretch	Upper stretch	**Entire stretch#**
Number of family surveyed	100	200	200	500
Total monthly income(Rs)	10226	9380	8984	9391
Income from fishing (Rs)	7759	6758	5868	6602
Contribution of fishing (%)	75.88	72.04	65.32	70.30

*Taking into account all the family members; # Weighted average of three stretches.

8.3 Inconveniences due to barge movement

8.3.1 Impact of barge movement on fishing

Fishers reported many constraints which were grouped into 6 categories (Table 18). The constraints are more pronounced at upper and middle stretches. The major constraints are suspension of fishing operations, dislodging of nets, distraction during fishing, loss of fishing time and chance of net damage. In upper stretch 41.50 percent of fishers reported that they have to suspend the fishing operations when barges move. They can't pay full concentration on fishing due to the apprehension about the barge movement. The barge comes almost silently and they are caught unaware. This is more problematic near the bends of river. Loss of fishing times happens due to coincidence of barge movement and fishing activities. Both the activities depend on tidal activities in the tidal stretch up to middle stretch. Moreover, 11% fishermen reported chances of accident and the percentage is 1%, 6%, 20 % in lower, middle and upper stretch respectively.

Table 18 . Inconveniences reported by fishers due to barge movement (% of fishers reported)

Parameters	**Lower stretch**	**Middle stretch**	**Upper stretch**	**Entire stretch#**
Number of family surveyed	100	200	200	500
Suspension of fishing operation due to barge movement	8.00	23.00	41.50	27.40
Net damage	8.00	15.00	20.50	15.80
Net dislodged due to waves generated	9.00	13.00	29.50	18.80
distraction during fishing	11.00	17.50	24.00	18.80
Barge anchors in fishing areas	9.00	0.00	1.50	2.40

Weighted average of three stretches.

8.3.2 Visible impact on ecology

The fishers were asked to elicit their responses on the perceived impact of barge movement on rivers and surrounding environment. Based on respondent's opinion, the impact was recorded. Around 2 percent fishermen reported soil erosion in lower stretch while 40 percent fishers narrated the same problem in upper stretch. The river in upper stretch is narrower and the wave created by the movement of barge cause soil erosion in the banks. In the lower stretch, it is not a problem as the river is wide enough to subside the wave strength when it reaches the banks. Majority of the fishers in lower stretch, did not perceive any visible impact. Fishers reported that if the barge movement continues for long, without taking adequate mitigation measures, there is a risk of loss of agricultural land located on the side of the river banks. This may damage the villagers' house on the banks also. However, only some of the fishermen of upper and middle zones narrated this problem. Some fishermen also reported increased turbidity, aquatic plants destruction, pollution in water as some of the perceived impacts due to barge movement.

8.3.3 Impact on fisheries

Some cases of destruction of nets have been reported particularly from upper and middle stretches. Keeping in view the socio-economic condition and fishing activities being the major contributor of their family income, the destruction of nets has significant impact on the livelihood of the fishermen. The observation revealed that the impact on fishing was mainly restricted to the upper and middle stretches only. However, till date the change in occupation or incidence of leaving fishing operations are not reported due to barge movement. Also, the barge movement, as such, doesn't have any impact on type of crafts used, number of family members involved and fish species caught presently..

Table 19a. Impact on fisheries (% of fishers reported)

% of fishermen	Lower stretch	Middle stretch	Upper stretch	Entire stretch#
Number of family surveyed	100	200	200	500
Destruction of nets	1.00	1.50	9.00	4.40
Boat sinks	1.00	0.50	1.50	1.00
Decrease in fish catch	2.00	7.50	28.50	14.80

Weighted average of three stretches

Barge movement has some impact on fishing hours (Table 19b). Both the barge movement and fishing activity depend upon the tidal activity, particularly in the middle and lower stretches. Fishermen have to terminate the fishing activity and winding up the nets when vessel comes. The fishermen reported that they don't have any prior information about the barge movement.

In the lower stretch, particularly from Nurpur/Roychak to Sagar the barge movement does not have any impact on fisheries. At this stretch the river is wide enough and the route is also very busy for vessel movement. Hence, fishermen were habituated with the vessel movement.

Table 19b: Impact on fishing activities

	Lower stretch	Middle stretch	Upper stretch	Entire stretch#
Number of family surveyed	100	200	200	500
Fishing time loss (% of fishermen reported)	10.00	27.00	62.00	37.60
Fishing minutes lost per incidence of barge(s) movement (out of those reported fishing time loss)	21	31	37	35
Fishing minutes lost per incidence of barge(s) movement (out of sampled population in each zone)	2.1	8.325	23.05	12.97
Catch loss reported (sampled population)	2.00	7.50	28.50	14.80
Decrease in catch in kg per incidence of barge(s) movement (out of those reported catch loss)	0.25	0.39	0.41	0.40
Decrease in catch in kg per incidence of barge(s) movement (out of sampled population in each zone)	0.005	0.029	0.1175	0.0596
Value (Rs) of decrease in catch per incidence of barge(s) movement (Only those reported)	37.5	58	61.84	60.40
Average monetary loss in Rupees per incidence of barge(s) movement (Overall sample)	0.75	4.35	17.625	8.94

Weighted average of three stretches.

The vessel itself and the subsequent wave generated disturbed the fishing activity. Overall, 38% of the fishermen reported loss of fishing hour; the percentage is lowest in lower stretch. The highest percentage of fishing hour lost is reported in upper stretch (62%), followed by middle (27%) and lower (10%) stretches. On an average, the vessel movement causes 35 minutes disturbances in fishing activities per incidence of barge movement. The extent of disturbances is 21 minutes in lower stretch to 37 minutes in upper stretch. However, approximately 15% of the fishermen reported catch loss due to barge movement out of the total sampled fishers (500 persons). They have to forego 250 to 410 g of catch in different stretches per incidence of barge(s) movement.

Assuming Rs. 150/- as the sale price of per kg of the fish, the loss in monetary terms is worked out to be Rs. 37 /- in lower stretch to Rs. 62 /- in upper stretch. Overall, in sample population, the decrease in monetary value in fish catch per incidence of barge(s) movement is estimated to be Rs. 0.75 in lower stretch and Rs. 18/- in upper stretch. In addition to this, fisherman incurs a loss of Rs. 1,500/- to 2,000/- for single instance of damage of net due to entangling with barge.

8.4 Suggestion regarding regulation of Barge movement

The fishermen face various inconveniences when the barge moves *viz.* suspension of fishing operations, not able to pay full concentration on fishing, loss of fishing times, dislodging of nets, chances of net damage and other forms of accident. Few fishermen also reported less fish catch, particularly in the upper zone. Therefore, suggestions were asked directly from the fishers which may lead to smooth movement of barges but reducing hindrance in the fishing operations.

Table 20. Suggestions for minimizing disturbances on fishing activities due to barge movement (% of fishermen reported)

	Lower stretch	Middle stretch	Upper stretch	Entire stretch#
Number of family surveyed	100	200	200	500
Can't say	23.00	24.50	13.00	19.60
Speed control	9.00	18.50	48.00	28.40
Powerful light and horn	2.00	42.00	54.00	38.80
Advanced announcement of time schedule	9.00	37.50	32.50	29.80
Compensation	5.00	39.00	24.50	26.40
Movement in designated channel	8.00	12.50	16.00	13.00
Stop the barge movement	0.00	2.00	3.50	2.20
Bank protection	0.00	4.50	5.50	4.00

Weighted average of three stretches

Around 39 % fishermen suggested improving search light and horn for easy recognition of barge movement in rivers during night (Table 20). In upper zone, heavy search light and horn were suggested by 54 % of sampled fishermen followed by speed control (48 %) and pre-announcement of time schedule (32%). Quick compensation in case of damage of nets and boats are other important suggestions.

8.5 Specific observation

The study indicated that the condition of the fishermen along the Bhagirathi–Hooghly stretch are socio-economically backward. The income from fishing activities contribute major share (70%) in their total income. The numbers of non-fishing activities are more in the upper zone as the fishery alone is not sufficient to provide full livelihood in the stretch. Although fishing hour loss due to barge movement was observed particularly in upper stretch, however, the same does not have impact of similar intensity on fish catch across the stretches. Overall, fishermen reported 13 minutes lost per incidence of barge movement. The monetary value of decrease in fish catch was observed to be meager, Rs. 0.75 in lower stretch and Rs. 4.35 in middle stretch per incidence of barge movement. The loss is relatively more in the upper stretch amounting to Rs. 18/- on an average per incidence of barge movement. Heavy search light and powerful horn are suggested for minimizing disturbances caused by barge movement on fishing activities. They are of the view that if the barge movement continues for long without taking any adequate mitigation measures, there is a risk of loss of agricultural land and villagers' house located on the banks of the river due to breaking of embankments as a result of waves generated due to barge movement.

8.6 Fishers involved in capture fisheries

It is very important to know the total number of fishers involved in capture fisheries in the studied stretch. It is reported that almost every village along both sides of the river is having some fishermen who earn their livelihood by fishing in the river. There is no census data available regarding fishers specifically involved in capture fisheries in the whole studied stretch. However, some earlier data are available related to specific gear employed by the fishers. Attempt has been made to know the number of fishers actually involved in fishing at the selected sampling centres under the present project. The observations are given below.

Hilsa fishery is most important in the studied stretch. It was reported that an estimated 20,390 number of fishermen were involved in hilsa fishery in lower stretch below Dakshineswar, whereas about 5600 number of hilsa fishermen are there in the stretch of Dakshineswar to Farakka (Bhuamik and Sharma, 2012).

A detailed fishers' census done by CIFRI during Eighties (1982-83) in the stretch of Medgachi (station between Balagarh & Ambica Kalna) to Baranagar (stretch I) and Baranagar to Nurpur (Roychak) (stretch II) of Hooghly estuary (Mitra et al., 1987). The number of fishers as reported is given in Table 21.

Table 21. Number of fisherman in Medgachi - Baranagar (stretch I) and Baranagar to Nurpur (Roychak) (stretch II) during 1982-83

Stretch	**No of fishermen villages**	**No of fishermen possessing at least one net**	**No of boats engaged in fishing**	**Fishermen population engaged in actual fishing**		**Total**
				Principal occupation	Part time occupation	
I	164	3421	2284	3206	1404	4610
II	61	1453	1401	1940	3051	4991

Similar census was again performed during 1997 and the data was compared with the above data (Mitra *et al.*, 2001). There was a significant shift from full time to part time fishermen in 1997 as compared to 1982 as given Table 22.

Table. 22. Number of fisherman in Medgachi - Baranagar (Zone I) and Baranagar to Nurpur (Roychak) (Zone II) during 1982-83 and 1997

Stretch	**No of fishermen**				**Total**	
	Full-time		Part-time			
	1997	1982-83	1997	1982-83	1997	1982-83
I	1023	3206	5430	1404	6453	4610
II	1006	1940	3006	3051	4012	4991

In the project period, an attempt has been made to know the total number of fishermen actually involved in capture fisheries at the sampling centres. It was reported that a significant number of fishers are part-time in nature. The data are given Table 23.

Table 23. Number of fishers at the sampling centres

Sl. No.	Station	No of fishermen
1.	Farakka	60
2.	Putimarimore	10
3.	Dhulian	3
4.	Hasipur	15
5.	Sarala Kishorepur	15
6.	Jangipur	40
7.	Taltala	10
8.	Sundarpur	5
9.	Jiaganj	40
10.	Lalbagh	60
11.	Gandhi Nagar	4
12.	Sammati Nagar	9
13.	Kestomati	30
14.	Hotnagar	20
15.	Chowrigacha	35
16.	Plassey	6
17.	Katwa	35
18.	Pakhichar	35
19.	Prachin Mayapur	250
20.	Jhasudanga	15
21.	Nabadwip	95
22.	Ambica Kalna	300 (35 full-time)
23.	Balagarh	300 (35 full-time)
24.	Medgachi	35
25.	Halisahar	41
26.	2 no khasbati colony	10
27.	Hotath pally kalyani	17
28.	Sannyalchor	32
29.	Triveni (Netaji Colony)	35
30.	Shayamsundari ghat	6
31.	Ichapur	15
32.	Hooghly Ghat	100
33.	Bichalighat	30
34.	Nawabganj-Debitala	35
35.	Baranagar-Bally	30
36.	Uluberia	15
37.	Godakhali	12
38.	Burul	45
39.	Henrar Khal	10
40.	BarendraGhat	8
41.	Roychak	6
42.	Ghoramara Island	8
43.	Mayagoalini Ghat	5
44.	Jaganathpur	15
45.	Sagar light house	12

(The numbers are approximate and as per the data collected through surveys during sampling)

8.7 Major fishing gears in operation

Since fishers are facing difficulty in operation of some of the fishing nets under present circumstances, effort were made to record the details of fishing nets and gears which are in use. The data will serve as the base line for understanding impact of barge movement on fishing operations. Major fishing gears involved in capture fishery in the Bhagirathi-Hooghly river stretch are the various forms of gill net and bag net. On an average, bag nets contribute 73% whereas drift gill net contribute 24% of the total fish catch in Hooghly estuary (Mitra *et al*., 2001). The rest of the gears contribute only 3% of the total catch. Lot of variations in material and mesh size in drift gill net is observed depending upon the target fishes. However, the drift gill net is the major nets used to catch hilsa, the main migratory fish of Bhagirathi-Hooghly river system. Though the recommended mesh size for hilsa is >90 mm to avoid catch of smaller hilsa (<500 gm), net with smaller mesh size of 55-80 mm is quite rampant especially during winter migration of hilsa. Even 14-26 mm mesh size drift gill nets are used to catch juvenile hilsa (10-30 gm) during their return journey to sea especially during the months of March-May. All different types of gill nets have their distinct seasonality depending upon the availability of the target species.

Monofilament drift gill net (locally called *current jal / chhandi jal*) of different mesh size targeted for hilsa mainly operated during monsoon months (July-October) and winter months (February-March) to catch them during migration. Fishers use different mesh size net piece to assemble together to make a long drift gill net. Width of the net varies widely. However, length of drift gill net increases as width of the river increases. At Lalbagh, in tin-made *dingi* boats only one piece of net (approx. 100 ft long) is used whereas in large wooden boats 3 pieces are used to cover the whole river there. At Dakshineswar, 6 such pieces are added to have a length of approx. 750 ft. At Godakhali (between Uluberia and Burul), length of hilsa net is approx. 1800 ft, which increases to approx. 8400 ft at Nischintapur region (above Ghoramara Island). In some places, those nets are operated even during non-migration period as some hilsa are available throughout the year. At Nischintapur, drift gill net are set both at surface or bottom using proper floats. As expected, bottom set drift gill net drifts less with time, but catch is more in surface set gill net.

Nets with bigger mesh size (locally called cot jal made of parachute wire; 5-9" mesh size) are operated in entire stretch of the river to catch large fishes. At Chowrigacha (near Hotnagar), cot jal catch includes *Catla catla*, *Pangasius pangasius* etc. At Diamond Harbour (below Roychak), such nets are called as Pangas jal (as it catches *Pangasius pangasius*). At still lower stretch, 9" mesh Sele jal is used during winter months (named such as its catch includes large sele fish, *Polydactylus indicus*). Other targeted drift gill net like *Bhola jal* (42, 44, 46, 48 mm mesh gill net) to catch sciaenids like *Otolithoides pama* is operated in lower estuary mainly during the months of September-November. Topsey jal (26, 28 mm mesh net targeting *Polynemus paradiseus*) is used during the months of February-June. Vacha / Gorcha/ Ghero / Ghoura jal with 1" mesh size gill net targeting *Eutropichthys vacha*, *Clepisoma garua* etc. are operated at different stations from Farakka to Triveni. All selective gill nets are observed to catch some other fishes with similar dorso-ventral length. Piuli jal (14 mm mesh) meant for *Aspidoparia morar* are also observed to catch small hilsa juveniles in upper Hooghly estuary and Bhagirathi river. Similar mesh size net, Chela jal was observed to be operated in upper estuary. Bhola / Topsey jal catch in lower estuary also have minor contribution from *Sillago* sp., *Setipinna phasa*, *Eleutheronema tetradactylum* etc. and even small size hilsa. Similarly, Hilsa jal catch in middle estuary observed to include *C. garua*, *S. phasa* etc. In lower estuary, tidal and lunar cycle used to influence catch of both gill net and bag net. For example, in September, same fisher at Diamond Harbour was observed to use hilsa jal during days around full / new moon (Bhora kotal) whereas during other days when flow is less (mora kotal) operates bhola jal. Similar to current jal, gill net made with nylon are used to catch other fishes especially near shoreline areas. Various other forms of drift gill nets with different mesh size like Nagin jal, Kajli jal, Phasa jal, Dholi jal, Gule jal are used in different regions targeting various fishes with higher abundance. Nagin jal, Kajli jal, Vacha jal, Ghero jal are almost similar type gill net with slightly local variation. At Prachin Mayapur (Nabadwip area), Dholi jal catch included Tulbele (*Sillago panijus*), Tengra (*Mystus* sp.) etc. Patan jal is a set gill net observed to be used in some places like Balagarh. Kona jal, though previously reported as gill net, is observed to catch fishes by trapping them in pockets near sinker.

Bag net operation generally remains suspended during monsoon months of July-October at most of the places because anchoring rope of bag net creates problem for drifting of gill net targeting hilsa. Bag nets are not used during full/new moon days due to heavy water current in lower estuary like Nischintapur, Diamond Harbour, *etc.* whereas in upper estuary from Triveni to Godakhali, catch is more during those full/new moon days. Bag net catch used to increase from upper to lower estuary. On an average, 15-20 kg catch was observed per bag net operation at Nischintapur. Bag nets are mostly set at bottom using PVC / Thermocol float, however surface set bag net are observed in some areas like Godakhali.

Fig. 57. *Current jal* with hilsa catch

Fig. 58. *Sele jal* to catch large fishes

Fig. 59. *Bhola jal* along with its catch at D. Harbour

Fig. 60. *Topse jal* targeting Topsey (*Polynemus paradiseus*)

Fig. 61. *Kona jal* operation in Farakka

Fig. 62. *Vacha / Ghoura jal* with its catch of *Clupesoma garua* & *Eutropichthys vacha*

Fig. 63. Small mesh gill net responsible for catch of hilsa juvenile (10-20 gm)

Fig. 64. *Chela jal*, small mesh gill net targeting *Chela* / *Salmostoma* sp.

Fig. 65. *Dubo Beenti* **-** bottom set bag net, the main fishing gear of Hooghly estuary

Fig. 66. *Bhasa beenti*, surface set bag net operated at middle Hooghly estuary

9.0 Component III: Water and sediment quality of the studied river stretch

9.1 Physico-chemical features of water

9.1.1 Water Temperature

A congenial water temperature for aquatic production processes has been recorded in the river stretch of Farakka to Sagar Island (26 – 32 ^{o}C). Higher water temperature was recorded during monsoon survey as compared to pre-monsoon period (Fig. 67). Increasing trend of water temperature was noticed from Farakka to Triveni during both the periods, whereas tidal stretch showed decreasing trend from Dakshineswar to Ghoramara. Rain decreased water temperature at Uluberia and Burul as compared to nearby stations during premonsoon.

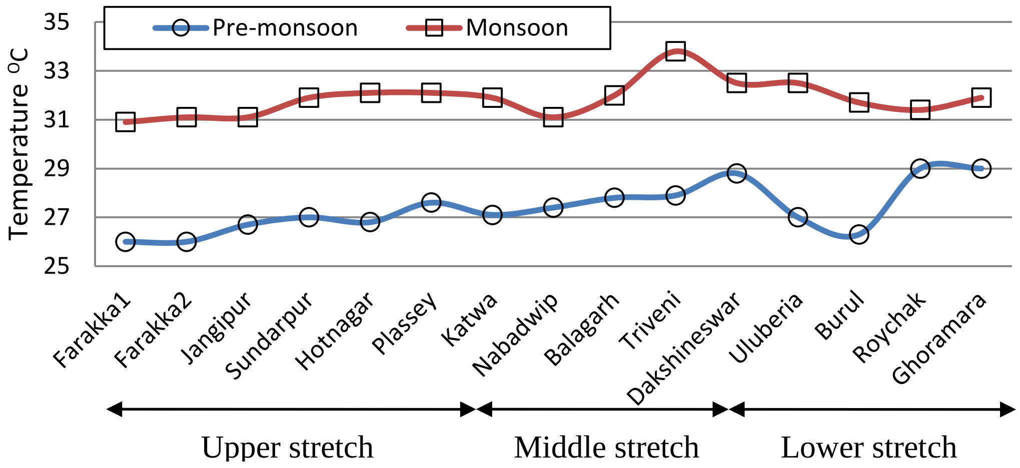


Fig 67. Spatio-temporal changes of water temperature

9.1.2 Water depth

It is one of the most critical factors because the physical process of barge movement requires the water draft of about 3.0 m. Aquatic organisms also require sufficient water depth for good biological activity and migration. River depth has been reported to have an important role in migration of *Tenualosa ilisha* from sea through the estuarine corridor to river Hooghly for breeding which prefers about 5.2 m depth for their migration (Bhaumik *et al*., 2011). Up to 3-4 m variation in river depth is quite common especially in gradient and marine zone sampling centers in Hooghly estuary due to semi-diurnal tidal rhythm. During early part of twentieth century, Hora (1943) reported severe scarcity of freshwater discharge through the river Hooghly with evidence of 'a foot depth' of water in parts of Hooghly during low tide. Higher freshwater discharge through feeder canal in post-Farakka period increased the water depth of Hooghly estuary significantly. The same locations as indicated by Hora (1943), are now retaining about 6-7 m water depth throughout the year. Not much variation between pre-monsoon and monsoon survey in water depth was observed during our survey which may be due to regulated release of water through feeder canal feeding the whole Hooghly-Bhagirathi river system (Fig. 68). Observed water depth variation was due to change in season, some variations in sampling site and in the estuarine stretch due to variations in tide. In some of the sites of the navigation channel the depth has been noticed to be very low of about 3 m.

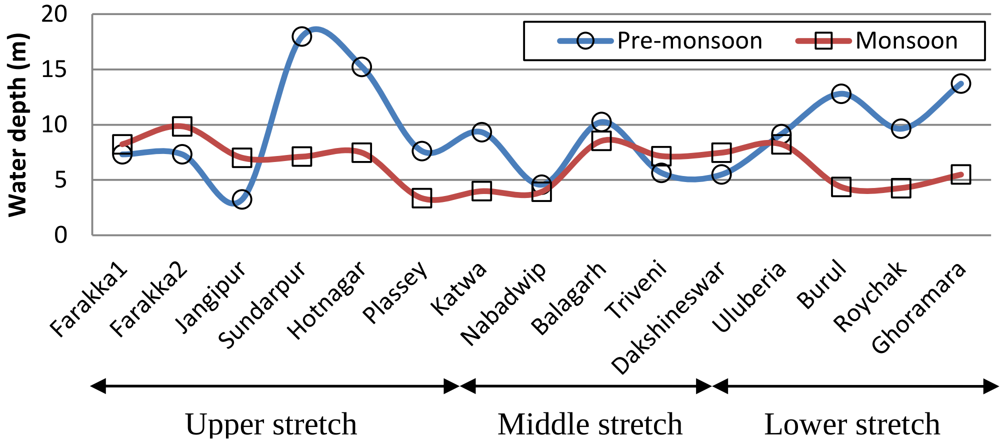


Fig.68. Spatio-temporal changes of water depth

The bathymetric details of the river stretch are also given in Fig. 69 to 74.

Fig. 69. Sagar to Nayachar stretch of National Waterway No. 1 (The notations along the water way namely 6_3, 8_4, *etc.* represent water depth as 6.3 m, 8.4 m and so on)

Fig. 70. Nayachar to Ravindra Setu (Kolkata) stretch of National Waterway No. 1 (The notations along the water way namely 6_3, 8_4, *etc.* represent water depth as 6.3 m, 8.4 m and so on)

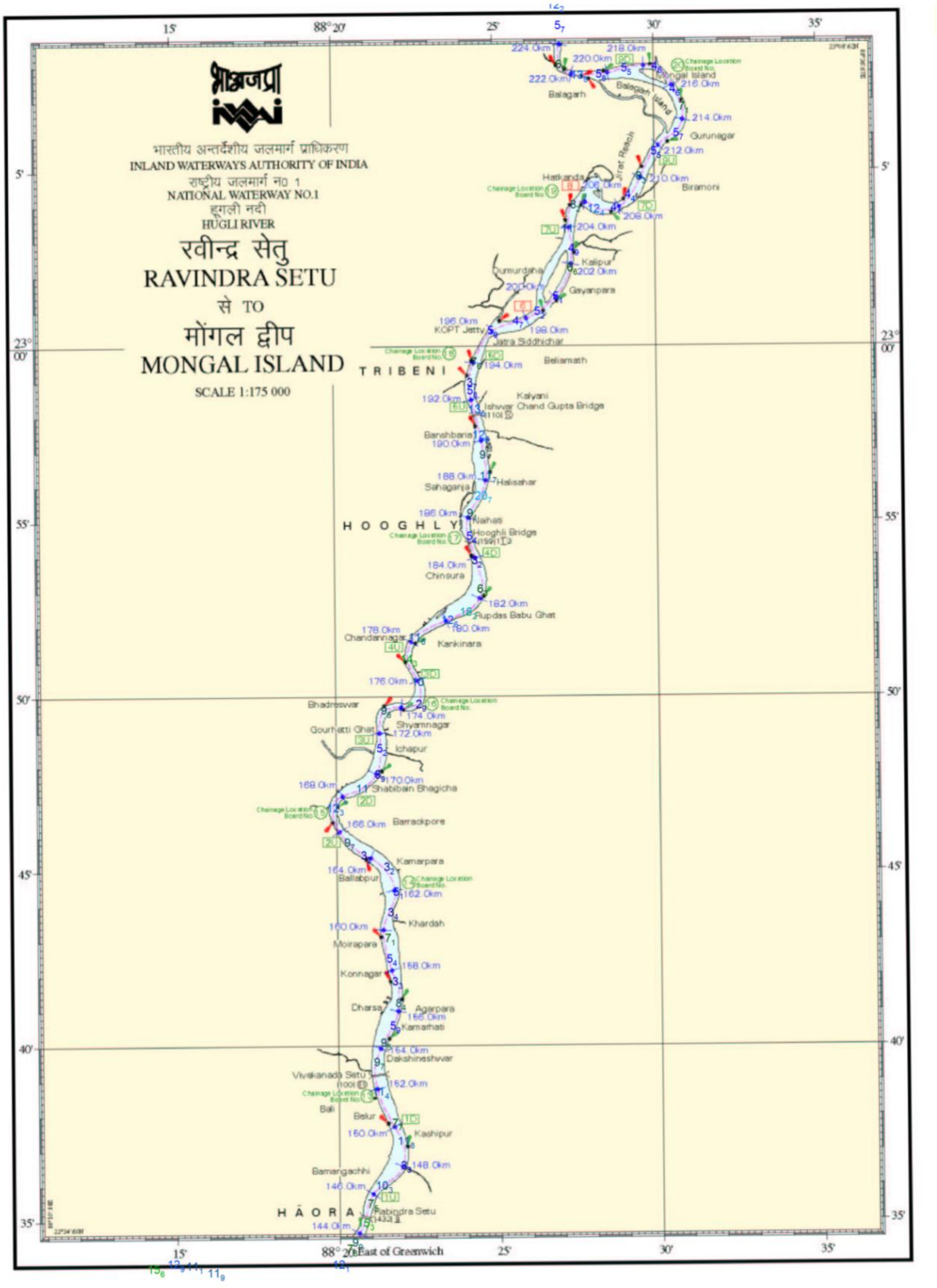


Fig. 71. Ravindra Setu (Kolkata) to Mongal Island (Balagarh) stretch of National Waterway No. 1 (The notations along the water way namely 6_3, 8_4, *etc.* represent water depth as 6.3 m, 8.4 m and so on)

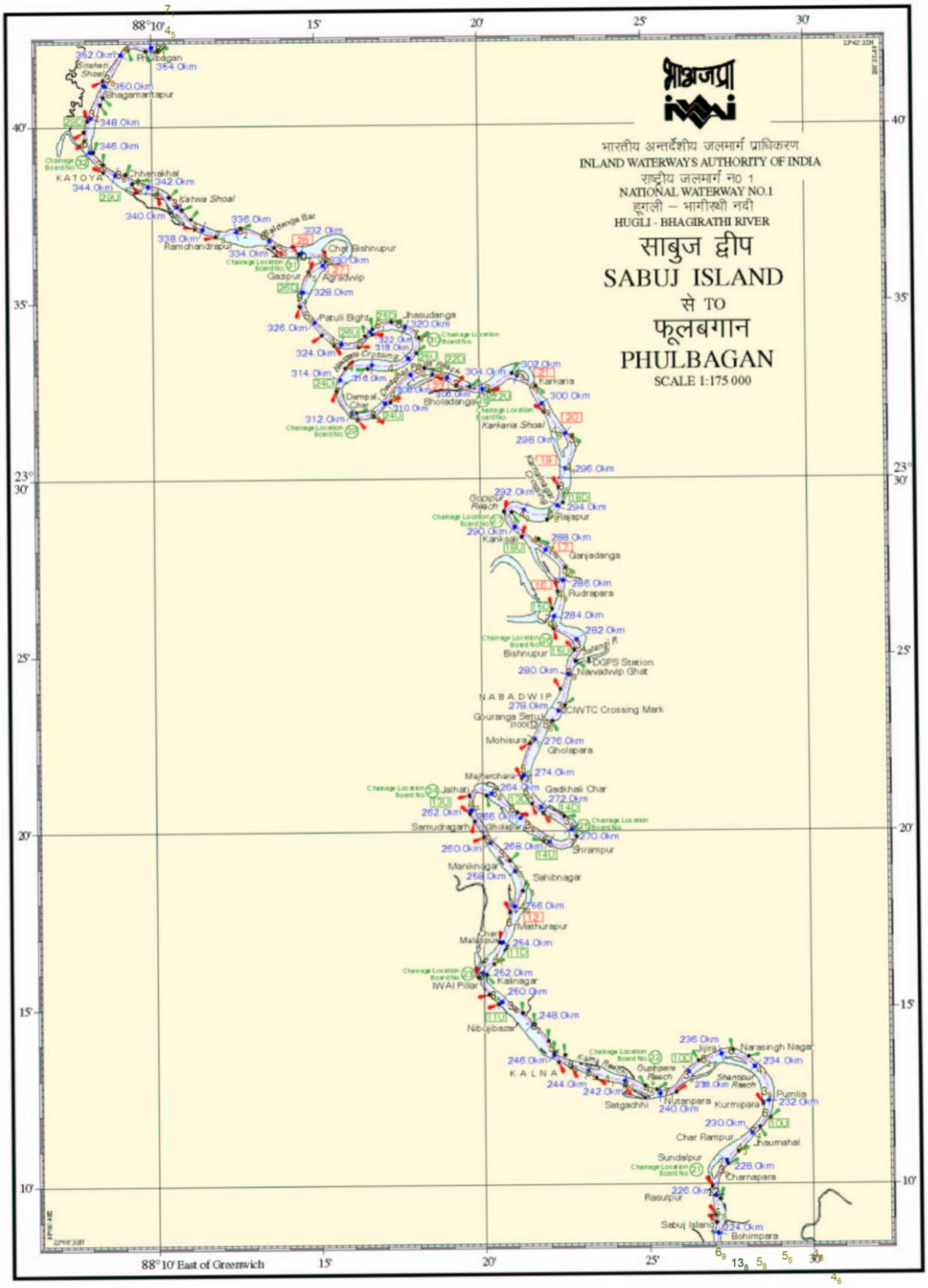


Fig. 72. Sabuj Island (Balagarh) to Phulbagan (Katwa) stretch of National Waterway No. 1 (The notations along the water way namely 6_3, 8_4, *etc*. represent water depth as 6.3 m, 8.4 m and so on)

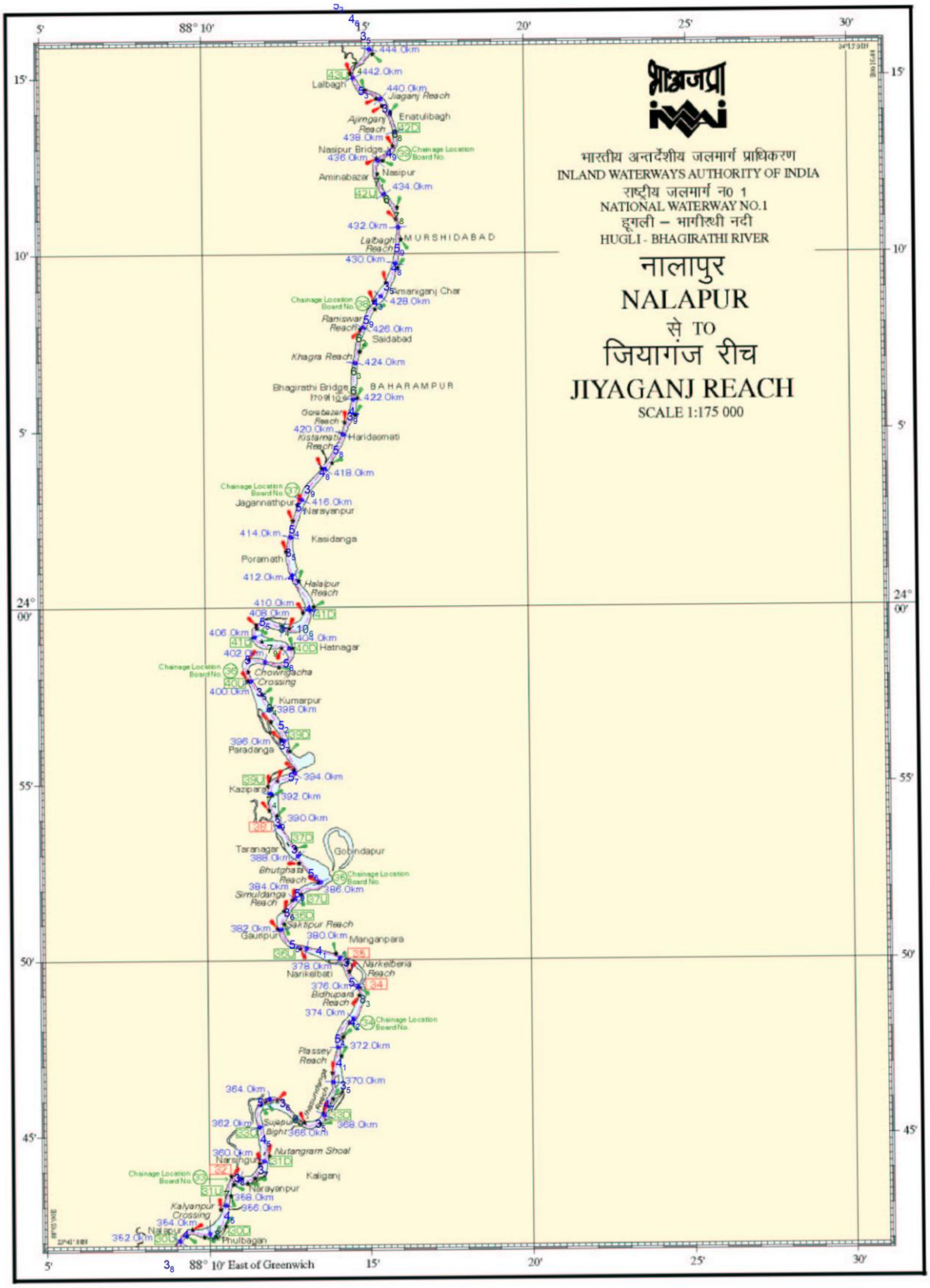


Fig. 73. Phulbagan (Katwa) to Jiyaganj (Lalbagh) stretch of National Waterway No. 1 (The notations along the water way namely 6_3, 8_4, *etc*. represent water depth as 6.3 m, 8.4 m and so on)

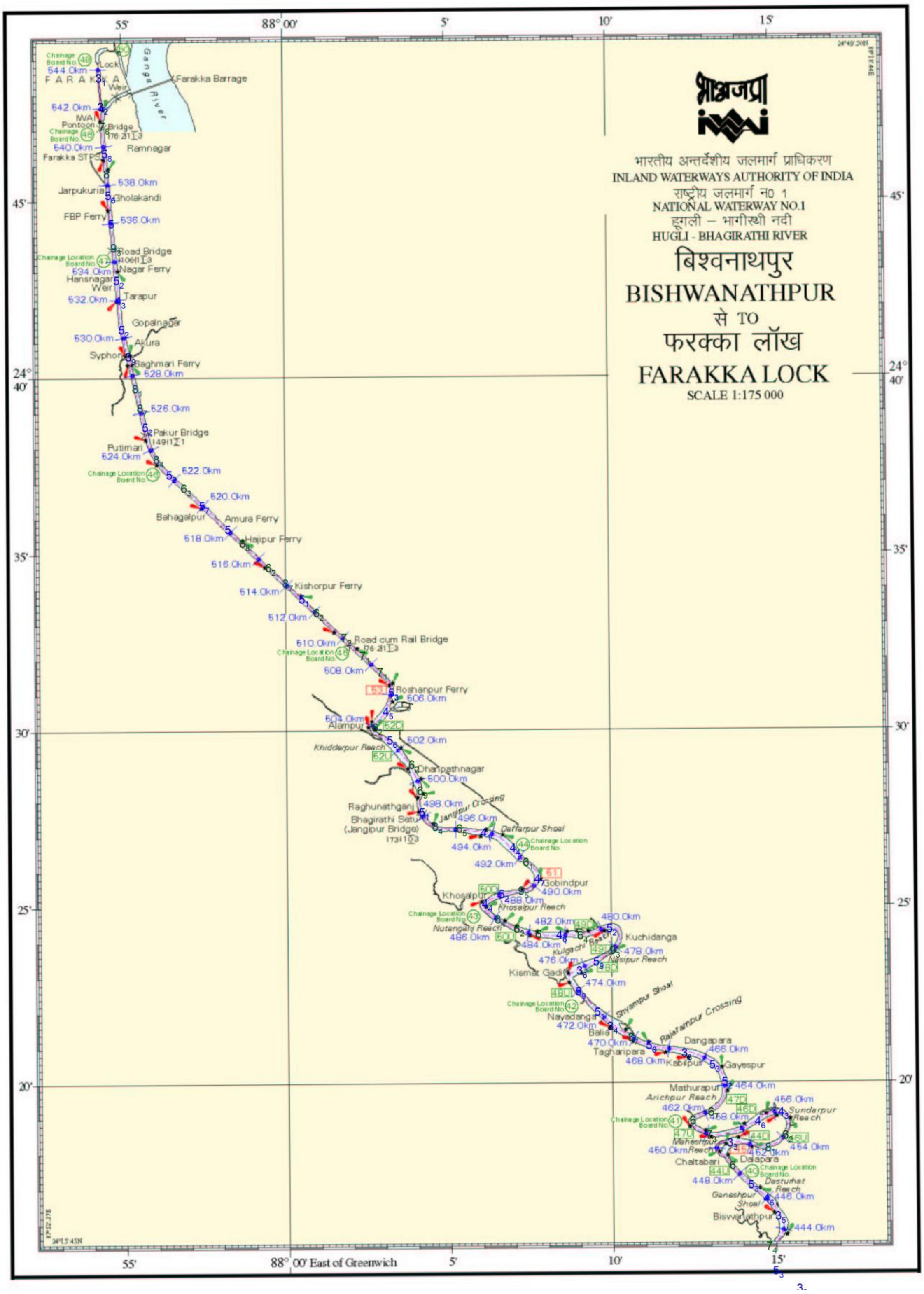


Fig. 74. Biswanathpur (Lalbagh) to Farakka stretch of National Waterway No. 1 (The notations along the water way namely 6_3, 8_4, *etc*. represent water depth as 6.3 m, 8.4 m and so on)

9.1.3 Water transparency

It indicates the penetration of light in the water column and regulation of the rate of photosynthesis and thereby the autochthonous food chain in the river. A significant decreasing trend of water transparency was observed from Farakka to Ghoramara island during pre-monsoon (Fig. 75). However, monsoon runoff made whole stretch highly turbid in nature with little variation among the stations. In Hooghly-Bhagirathi river system, transparency is mainly controlled by suspended silt or clay particle as concentration of plankton or suspended detrital load generally remained low.

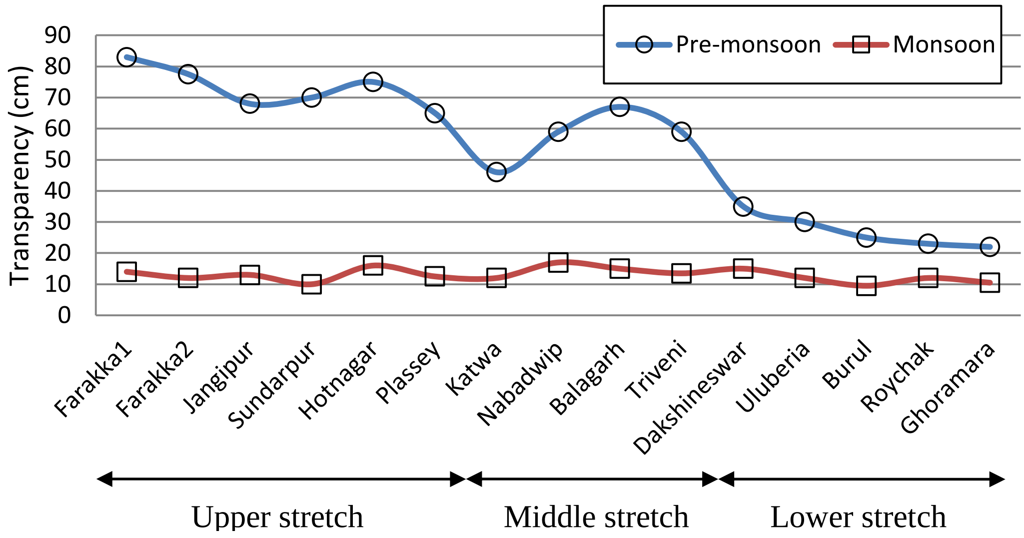


Fig. 75. Spatio-temporal changes of water transparency

9.1.4 Dissolved oxygen

Most important parameter for survival and growth of the aquatic community. It is also an indicator of aquatic health. Significantly lower dissolved oxygen was recorded during monsoon as compared to our pre-monsoon survey. Low photosynthetic activity by low density of plankton in highly turbid water during monsoon caused such lower dissolved oxygen (DO) in water. From Farakka to Triveni, DO remain relatively constant during both the seasons. Industrial and urban effluents decreased DO content significantly in city stretch which again recovered in lower estuary (Fig. 76). Productive water should have DO concentration more than 5 mg/l. The recorded lower level of dissolved oxygen of 3.8 ppm is common in the river stretch as has been observed earlier (reports on Survey of river Ganga 2012-13 of CIFRI and data of CPCB, MoEF, Government of India).

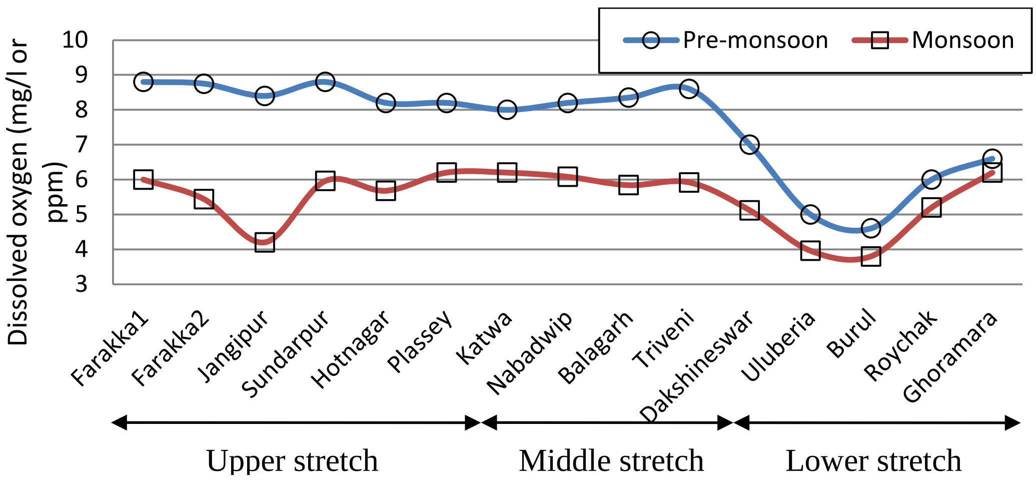


Fig. 76. Spatio-temporal changes of dissolved oxygen

9.1.5 Water pH

Lowering of water pH from Triveni onwards was observed during our both the surveys (Fig. 77). This was due to the entry of effluents into the river. Decomposition of sewage organic matter releases CO_2 and humic acid to make water acidic. However, water remained alkaline at all centers, a prime requisite for survival and growth of fishes as water pH in the range of 7.0-8.0 is known to be ideal for fish growth. As a whole, the water pH was in congenial level.

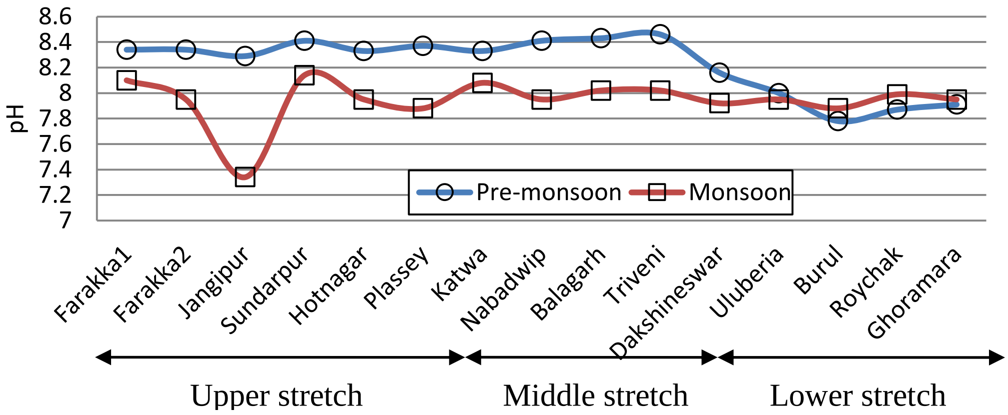


Fig. 77. Spatio-temporal changes of water pH

9.1.6 Total alkalinity

In the studied stretch of the river alkalinity recorded was in the favourable range in relation to the aquatic productivity although during pre-monsoon, total alkalinity was much higher (112-115 mg/l) as compared to monsoon (56-90 mg/l) (Fig. 78). Spatial variation was less during pre-monsoon as compared to monsoon.

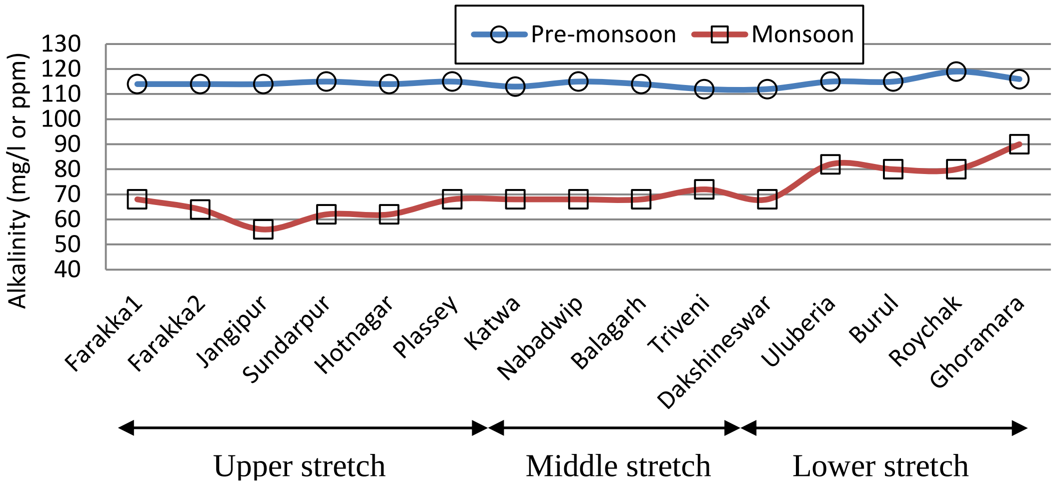


Fig. 78. Spatio-temporal changes of total alkalinity

9.1.7 Total hardness

Total hardness (TH) was also recorded in the favourable range with respect to aquatic productivity. During pre-monsoon, total hardness was significantly higher in freshwater stretch as compared to total hardness in monsoon (Fig. 79). Total hardness starts increasing from Uluberia onwards during both the seasons due to mixing of saline water during high tide. Roychak and Ghoramara island observed higher total hardness due to ingress of sea water.

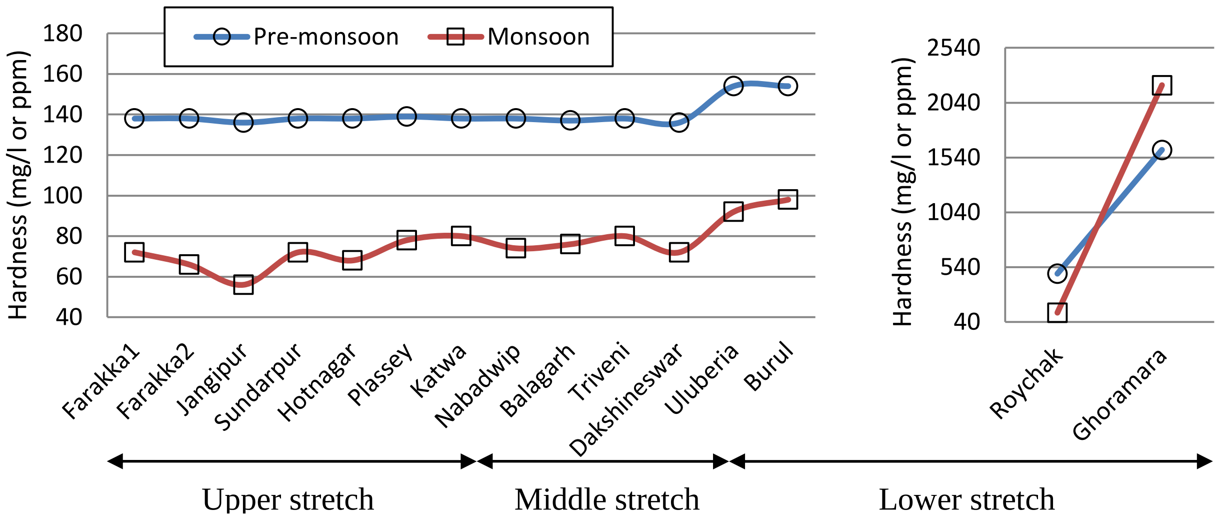


Fig.79. Spatio-temporal changes of total hardness

9.1.8 Specific conductivity

Specific conductivity showed similar trend of hardness as saline water controls both the parameters. Specific conductivity is an index of the amount of water soluble salts present in water. Higher sp. conductivity was recorded during pre-monsoon as compared to monsoon (Fig. 80). Saline water intrusion made sp. conductivity higher in Roychak and Ghoramara island.

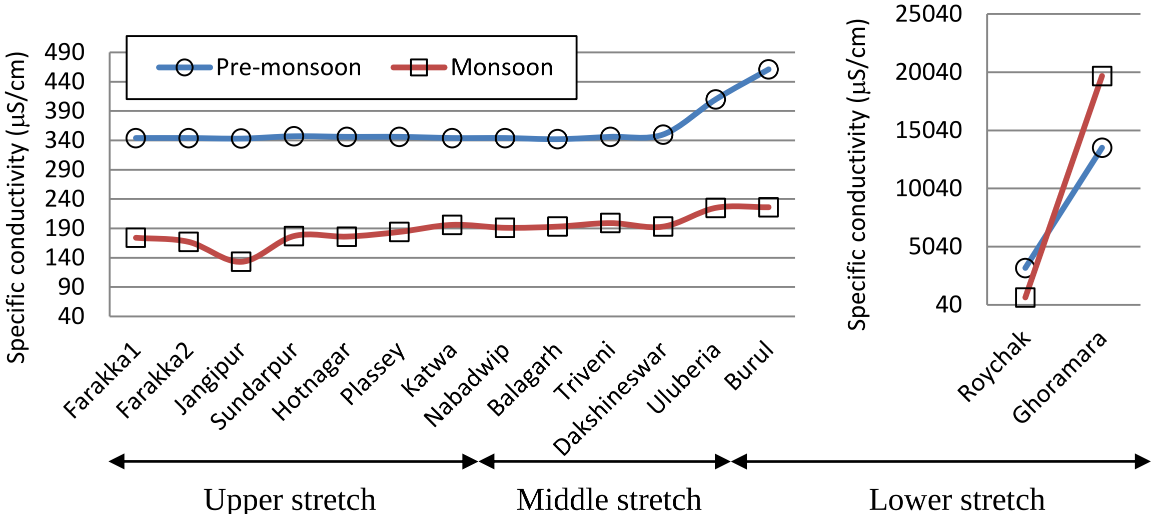


Fig.80. Spatio-temporal changes of specific conductivity

9.1.9 Salinity

Salinity is the key parameter controlling distribution of fish and other aquatic organisms in any estuary. Monsoon freshwater inflow made Roychak a freshwater zone (0.27 ppt) as compared to 1.6 ppt recorded during pre-monsoon survey (Fig. 81). Salinity at Ghoramara island used to be strongly influenced by tidal action. Higher value of salinity at Ghoramara island during monsoon may be attributed to sampling during high tide.

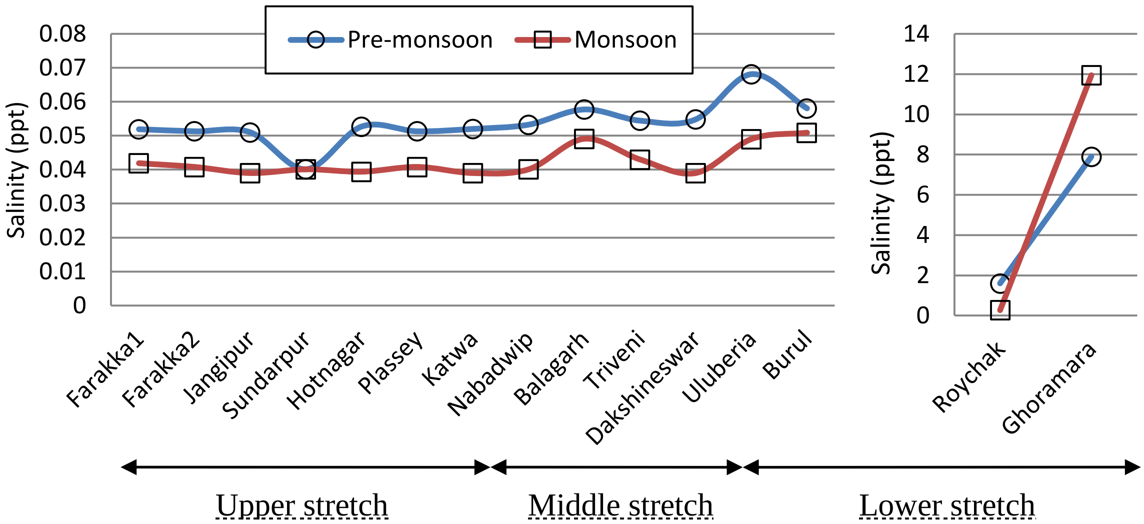


Fig. 81. Spatio-temporal changes of salinity

During pre-Farakka barrage (before 1975), water flow was much less through Bhagirathi- Hooghly river system. Accordingly, effect of saline water intrusion during high tide was felt even at Barrackpore (Nawabganj) with salinity up to 1.16 ppt (Fig. 82). However, increase in freshwater discharge in post-Farakka period increased the length of freshwater stretch downwards up to Godakahli (between Uluberia and Burul). Accordingly distribution and fish species availability was also thoroughly modified. Details of the salinity based zonation and its effect on fish species distribution was recently reviewed by Manna *et al*. (2013).

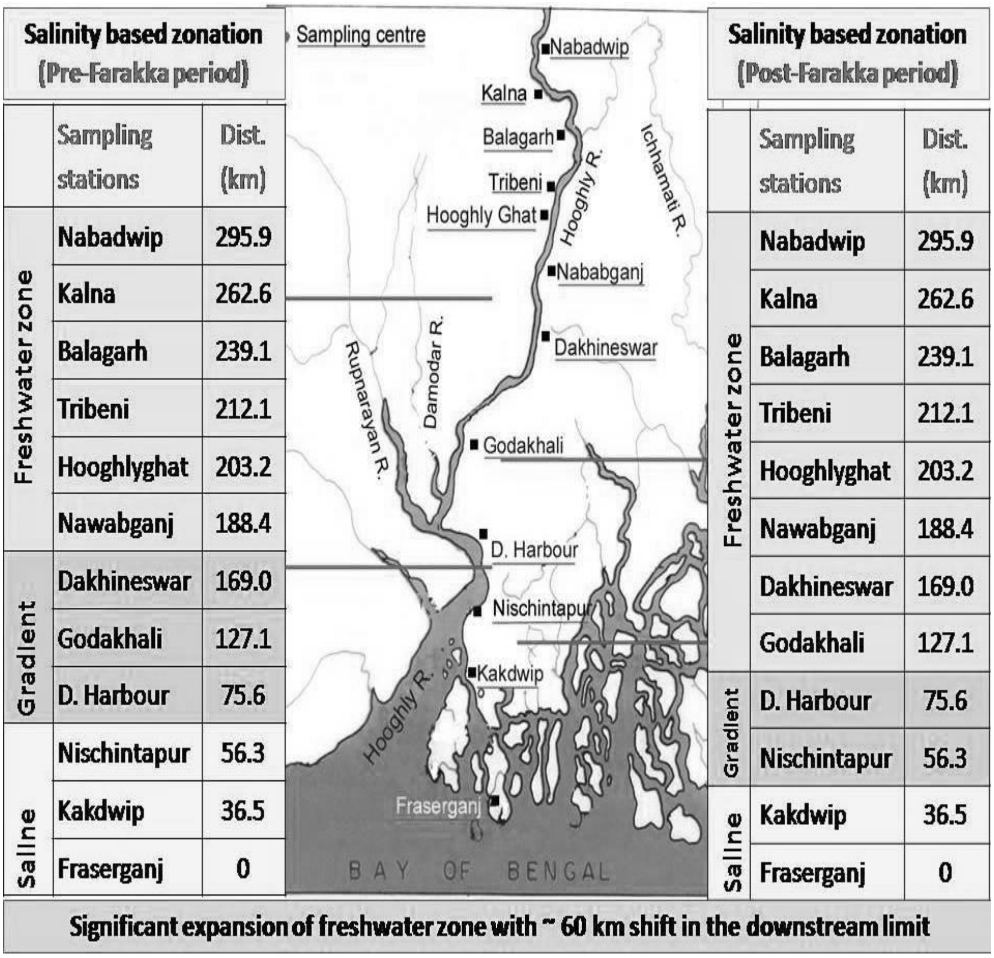


Fig. 82. Salinity map of river Hooghly during pre- and post-Farakka period

(Source: Manna et al., 2013)

9.1.10 Biochemical oxygen demand

Though Hooghly-Bhagirathi river system receives lot of pollution from cities and towns along the river, BOD level was not much higher mainly due to dilution by large volume of water diverted from Farakka barrage as well as ingress of sea water during high tide (Fig. 83). In effluent discharge point generally very high BOD was observed, which reduced after some distance due to dilution by mixing with river water. Pre-monsoon survey observed higher BOD than that in monsoon at most of the stations during our survey. At Triveni, during monsoon, a significantly higher BOD was recorded which reduced slowly in downstream stations.

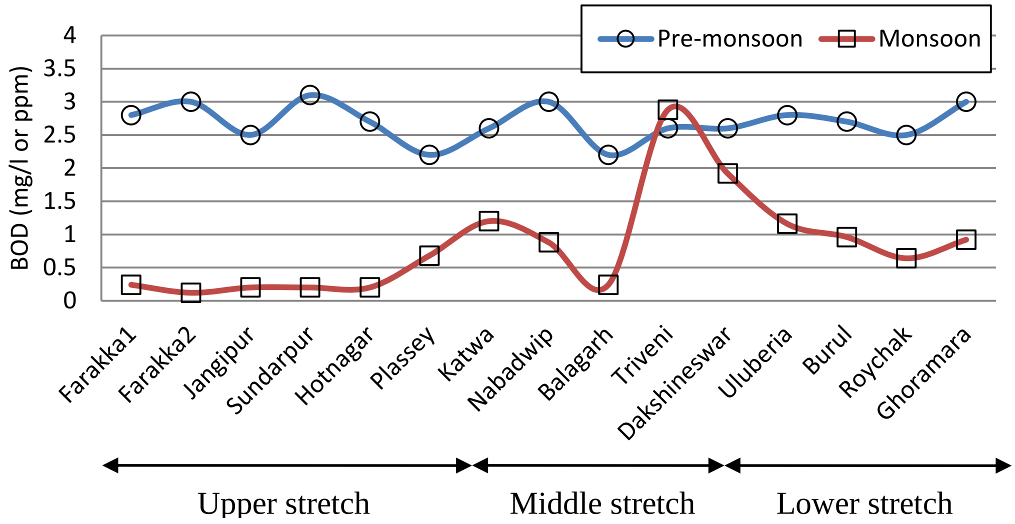


Fig.83. Spatio-temporal changes of biochemical oxygen demand

In December 1984, the MoEF, Government of India, prepared an action plan for immediate reduction of pollution load of the Ganga to bathing standard (DO not <5 ppm; BOD not >3 ppm, coliforms not >10,000 per 100 ml). The Government of India approved this as Ganga Action Plan (GAP) in April 1985. According to Ganga Action Plan, the data developed in the Hooghly river indicated that the stretch below Palta, the average BOD load reaches more than 3.0 during the premonsoon months when the head water discharge remains relatively low. The effect is well understood from the data of Central Pollution Control Board (Table 24). In the present study, although the recorded BOD was up to 3.1ppm, the dissolved oxygen was recorded to the value as low as 3.8 ppm during monsoon sampling at Uluberia-Burul stretch.

Table 24. Average BOD load of river Hooghly in different years

	Year				
Stretch of Ganga	2011	2010	2003	1993	1986
Palta	2.1	1.6	2.4	2.7	1.0
Dakshineswar	4.0	4.2	3.8	-	-
Uluberia	2.8	3.2	5.5	1.9	1.1
Diamond Harbour	2.3	4.2	1.3	-	-

(Source: CPCB, 2009, 2013)

9.1.11 Chemical oxygen demand

Lower chemical oxygen demand was observed at most of the stations during monsoon survey as compared to pre-monsoon (Fig. 84). This is due to dilution by monsoon rain which decreased the amount of oxidizable organic matter per unit volume. Though untreated municipal wastewater discharge is quite high in city stretch, dilution by large volume of water kept COD within the limit in lower stretch of river Ganga.

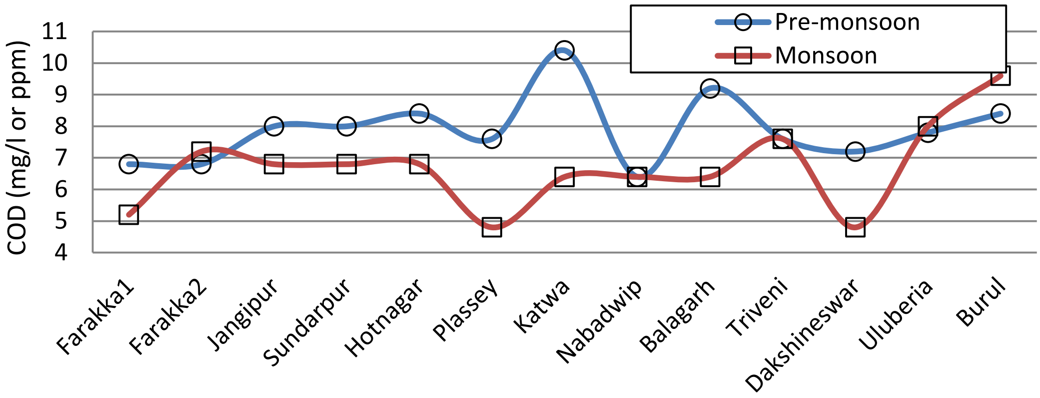


Fig. 84. Spatio-temporal changes of chemical oxygen demand

9.1.12 Soluble reactive phosphate phosphorus (SRP)

Although the studied river stretch receives large amount of effluents from the adjoining towns and cities, the effect was not recorded in the phosphate contents in the study sites probably due to huge dilution and strong tidal activities. The recorded levels are indicated in Fig. 85.

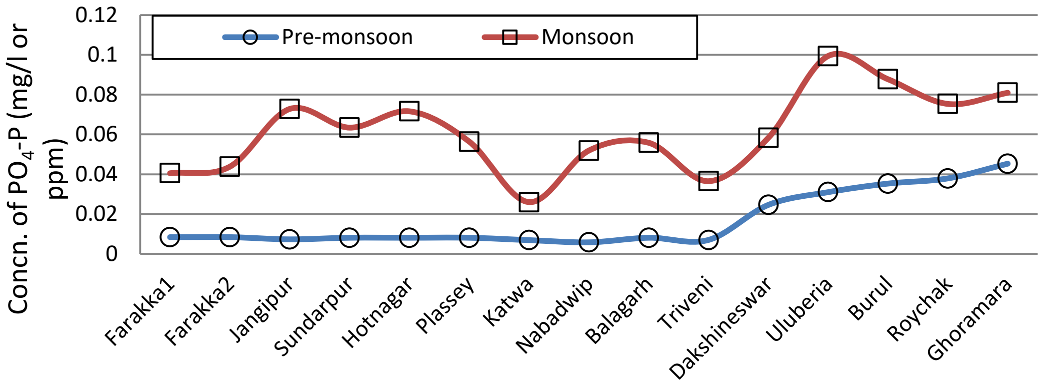


Fig. 85. Spatio-temporal changes of PO_4-P

9.1.13 Total Nitrogen

Like phosphate phosphorus, the total inorganic nitrogen in water was also recorded low. It is contributed by NH_4^+, NO_2^- and NO_3^-. The recorded water ammonia contents during the sampling periods are presented in Fig. 86.

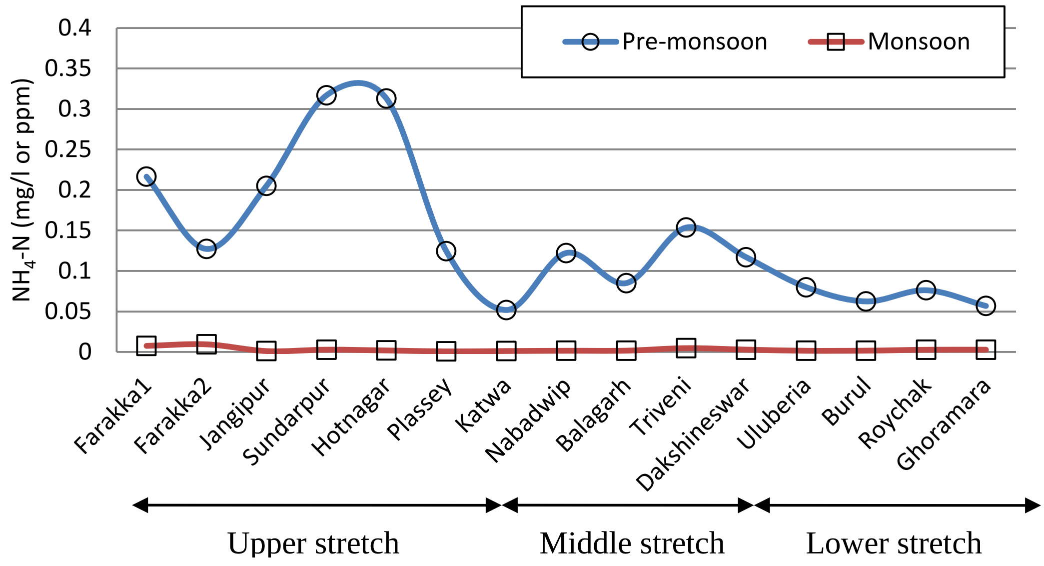


Fig. 86. Spatio-temporal changes of NH_4-N

9.1.14 Silicate-Si

We came across a similar decreasing trend of silicate from freshwater to saline zone during our study as is routinely observed. During pre-monsoon, sharp declining trend was observed from Burul downwards, whereas sharp decline of silicate-silica was observed from Roychak to Ghoramara during monsoon (Fig. 87).

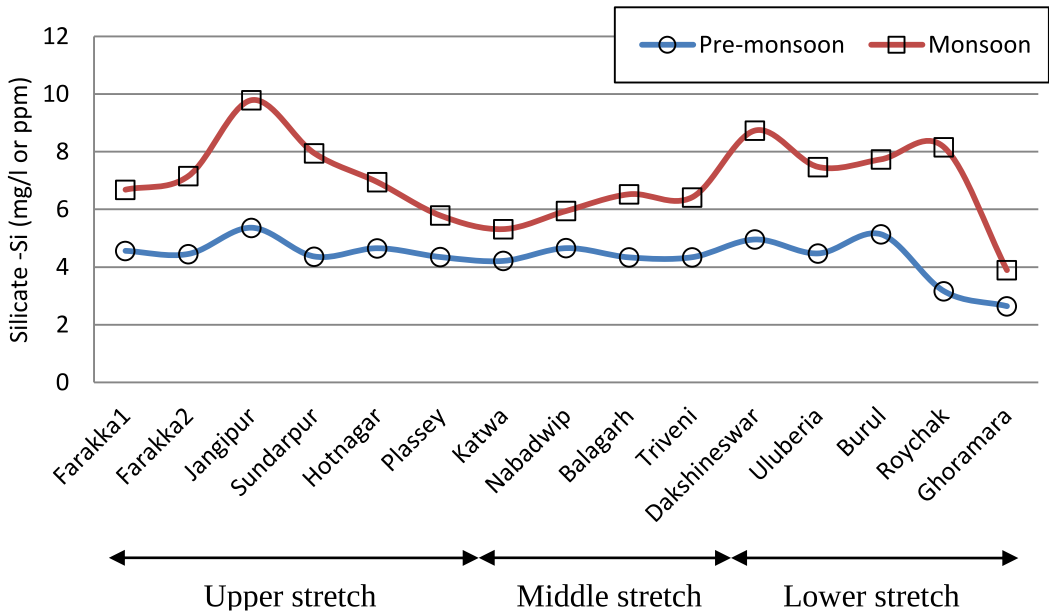


Fig. 87. Spatio-temporal changes of silicate-silica

9.2 Physico-chemical features of sediment

Along with water quality parameters the sediment quality parameters were also analyzed.

9.2.1 Sediment texture

During pre-monsoon, river bottom was mostly sandy in nature at all the sampling stations. During monsoon, surface run-off increased silt percentage at some stations especially in lower stretch. Clay content was generally low except at few stations with slightly higher values. In city stretch sampling stations like Balagarh, Triveni, Dakshineswar observed slightly higher content of clay.

9.2.2 Sediment pH

It is one of the most important critical factors as it controls all chemical reactions like mineralization, availability of phosphorus, etc. Growth and survival of benthic communities are also governed by soil pH. During monsoon survey, slightly lower pH was observed at most of the stations of the studied stretch (Fig. 88). However, during both the seasons sediment at all the stations was alkaline in nature.

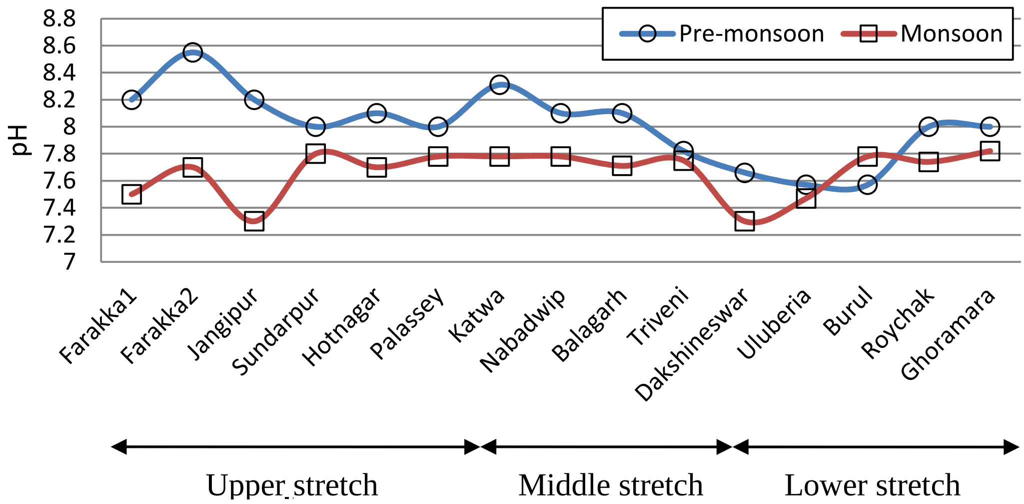


Fig. 88. Spatio-temporal variation of sediment pH

9.2.3 Sediment specific conductance

Sediment sp. conductance of the studied river stretch was observed to be mostly governed by sp. conductivity of overlaying water. Ions of saline water are absorbed in sediment governing its sp. conductivity in lower stretch. Higher values at Dakshineswar as compared to nearby stations may be attributed to intense pollution load through drains and canals (Fig. 89).

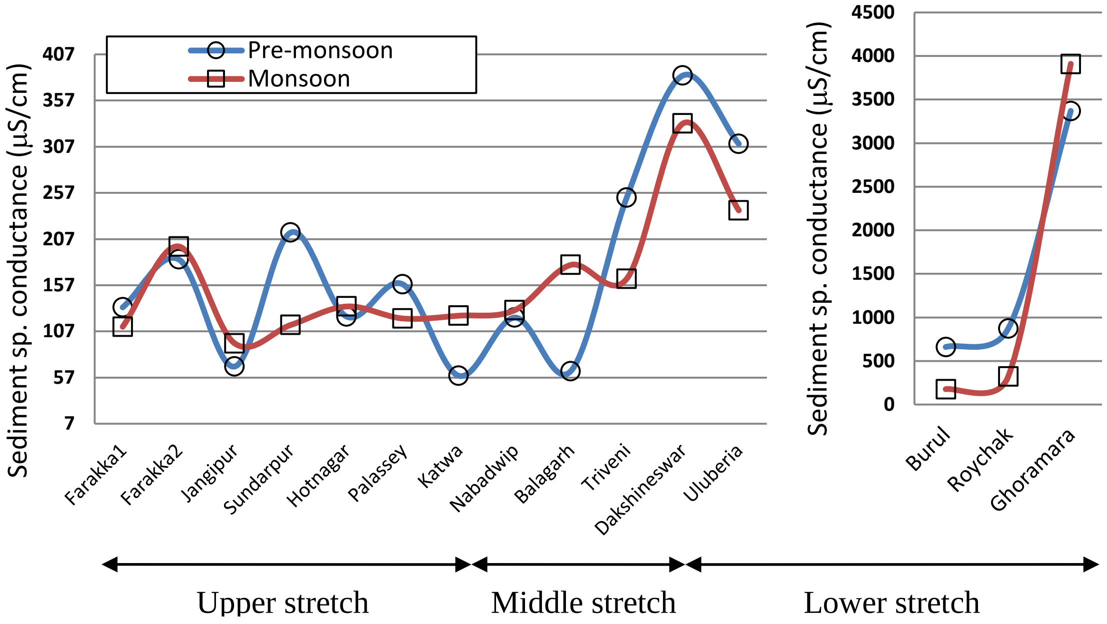


Fig. 89. Spatio-temporal variation of sediment sp. conductance

9.2.4 Sediment free $CaCO_3$ content

Free $CaCO_3$ was in the desirable range (2.6-9.1%) in the studied stretch (Fig. 90).

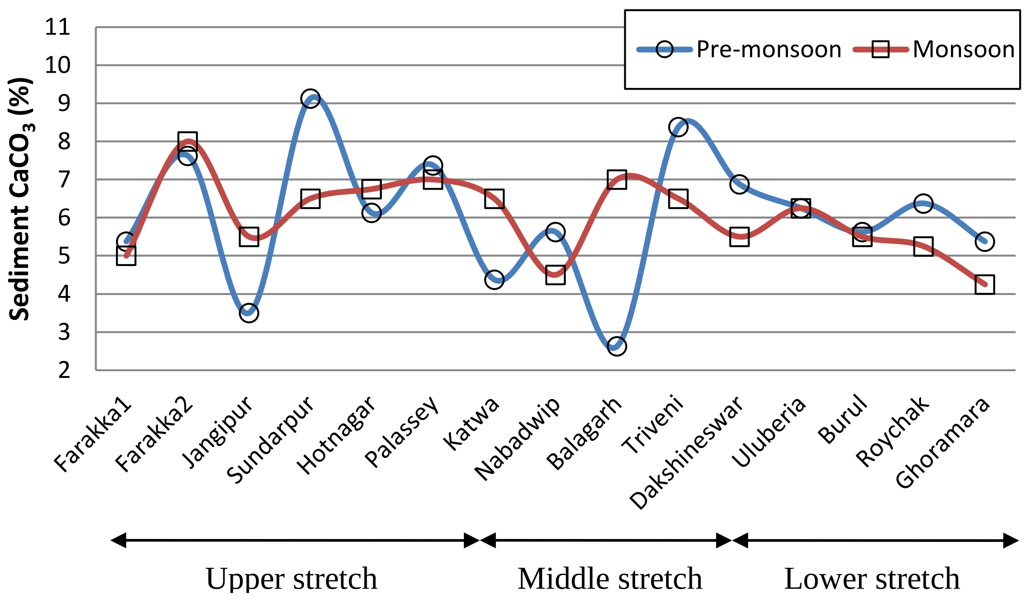


Fig. 90. Spatio-temporal variation of sediment $CaCO_3$ content

9.2.5 Sediment organic carbon

Variation in sediment organic carbon is mostly governed by amount of organic matter coming through surface run-off with little contribution from plankton. It acts as a direct source of energy to microbes present in soils that take part in mineralization. The observed organic matter content was in the normal expected range (Fig. 91).

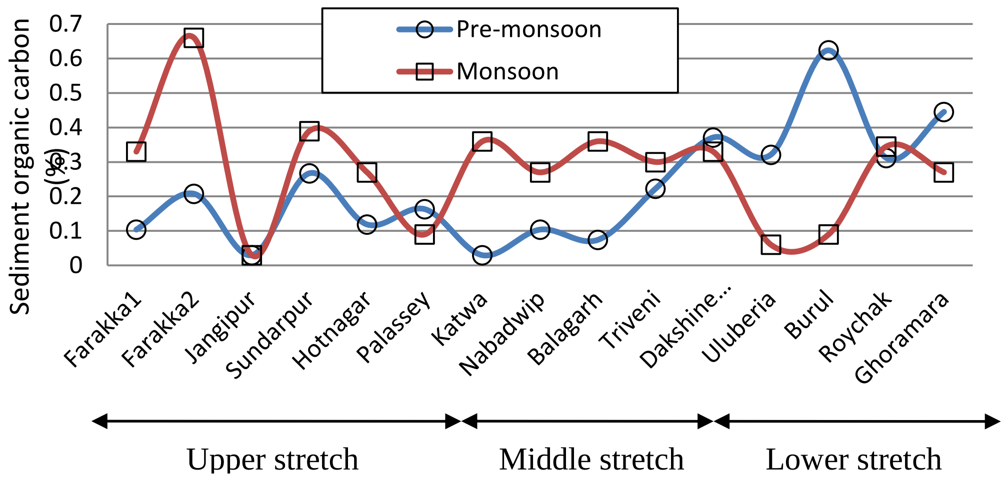


Fig. 91. Spatio-temporal variation of sediment organic carbon

9.2.6 Sediment nitrogen

Sediment nitrogen is one of the major contributing factors to control aquatic productivity. It remains mostly in organic form and mineralized by soil microbes to be liberated as different ions like NH_4^+, NO_3^-, NO_2^-, *etc*. for utilization by plankton in water phase. For any productive soil, available nitrogen must be above 250 mg/kg. However, in the studied stretch sediment available N was low due to sandy nature and low organic C of the bottom (Fig. 92). Increased silt load during monsoon may have contributed in increased available N in most of the stations.

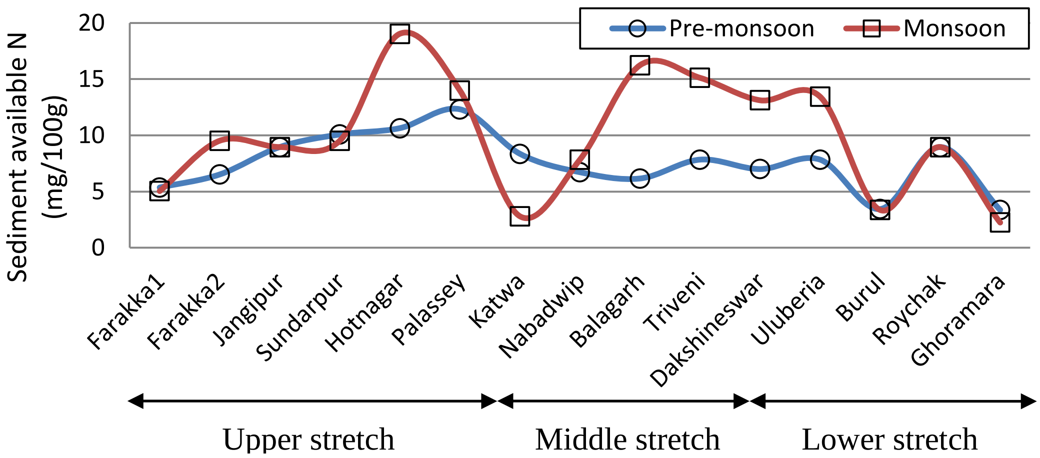


Fig. 92. Spatio-temporal variation of sediment available N

9.2.7 Sediment total N

Sediment total N was low during both the seasons at all the sampling centers due to sandy river bed with low organic C (Fig. 93).

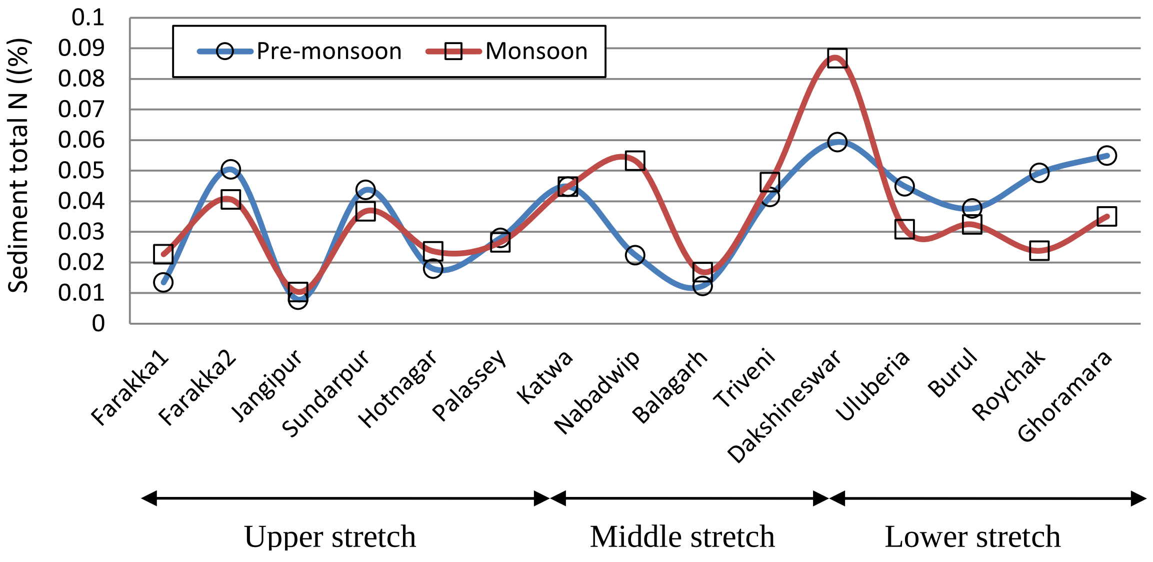


Fig. 93. Spatio-temporal variation of sediment total N

9.2.8 Sediment available phosphorous

Lower level of available phosphorus was recorded in all the sampling sites due to sandy bottom of the studied river stretch (Fig. 94).

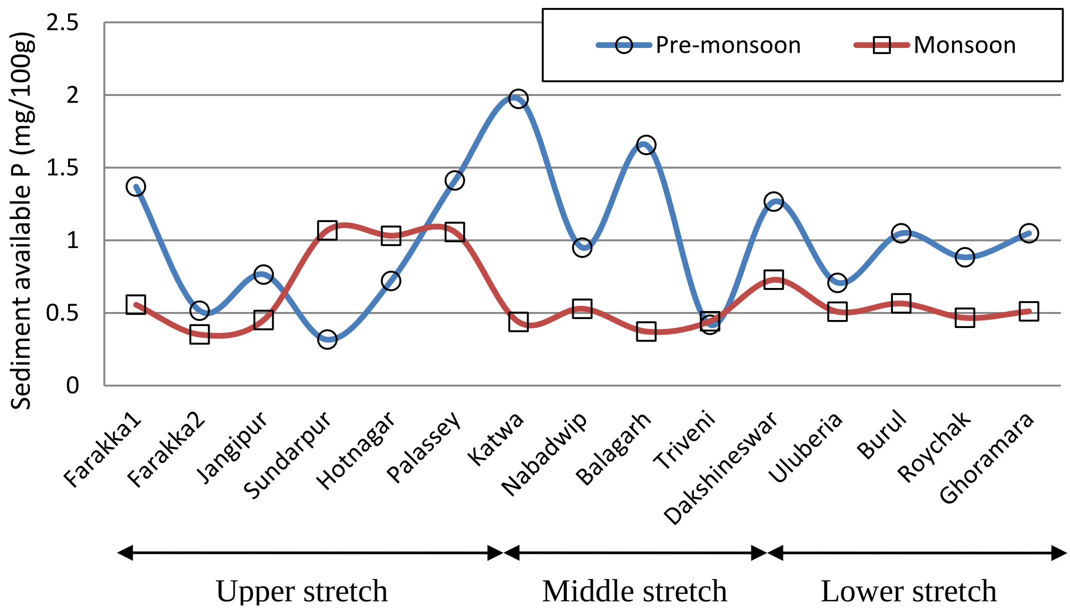


Fig. 94. Spatio-temporal variation of sediment available P

9.3 Impact of barge on water quality parameters

Field study was conducted to understand the impact of barge movement on water quality parameters. In a study conducted on 26.10.2016 at Balagarh and Barrackpore indicated that although the propeller wash generated turbulence and churning in the river water, it did not cause appreciable change in dissolved oxygen as is routinely anticipated. Since the channel in both the sampling locations was deep (Balagarh 12 m and Barrackpore 14 m), and river water was highly turbid due to the monsoon effect, there was no change in turbidity (Secchi Disc reading 13 cm in both the sites). There was no variation in pH and specific conductance also (Table 25). Name of barge moved in was Drishti. It was in ballast.

Table 25. Physico-chemical parameters of river water before and after barge movement

Stations	1		2	
Centers	Balagarh		Barrackpore	
Date of sampling	26.10.16		26.10.16	
Sampling period	Before Barge	After Barge	Before Barge	After Barge
Sampling time	11.20 AM	11.40 AM	02.50 PM	03.05 PM
Weather	Clear	Clear	Cloudy	Cloudy
Depth (m)	12	12	14	14
Secchi Disc Transparency (cm)	13	13	13	13
Dissolved oxygen (ppm)	6.40	6.45	6.20	6.20
pH	8.01	8.02	7.95	7.95
Sp. conduct. (μS/cm)	234	234	238	238
Salinity (ppt)	0.00	0.00	0.00	0.00

Fig. 95. Barge Drishti

10.0 Component IV: Characterisation of sewages generated in the barges and its disposal

The value of the basic water quality parameters including pH, dissolved oxygen, conductance and salinity indicated that all the parameters were at its normal expected range. In case of barge sewage the dissolved oxygen was in very low level of 0.15 to 2.4 mg l^{-1}. It is quite expected with the nature of waste.

Table 26. Barge sewage and river water quality parameters

Parameters	River water	Sewage treatment plant of barge
pH	7.4 – 7.7	6.95 - 7.80
DO (mg l^{-1})	4.30 –6.52	0.15 –2.38
BOD (mg l^{-1})	2.0 – 6.0	4.0 – 20.0
Salinity ppt	0.00 - 1.46 ppt	0.0 –3.5 ppt
Conductivity (µS cm^{-1})	196 - 2820	451 - 6600
Faecal coliform (number ml^{-1})	1.1 to 1.4 x 10^4	1.5 x 10^3 to 4.6 x 10^5

The average MPN count for faecal coliform in water sample collected from river Ganga was 1.1 to 1.4 x 10^4 number/ ml and in sewage it was 1.5 x 10^3 to 4.6 x 10^5 number/ ml. The inoculum taken from all the dilutions when plated, showed formation of dark coloured colonies with metallic green sheen which confirmed the presence of faecal coliforms. According to USEPA guidelines 2004, for urban use and ground water recharge purpose water should contain no faecal coliforms per 100 ml water, whereas for agricultural and recreational use, water may contain <200 faecal coliform count per 100 ml. Thus, both the Ganga water and sewage exceeded the permissible counts. Excessively high MPN count indicated that the water is highly contaminated with microorganisms and is hazardous for human uses. The presence of the indicator bacteria indicated the occurrence of faecal contamination both in river and in high value in barge generated sewage.

10.1 Specific suggestion:

Barge generated sewage should be discharged at designated site instead of disposal for irrigation purpose. Need based replacement/refilling of chemicals of the barge sewage treatment plants is suggested. Barge staffs are to be encouraged to generate less amount of garbage waste.

11.0 Component V: Estimation of optimum barge traffic load without serious eco-biological and social impacts

In order to achieve a conclusive result to predict the tonnage of coal that can be transported through the waterway, ICAR-CIFRI is undertaking field and model experiments. Arriving into a definite values will take some more time. However, based upon the field data analyses it is concluded that the existing permitted rate of 1.5 MTPA (Million Metric Ton Per Year) which is equivalent to movement of average 2 to 3 barges upward and similar number downward per day showed no impact on ecology. This is based upon the average barge load of 1500 ton (equivalent to 83 loaded barges per month). The IWAI has reported that necessary steps are being taken to maintain least available depth (LAD) of 3 meters with minimal intervention in the waterways. Considering that situation, in case of more water availability i.e. least available depth of more than 3 meters (which will be equivalent to average depth of 5 meter including the deep pools and deeper channel in consideration) the permitted rate may go up to 3.0 MTPA, considering the average barge load of 2000 ton (equivalent to 125 loaded barges per month or 4 barges per day) in order to study the impact of barge movement on river ecology.

12.0 Energy conservation and other perceived benefits vis-a-vis road and rail transportation

Inland Waterway Transport (IWT) offers a comparatively low cost and environmentally sound alternative to road and rail transportation especially for bulk and containerized cargo. Infrastructure requirements of IWT in comparison to road and rail transport are also relatively low, although some investments in port facilities, connecting road/rail infrastructure and the establishment and maintenance of waterways' minimum draft and for aids to navigation have to be made. Compared to other modes of transport which are often confronted with congestion and capacity problems, inland waterway transport is characterized by its reliability, low fuel/energy requirement for transport of specific weight (Fig. 96), its low environmental impact (Fig. 97) and its major capacity for increased exploitation.

Fig. 96. Energy efficiency of shipping methods

Mode of Transportation	Energy consumption
Waterways 	0.0048 l/Tkm
Railways 	0.0089 l/Tkm
Roadways 	0.0313 l/Tkm

Source : 11th Working Group Report on shipping and IWT (Based on EU: Progress Report on short sea shipping 1999)

Fig. 97. Environmental quality of shipping methods

Comparison of emissions of different gases into atmosphere from different transportation methods

Emission of Greenhouse gases	Freight Transport (g/tkm)		
	As per '12th Five Year plan	Mckinsey 'Transforming the railways logistics infrastructure' 2010	International Union of railways
Road	160	64	84
Rail	29	28	17
Waterways	31	15	-

Mode of Transportation	Hydrocarbons Emitted (lbs/ton-mile)	Cabon Monoxide Emitted (lbs/ton-mile)	Nitrous Oxide Emitted (lbs/ton-mile)
Waterways 	0.0009	0.0020	0.0053
Railways 	0.0046	0.0064	0.0183
Roadways 	0.0063	0.0190	0.1017

Source : http://business.tenntom.org/why-use-the-waterway/shipping-comparisons/

12.1 Energy conservation:

In order to calculate the benefits in energy / fuel savings due to change in mode of transportation from rail and road to the proposed Inland Water Transport system, the quantity to be transported has been considered as 3 million metric ton. The actual average fuel consumption of barges of Jindal ITF Ltd. in the Inland Water Transport system and accepted norms of fuel consumption for transportation of bulk goods by Railways and Road have been worked out as following:

A. Inland Water Transport <u>*vis-à-vis Railways*</u>

Saving in High Speed Diesel (HSD) in transportation of 3 MTPA imported coal from Haldia to Farakka by NW-1 as against by Railways (considering 30% from Haldia port and 70% from Paradip ports in case of Railways) = 9.1 million litre per annum (or Rupees 45 crore per year) (Point No.III of Annexure V)

B. Inland Water Transport <u>*vis-à-vis Roadways*</u>

Transportation of 3 MTPA of coal by road is not a practical proposition at all. For 3 MTPA coal movement, about 800 trucks (of 10 ton capacity) will be required to be moved one way every day between Haldia to Farakka, which, considering the present condition of the road and traffic density, is simply not feasible. Moreover, road movement will consume 3 to 4 times more HSD then IWT mode.

12.2 Other perceived benefits of Inland Water Transport would be as follows:

- Less CO_2 and CO emission
- Saving in rail and road maintenance cost
- Reduction in accidents on road and rail
- Availability of supplementary mode of transport for NTPC Ltd
- Employment generation is under-developed hinterlands along river banks
- Zero /lass pilferage in transit between Bay of Bengal and coal stock yard at Farakka

Detailed discussions on advantages of Inland Waterways Transportation

1. Fuel efficiency and cost effectiveness:

The cost of transportation in different modes are compared and presented in Table 27 which clearly indicates that the Inland Waterways Transportation is the cheapest mode. The other benefits obtained from the IWT are described in Table 28.

Table 27. Cost of Transportation through Different Modes

Mode	VOC/Freight (Rs/Km)	Taxes	Total Rs/TKm
Railway*	1.36	3.71%	1.41
Highways**	2.50	3.09%	2.58
IWT	1.06	Nil	1.06
Source: Railways-Ministry of Railways, Road-TTSS, IWT-IWAI * Service Tax on rail Transport is 12.36% abatement is 70%			
****Service Tax on Road Transport is 12.36% abatement is 75%**			

Table 28. Other benefits of IWT

	Waterways	Road	Rail
	Rs. /Tkm	**Rs. /Tkm**	**Rs. /Tkm**
External Costs of Air Pollution *Source : Total Transportation System Study - Planning Commission Report*	0.03	0.20	0.0366
External Cost of Noise Pollution *Source : Union Internationale des Chemins de fer (PIANC)*	NIL	0.0032	0.0012
Accident Cost *Source : Total Transportation System Study - Planning Commission Report*	NIL	0.0620	0.0010
Surface Occupation *Source : Bundesamt fur Umweltschutz (PIANC)*	-	0.0002	0.0001

2 Eco-friendly: Low Green House Gas emission:

Carbon dioxide emission by IWT is less than half of lorry over distance of more than 150 km. As per a study by the Indian Network for climate Change Assessment, the number of vehicles in the country has increased from 5.4 million in 1981 to 99.6 million in 2007 and the carbon dioxide emission from road transport is likely to increase by six times between 2005 and 2035. Considering that in India, it is the share of road transport which is increasing, this trend is disturbing and on account of this alone, the role of IWT sector becomes extremely important.

3. Low Development Costs:

IWT routes use existing rivers/canals and hence they do not require substantial land acquisition. Further, the cost of development of waterway per km is about 10% of the cost of developing an equivalent four lane expressway or railway. Moreover, the maintenance cost of inland waterways is potentially of the order of 20% of that of road.

4. Decongestion:

Waterways provide port hinterland connectivity to a vast underdeveloped hinterland, and hence IWT can also help in decongestion of roads. IWT can also share the burden of railways in transportation of bulk cargo.

5. All weather mode:

In India at times the efficacy of road and rail modes gets seriously affected during monsoons. IWT on the other hand is an all weather mode of transport.

6. Requires minimal land acquisition:

Unlike railways and roads, development of IWT infrastructure does not require significant land acquisition.

13.0 Impact on bank erosion vis-a-vis safeguard measures like stabilization of banks with native vegetation (including mangroves) that will prevent erosion.

There are reports of serious bank erosion occurring along some parts of Bhagirathi-Hooghli river stretch of the National Waterway No.1 these include the Farakka Feeder Canal and in different locations of the river. There is a perception amongst people that the bank erosion is primarily due to the effects of barges transiting the waterway.

13.1 Bank erosion phenomenon

Natural rivers are dynamic bodies of water that have no fixed boundaries and have a tendency to meander. If the bed slope be unfavourable for an equilibrium regime (equilibrium occurs when the average transport rate of sediment equals the average rate of sediment supply), the river meanders to increase its length.

Instability of the river bed and banks is generally observed near the apex of river bends and meanders, even in regime or stable rivers. Non regime or unstable rivers show marked variations in layout, heavy scour and deposition of sediments. Many sections of the Bhagirathi-Hooghly river are unstable.

By contrast artificial channels, such as canals, tend to be relatively straight and have regular, often trapezoidal cross-section. In this case also banks may fail if they are too steep especially around the structures projecting into or crossing the canal.

13.2 Policy for bank protection measures

Where infrastructure, human health and safety or built property is placed at direct risk from bank erosion (either naturally occurring or exacerbated by human activities), there will be a requirement to take steps to address the problem, either through erosion control or by redesigning or relocating a structure. If there is no significant risk to infrastructure, human health and safety, or built property, it will be necessary to re-consider whether engineering works are necessary. Where infrastructure, human health and safety or built property are not at risk, natural erosion processes should be allowed to continue.

As per present policy, concerned State Governments are responsible for carrying out bank protection works. IWAI may assist the State Govt. with bank protection measures in those reaches where the problem is likely to get accentuated by movement of vessels.

In areas where bank erosion threatens populated areas, strategic and archeological monuments, it may be appropriate to take up bank protection measures such as vegetation, plantation, geo-textiles matting, groynes or revetments.

13.3 Factors governing type of bank protection measures

Type of bank protection measures to be adopted depend upon many factors, such as, bank failure mechanism, type of material in bed and banks, height of the bank, bank slope, river configuration, river width, hydraulic characteristics i.e. flow, velocity, variation in flow and water levels, nature of the assets to be protected, availability of land etc.

13.4 Stretches vulnerable to bank erosion

The following sections of have been reported as suffering from problematic bank erosion.

Farakka Feeder Canal

General:

The erosion has been observed at the places with one of the following features:

(i) Intake structure for Farakka Thermal Power Plant (Farakka TPP)

(ii) Waste water disposal structure (Disposal of cooling water from Farakka TPP)

(iii) Structures crossing Feeder Canal such as cross drainage works and bridges

(iv) Jetties projecting into the Feeder Canal

(v) Mooring and landing areas used by local boats

13.5 Specific locations:

The places where erosion has occurred and bank protection works are required are listed in Table below:

Table 29. Principal locations of bank erosion in feeder canal requiring bank protection works

Ref. No.	Name	Approx. Length (km)
1	NTPC Super Thermal Power Plant, Farakka – West Bank	0.370
2	NTPC Super Thermal Power Plant, Farakka – East Bank	0.370
3	Ballapur	0.240
4	Ballapur – incomplete bridge, West Bank	0.135
5	Ballapur – incomplete bridge, East Bank	0.145
6	Sanko Para	1.100
7	South Sanko Para	0.190
8	Not named bridge – West bank	0.550
9	Not named bridge – East bank	0.580
10	Nr. Mahadeb Nagar	0.140
11	Around the Bagmari Syphon – West bank	1.365
12	Around the Bagmari Syphon – East bank	1.365
13	Malancha – West bank	0.800
14	Malancha – East bank	0.220
15	Pakur bridge – West bank	0.920
16	Pakur bridge – East bank	0.960
17	Amuha Ferry Crossing – West bank	0.700
18	Amuha Ferry Crossing – East bank	0.640
	Total	**10.790**

13.6 Other locations of Bhagirathi-Hooghly River between Haldia-Farakka

The places where erosion is taking place are listed in Table 30:

Table 30. Details of locations of bank erosion in Bhagirathi-Hooghly river between Haldia and Farakka

S. No.	Name of Village	Length of Bank Erosion (km)	Existing Stone Pitching/Bank Protection Works (km)
1	Nasirpur	2.47	0.10
2	Birendranagar	2.77	NIL
3	Katalia	1.70	0.25
4	Mohitpur	3.56	0.20
5	Mahammadpur	1.55	0.06
6	Kazipara	1.60	NIL
7	Mirzapur	1.16	0.315
8	Kumarpur	3.32	NIL
9	Simuldanga	1.58	NIL
10	SanToshpur	1.57	NIL
11	Natungram	3.21	NIL
12	Jhasudanga	1.86	NIL
13	Basantpur	2.53	0.185
14	Bishnupur	2.89	NIL
15	Agradwip	4.42	NIL
16	Metiary	3.20	0.10
17	Kamalnagar	1.92	0.23
18	Udaychandpur	4.80	0.12
19	Bholadanga	9.80	0.13
20	Srirampur	5.35	NIL
21	Kuntighat	2.23	NIL
22	Jirat	3.43	0.07
	TOTAL	**56.42**	**1.535**

Out of the above stretches of the river, stretches have been shortlisted based on vulnerability to populated areas for bank protection works. These are given in Table 31:

Table 31. Locations of river reaches shortlisted for bank protection works

S. No.	Name of Village	Length (km)
1	Gadde	1.88
2	Katalia	1.35
3	Kamarpara	0.52
4	Mirzapur	1.73
5	Kazipara	1.60
6	Natungram	1.13
7	Bishnupur	0.61
8	Sitahati	1.32
9	Agradwip	1.00
10	Kuntighat	6.90
11	Srirampur	1.15
	TOTAL	**19.63**

13.7 Bank protection around proposed structures

Bank protection is also likely to occur at the locations where structures such as IWT terminals, Jetties and Ro-Ro Terminals are planned.

13.8 Type of bank protection works

13.8.1 General

For protecting the banks of rivers from collapsing, certain structural interventions are required to be implemented. Type of bank protection work has to be in accordance with the conditions of the specific site. Following type of bank protection works have been suggested:

13.8.2 Green bank protection -Native plant vegetation

This includes techniques that are sympathetic to the environment, such as protecting the bank by use of natural materials (plants), bank re-profiling (dressing of slope) and biodegradable textiles. Here toe of the bank is also protected by naturals such as bamboo porcupines, bundle of tree branches etc. such works may be useful if velocity of flow is small. Figure and show typical way of bank protection by growing native trees, grasses, shrubs etc. on the bank.

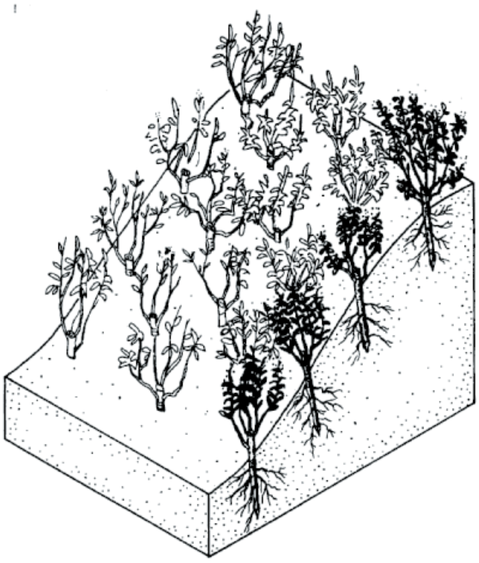
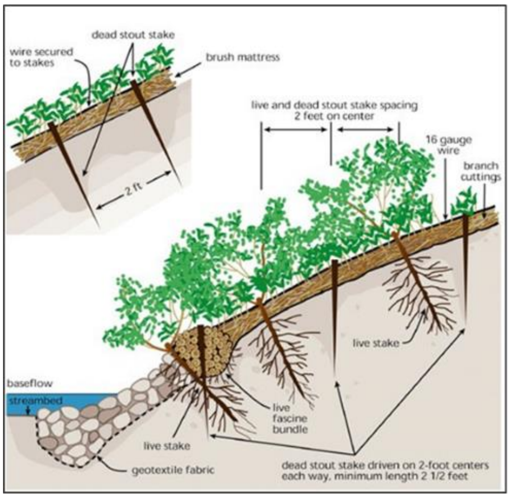


Fig. 98. Planting tree on the bank slope   Fig99. Planting tree on bank top and grasses on the bank slope

13.8.3 Native plant vegetation with toe protection

In the situations where water velocities are especially high, or where a structure is threatened by its proximity to the bank, additional protection of Toe by boulders may become necessary: (Figure 100 and 101).



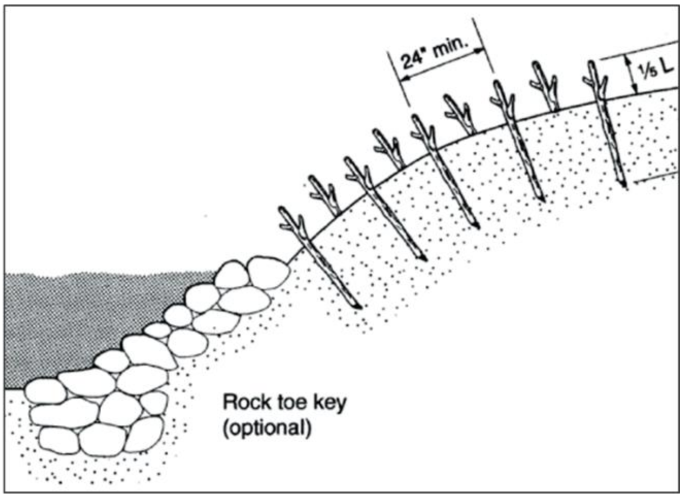


Fig. 100. Trees on bank slope with boulders at toe   Fig. 101. Tree branches driven on the slope and bounders at toe

13.8.4 Grey bank protection

Grey bank protection may be required where human health, infrastructure or valuable resources are at risk. It usually represents a strong engineering structure that solidly defends a particular section of river bank. In this case bank protection can be provided by pitching the graded bank slope by boulders/ PCC blocks with PCC toe wall and / or launching apron. These are shown in Fig. 102 and 103.

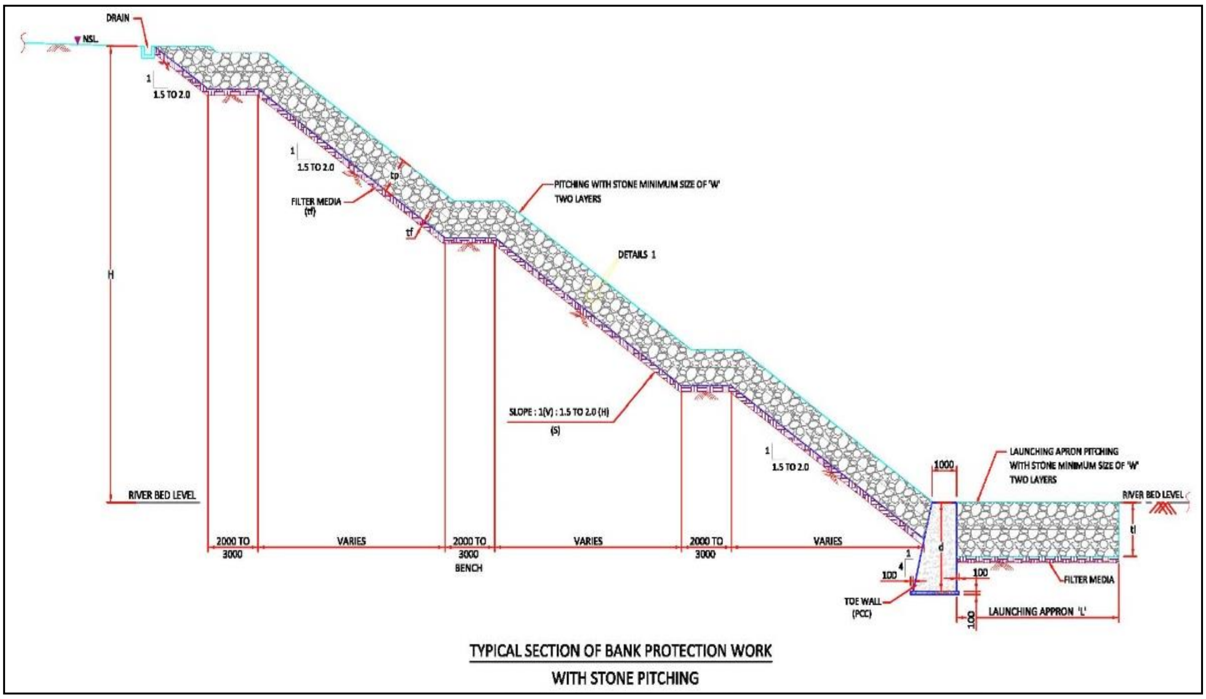


Fig. 102. Revetment using Boulders pitching with PCC toe wall and/or launching apron

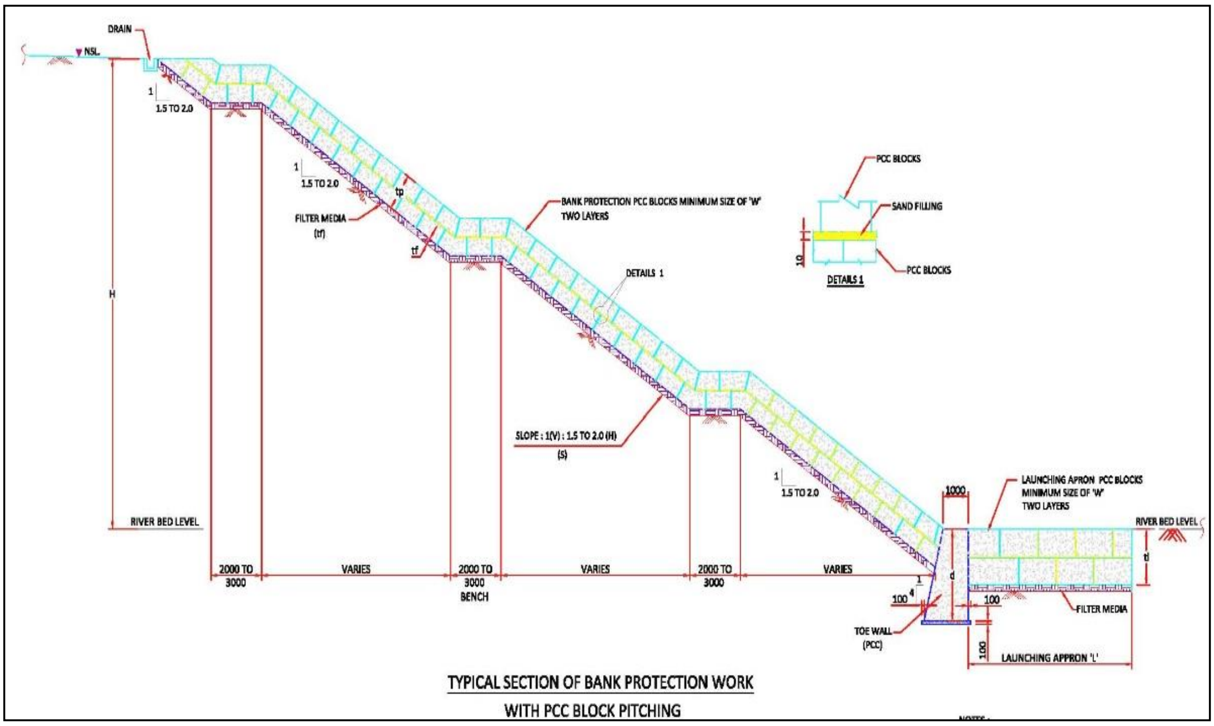


Fig. 103. Revetment using PCC Block pitching with PCC toe wall and/or launching apron

13.8.5 Combination of green and grey bank protection

Most appropriate solution is combination of Green and Grey Bank Protection. The bank erosion in the Bhagirathi – Hooghly reach of NW-1 is erosion at toe of the bank and consequent collapse of the bank. The typical sketch of bank protection combining the green and grey bank protection technology is given below:

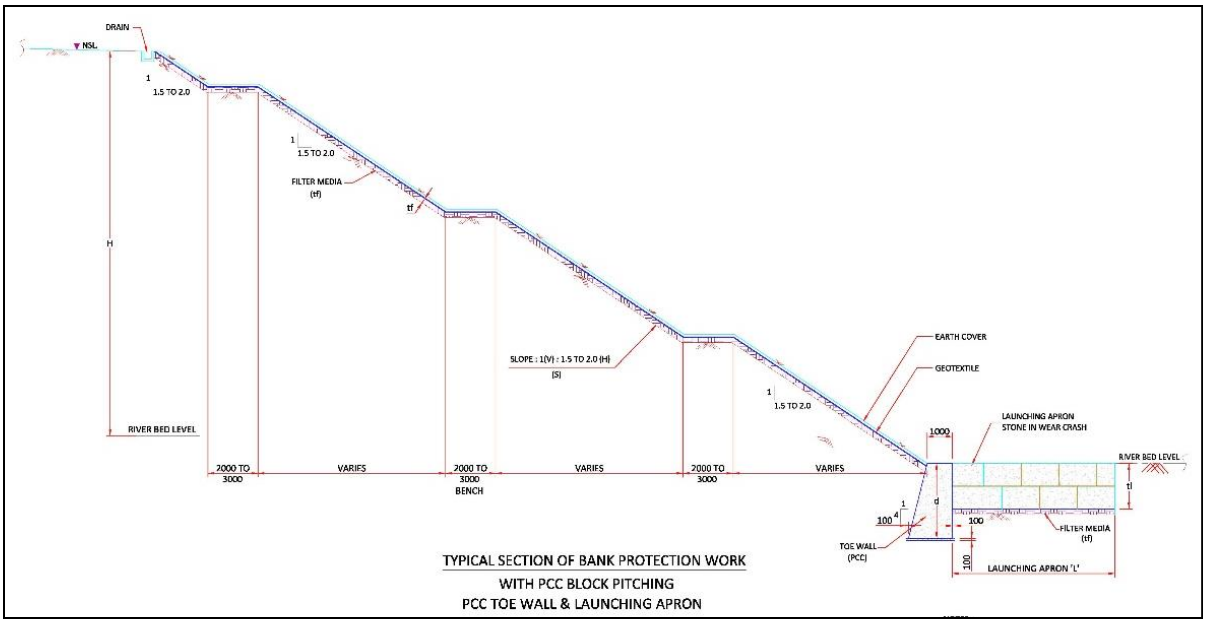


Fig. 104. Typical Sketch of Bank Protection Work

13.9 Detailed design and preparation of detailed project report

A joint visit to the vulnerable sites was carried out by the Engineers of the IWAI (including experts' team of Howe JV), FBP & State Govt. in middle of July 2016 for final short listing of the sites for bank protection works. The detailed site survey including geo-technical investigations and specific designs for each identified site are in the process of preparation.

14.0 Constraints faced

1. Movement of insufficient number of vessels due to one reason or the other was a serious problem for the research group of ICAR-CIFRI during the project tenure. For this data could not be generated as per plan. This caused delay in submission of the report.

2. Availability of water in the Feeder canal and subsequently in river Bhagirathi-Hooghly had bearing on movement of barges. Due to India-Bangladesh agreement on water sharing from Farakka, there is a provision of release of 35,000 cusecs water to either country in the alternate 10-day segment during the period from 11 March to 10 May. Accordingly, water release was in progress but reduced water level has drastically limited the movement of coal laden barges. River draft was less than 2.0 meter and the coal carrying barges stuck at different points during the project period. As for example, during 28th February 2016 to 23rd March 2016, 14 barge stuck at Syphon (CH 529, in Feeder canal) and during 1st to 23rd March 2016, 09 barges stuck at Sagar Dighi (CH 445) due to less amount of water in the river channel.

The carrying of coal during October, 2015 to July, 2016 was as per the table given below which is clearly indicating the decrease in barge movement during a significant period of the study.

Table 32. Coal transportation and barge movement details for last one year

MONTH	Days of operation	Quantity	Number of barges operated
NOVEMBER,2015	30	86563	62
DECEMBER,2015	30	93195	70
JANUARY,2016	30	64148	54
FEBRUARY,2016	30	71141	71
MARCH,2016	9	20850	21
APRIL,2016	9	57193	53
MAY.2016	10	42736	44
JUNE,2016	30	82162	60
JULY,2016 *		6320	5
AUGUST,2016	0	0	0
SEPTEMBER,2016	14	7782	7
OCTOBER,2016	27	4100	3
Total transportation in last one year		**536190**	**450**

3. Worldwide no study has been conducted on impact of navigation on river ecology for estimation of optimum traffic load. This study is a unique one and requires generation of long term data and then, development of mathematical model for optimum traffic load. Ecology of Indian rivers is also completely different from that of other parts of the world. A sizable population also depends directly or indirectly for their livelihood on the studied river stretch. Change in ecology of the river, shift in biotic community structure are very slow processes and therefore, assessing impact needs long term study. ICAR- CIFRI may come out with recommendations on optimum traffic load based upon scientific data and understanding if the study continues on such longterm basis.

15.0 Summary and Conclusions

- The coal is transported between Sandheads/Kanika Sands and Farakka STPP through National Waterway – 1. Based on the recommendation of EAC, ICAR-CIFRI conducted the study on "Impact assessment of coal transportation through barges along the National Waterway No.1 (Sagar to Farakka) along river Ganga" in 2015-2016.
- The investigations were carried out to assess the impact on biotic community; impact on fish catch and livelihood of fishers; impact on water and sediment qualities; characterisation of sewage generated in the barges and estimation of optimum barge traffic load without serious eco-biological and social impacts.
- Physico-chemical analysis of river water and sediment samples revealed that there is no significant changes in water quality parameters in the river due to the current movement of barges in this short period of time, except increase in turbidity up to 5% in the bank side of the shallow channel stretches immediately after barge movement. In the deeper channel, no variation in turbidity was recorded.
- A total of 207 fish species belonging to 61 families and 17 orders were recorded from the study stretch, of which, 27 fish species have been listed as threatened as per the IUCN criteria. Lower stretch (Zone–I) harbours the lowest number of fish species with conservation significance (11 species) which might be attributed to stressed habitat conditions owing to its proximity with Kolkata metropolitan area, industrial establishments and highly intensive fishing activities. Though a rapid change in fish assemblage structure has been observed in the seine net catches during passing of barge, it is difficult to arrive at any conclusions regarding the change in fish assemblage structure due to barge movement in this short term study. Impacts of barge movement on fish community composition can only be assessed by studying the fish community composition over a longer period of time as the shift in species composition is a slow and gradual process which requires continuous monitoring. A temporal and seasonal fluctuation in fish catch and catch per unit effort (CPUE) including that of the migratory fish hilsa has been recorded. The variation in the abundance of fish larvae was insignificant during barge movement.
- Phytoplankton community consisted of 68 species distributed in 5 phylum, 9 class, 27 orders and 39 families; major groups being diatoms followed by green, blue green and yellow green algae. Among zooplankton, 12 taxa were reported mostly comprise rotifers and copepods. The impact of barge movement on plankton abundance and quality in terms of damaged cell structure was studied. Impact study of barge traffic on plankton abundance revealed that there was a 16% decrease in total plankton abundance (2772 nos/l) in comparison to the status prior to the barge movement (3275 nos/l). Quantitative study in terms of cell damage due to barge movement also revealed that there was 15% increase in the cell structure damage immediately after passage of barge, which was reduced to 10 % after 30 min of barge movement with respect to the normal condition (before barge movement). The observation of reduction in cell structure damage is due to flowing of damaged cell along the river gradient. However, continuous study may require for assessing fish stock depletion if any and suggesting mitigation measures in the long run.
- Macro-benthic community in the entire stretch comprised of 25 species under 10 families and 3 classes. The diversity of these communities was higher in the upper stretch (15 species),

followed by middle and lower stretches (9 species each). However, the impact of barge movement on macro-benthic community diversity could not be observed significantly in this short duration study since the variations in diversity itself is very slow and needs years together to observe the differences.

- So far, this study revealed no significant changes in water quality, abundance of fish larvae, benthic creatures and fish stock due to the present movement of barges. Further, it is suggested that long term continuous studies may be required to assess the impact of barge movement on ecology of the river, fish assemblage and stock.
- The Bhagirathi-Hooghly stretch of the river contains a sizable population of the endangered Gangetic dolphin (Platanista gangetica gangetica). The noise exposure behavior disturbance criteria for dolphins is 177 dB. However, the barge plying in NW-1 (1500-2000 DWT) with modern technology and regulated speed in the dolphin populated stretch generate noise of 110-140 dB. Since, the noise generated from the barge is below the noise exposure behavior disturbance criteria for dolphins, no adverse impact on the organisms is anticipated.
- The critically erosion prone zones need to be protected through erection of retaining walls, putting gabions with stones, stone pitching, establishing vegetation, etc. However, IWAI reported that it has taken suggestive measures from the Haldia to Farakka stretch.
- In addition, IWAI has intimated their planning to introduce shallow draft vessels, which will reduce any kind of disturbance to the benthic organisms and avoidance of any constrictions of the river flow, which lead to sustainability of environment. Also, maintaining the least available depth of more than 3 m of the navigation channel (or average water depth of 5 m, considering deep pools along the channel) may also reduce the disturbance to benthic habitat, facilitate escapement of fishes including hilsa and dolphins. Further, it is suggested that the barge speed may be reduced to 5 knot in dolphin dominated areas, in hilsa sanctuaries during breeding season and narrow stretches for reducing the wave action and thereby minimizing possibilities of bank erosion.
- To assess the impact on livelihood of fishermen, information were collected from 500 fishers along the study stretch through personal interview. The survey results indicated that some constraints have been faced by them due to barge movement. These were forced suspension of fishing operations, dislodging of nets, loss of fishing time and chances of net damage. The problem is more near the river meanders and narrow stretches. The fishers largely depend on the fish catch for their daily livelihoods. Disturbance caused by the movement of barge has direct bearing on the fishing operations. Around 38% of the fishers reported loss in fishing time. The average monetary loss per fishermen was found to be Rs. 0.75, 4.35 and 17.63 per incidence of barge(s) movement in lower, middle and upper stretchs, respectively.
- The monetary loss of the fishermen is marginal in lower and middle stretches with the frequency of barge movement during the study period and arises mainly due to the reduction in fishing time. However, this loss can be minimised by taking certain measures like prior announcement of barge movement schedule, generation of awareness on barge movement among public, especially the fishers and ferry operators. Stakeholders meetings may be organized periodically for sensitization. Additionally, measures may be taken to enhance the fisherman welfare. Furthermore, navigational aids in the form of night navigation facilities and channel marking,

enhancement of existing river information system, improved communication platform and expanded user reach and river monitoring systems will help fishermen to schedule their fishing time.

- The analysis of river water and barge sewage samples revealed that the coliform load in river water varied from 1.1 to 1.4 x 104 numbers/ml and sewage generated in the barges varied from 1.5 x 103 to 4.6 x 105 numbers/ml. Thus, with respect to coliform count, both the river water and barge sewage samples exceeded the permissible level for irrigation purpose (<200 numbers/100 ml).
- Energy conservation and other perceived benefits in inland water transport vis-a-vis road and rail transportation were assessed. The actual average fuel consumption of barges of Jindal ITF Ltd. (present transporter of coal) and accepted norms of fuel consumption for transportation of bulk goods by railways were worked out. It is estimated that there will be savings to the extent of 9.1 million litre per annum of high speed diesel (HSD) for the transportation of 3 MTPA coal between Haldia to Farakka using IWT mode as compared to railways. Transportation of 3 MTPA of coal by road is not a practical proposition since about 800 trucks (of 10 ton capacity) will be required to be moved one way every day between Haldia to Farakka. Therefore, IWT has the potential to substantially reduce the GHG emissions as compared with other mode of transportation. Also, other benefits in the waterways transportation are savings in rail and road maintenance cost, reduction in congestion and accidents on road &rail, minimum pilferage/loss in transit, etc. Therefore, it is concluded that, IWT is a competitive alternative to road and rail transport, offering an economical and environment friendly mode in terms of energy consumption, noise and greenhouse gas emissions.
- The above studies indicate that there is marginal impact on aquatic flora & fauna, fishing and livelihood of fishermen and wherever there are impacts, plans are suggested which can be easily implemented. The transportation of coal through covered and moist condition did not show any substantial impact on the river ecology. However, this movement reduces substantial carbon footprint in the form of saving diesel as compared to surface transportation.
- Considering the observation of the present study, in case of more water availability i.e. least available depth of more than 3 meters (which will be equivalent to average depth of 5 meter including the deep pools and deeper channel in consideration) the permitted rate of coal movement may be revised to 3.0 MMTPA for NTPC-Farakka STPP having capacity of 2100 MW.

The initiatives of Inland Waterways Authority of India regarding the advancements / measures that have been taken under Jal Marge Vikas Project are given in annexure VI.

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Annexure I : Copy of the Permission Letters received

J-13011/28/2006 - IA. II (T)
Government of India
Ministry of Environment, Forest and Climate Change

3rd Floor, Vayu Block,
Indira Paryavaran Bhawan, Jor Bagh Road,
Aliganj, New Delhi-110003

Dated: 26.10.2016

To

M/s NTPC Ltd.,
NTPC Bhawan, SCOPE Complex,
7, Industrial Area, Lodhi Road,
New Delhi-110 003.

Sub: **Farakka Super Thermal Power Project at Farrakka, District Murshidabad, West Bengal by M/s NTPC - regarding amendment of EC for transport of coal through National Waterway (NW) No. 1.**

Sir,

This has reference to your letter dated 25.07.2016 requesting the extension of permission for transport of imported coal through National Waterway (NW) No. 1. It is noted that MoEF&CC vide letter dated 31.07.2014 accorded permission for use of blended coal (Domestic:Imported-70:30) in Farakka STPP, Stage- I, II & III and temporary permission for transportation of imported coal through NW-1 for a period of one year subject to certain conditions. Further, based on the recommendation of EAC, the Ministry vide letter dated 29.09.2015 has accorded permission for continuation of transport of maximum 1.5 MTPA coal through NW-1 for another one year i.e. till 30.07.2016 and also sought additional information based on the study being carried out by CIFRI. It was also stipulated that, after a period of 6 months, the NTPC shall submit/present findings of the study and EAC shall review the findings of the studies and if need be, would undertake a site visit.

2. The matter was placed before the Expert Appraisal Committee (Thermal Power) in its 63rd Meeting held during 29th-30th August, 2015. In acceptance of the recommendation of the EAC (Thermal Power) and in view of the information/clarifications furnished by you with respect to the above project, the Ministry hereby accords *permission for continuation of the transport of maximum 1.5 MTPA coal through NW-1 for another six months i.e.* ***upto 31.01.2017*** *subject to continuation of the study being carried out by CIFRI and submission of the additional information sought earlier.*

This issues with the approval of the Competent Authority.

Yours faithfully,

(Dr. S. Kerketta)
Scientist 'F'

Copy to:

1. The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi-110001.
2. The Secretary, Environment and Forests Department, Government of West Bengal.
3. The Chairman, Central Electricity Authority, Sewa Bhawan, R.K. Puram, New Delhi-110066.

4. The Chairman, West Bengal Pollution Control Board, Paribesh Bhawan, 10A, Block- L.A, Sector 3, Salt Lake City, Kolkata – 700098.
5. The Chairman, Central Pollution Control Board, Parivesh Bhawan, CBD-cum-Office Complex, East Arjun Nagar, Delhi-110032.
6. The Additional Principal Chief Conservator of Forests (C), Ministry of Environment, Forest & Climate Change, Regional Office (EZ), A/3, Chandersekharpur, Bhubaneswar – 751023.
7. The District Collector, Murshidabad District, Govt. of West Bengal.
8. Guard file/Monitoring file.
9. Website of MoEF&CC.

(Dr. S. Kerketta)
Scientist 'F'

MINUTES OF THE 38th MEETING OF THE RE-CONSTITUTED EXPERT APPRAISAL COMMITTEE (EAC) ON ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF THERMAL POWER & COAL MINING PROJECTS

The 38th Meeting of the reconstituted EAC (Thermal Power) was held on **25th-26th June, 2015** at Teesta Meeting Hall, Vayu Wing, First Floor, Indira Paryavaran Bhawan (New Building), Jorbagh Road, New Delhi-110003. The members present were:

1. Prof. C.R. Babu - Vice Chairman (Acting Chair)
2. Shri T.K. Dhar - Member
3. Shri A.K. Bansal - Member
4. Shri J.L Mehta - Member
5. Shri N.K. Verma - Member
6. Dr. S.D. Attri - Member (Representative of CPCB)
7. Shri P.D. Siwal & Shri N.S. Mondal - Member (Representative of CEA)
8. Shri B.B. Barman - Member Secretary

Shri G.S. Dang, Dr. C.B.S Dutt, Dr. S.S. Bala, Dr. Ratnavel and Dr. Asha Rajvanshi could not be present. At the outset, the Committee recollected the excellent contribution of the outgoing Member Secretary, Ms. Sanchita Jindal and expressed their gratitude. List of other participants is at **Annexure – I.**

The Committee also welcomed the newly appointed Member Secretary, Shri B.B. Barman.

Thereafter, the following agenda items were taken up:

Item No.1: CONFIRMATION OF THE MINUTES OF THE LAST MEETING.
As no comments/observations were received, the Minutes of the 36th EAC (TP) meeting held during 19th-20th May, 2015 were confirmed.

Item No. 2: CONSIDERATION OF PROJECTS

(From Page 1 of 27)

2.9 Farakka Super Thermal Power Project at Farakka, District Murshidabad, West Bengal by M/s NTPC Ltd.- For Amendment of EC.

The PP along with Inland Waterways Authority of India (IWAI), Central Inland Fisheries Research Institute (CICFRI) and Jindal ITF Ltd. made a presentation and inter-alia provided the following information.

(i) The total installed capacity of Farakka STPP is 2,100 (3x200 + 2x500 + 1x500) MW. The coal requirement is 16.4 MTPA (about 45,000 TPD) and to be met from domestic coal mines through railways. In order to supplement shortfall of domestic coal to the project, it was proposed to import coal through sea route and transport it to Farakka STPS through National Waterway No.1 (NW-1) i.e river Hoogly. Accordingly, MOEF&CC vide letter dated 31.07.2014 accorded permission for use of blended coal (Domestic 70%: Imported 30%) and temporary permission for transportation of imported coal through NW-1 for a period of one year subject to specific conditions. The present proposal seeks Lifetime Permission for Transportation of Imported Coal through NW-1 to NTPC Farakka STPS. The proposal is claimed to be the first of its kind in India.

(ii) Ganga-Bhagirathi-Hooghly river system from Allahabad to Sagar is declared as NW-1 vide National Waterway (Allahabad-Sagar stretch of the Ganga-Bhagirathi-Hooghly river) Act, 1982 (49 of 1982). Out of the total 1620 Km stretch of NW-1, only 560 Km stretch from Sagar to Farakka of

River Hooghly is being utilized for transportation of imported coal. NTPC and IWAI have entered into a MOU to explore the possibility of use of inland waterways as a viable supplementary mode for transportation of coal for Farakka STPP. As per the MOU, IWAI shall maintain the waterway and provide a guarantee for navigability of channel. However, execution and implementation of the coal transportation project shall be done through a private operator. Accordingly a tripartite agreement amongst NTPC, IWAI & Jindal ITF Ltd. was signed on 11.08.2011.

As per the tripartite agreement M/s Jindal ITF Ltd. would be responsible for unloading the coal from the ocean going vessel and thereafter hauling the coal on barges using NW – 1 and ensuring delivery of coal at the coal stack yard of the Farakka STPP by utilizing the unloading infrastructure through grab crane on a civil service platform on Design, Finance, Build, Operate & Transfer (DFBOT) basis.

(iii) Among all modes of transport, inland navigation with adopting proper procedures is currently considered the most environmentally sound and sustainable form (United Nations, 1997; Colvile et al., 2001; European Commission, 2001). According to a report by the Working Group on Ports and Shipping under the National Transport Policy Development Committee of the Planning Commission during 2012, a litre of diesel would carry 105 tonnes over a kilometer through waterways, 85 tonnes through railways and 24 tonnes through roadways. The emission of greenhouse gases is also relatively low from the sector. In view of the above, it is requested that the permission for transport of coal through NW-1 may be accorded for the lifetime of NTPC Farakka STPS. The ecological study carried out by CIFRI and its recommendations werepresented.

2. Based on the information & clarifications provided and detailed discussions held on all the issues, the Committee recommended for continuation of the permission for transport of maximum 1.5 MTPA coal through NW-1 for another one year i.e. till 30.07.2016 and also sought the following additional information based on the study being carried out by CICFRI . After a period of 6 months, the NTPC shall submit/present findings of the study and EAC shall review the findings of the studies and if need be, would undertake a site visit:

I. Long term, and a minimum period of one year continuous study shall be conducted on the impacts of varying traffic loads on aquatic flora and fauna with particular reference to species composition of different communities, abundance of selective species of indicator value, species richness and diversity and productivity.
II. Impacts of noise generated by the barge movement on Gangetic Dolphin which has been declared a National Aquatic Animal.
III. Energy conservation and other perceived benefits vis-à-vis rail and road transportation.
IV. Impact on the abundance of economically important fish species (including Dolphin), fish growth and production at varying traffic loads.
V. Impact on bank erosion vis-a-vis safeguard measures like stabilization of banks with native vegetation (including mangroves) that will prevent erosion
VI. Impact on the fish catch under varying traffic loads and livelihood of fishermen and their views on the coal transportation by barges.
VII. NTPC shall set up a permanent laboratory of CIFRI at the site to expedite the study w.r.t above parameters and for making scientifically sound conclusions.
VIII. The characteristics of treated sewage which is being reportedly used for irrigation. The coliform count specially has to be monitored and reported.
IX. Accordingly, the study should conclusively come out as to what tonnage of coal can be transported through Waterways i.e. in the proposed route of NW-1 in an environmentally sustainable manner.

List of Participants

2.9 M/s. NTPC Ltd.

1. Sh. R.K. Baderia, HoD (Env. Engg.)
2. Sh. Vijay Prakash, AGM (Env. Engg.)
3. Sh. R. Padma Kumar, AGM (FM)
4. Sh. Ambar Kumar, AGM (FM)
5. Sh. Amit More, Manager (Env. Engg.)
6. Sh. A. Ghosh, AGM (Env.), Farakka STPS
7. Sh. R.P. Khare, Member (Technical), IWAI
8. Sh. M.K. Saha, Director, IWAI
9. Sh. Srikanta Samanta, Pr. Scientist, CIFRI, Barrackpore
10. Sh. Amiya Kumar Sahoo, ICAR-CIFRI, Barrackpore
11. Col. P.S. Gill, Sr. GM, Jindal ITF Ltd.
12. Sh. Joy Saxena, GP & WTD, Jindal ITF Ltd.
13. Sh. Anurag Verma, Project Coordinator, Jindal ITF Ltd.
14. Capt. Suvendu Chatterjee, AVP-Project, Jindal ITF Ltd.

Annexure II: Socioeconomic Survey Schedule

ICAR-Central Inland Fisheries Research Institute

Barrackpore, Kolkata – 700 120
Phone: +91 33 2592 1190/91, Fax +91 33 2592 0388, web; http://www.cifri.ernet.in

Survey Schedule

Project: Impact assessment of coal transportation through barges along the National Waterway No.1 (Sagar to Farakka) along River Ganga

Date____________________ Data collector ______________________ Schedule Number _____________________

Place_____________________________________District _____________________________________

1. Household information

a. Name of the head______________________________ Phone Number _______________________________________

b. *Details of the family members*

Sr. No.	Relation	Age	Education	Occupation	Monthly income (Rs.)	Social participation
1.	Family head					
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

2. Socio-economic information:

a. Size of operational holding (2014-15) bigha ____________________________ (1 ha= bigha)

b. Owned land: ________________ Leased in land: ____________ Leased out land:__________ Pond_______

c. Number of economic activities ____________________ d. Daily Cash income ₹ ____________________

d. Total Household income/month ₹ ____________________

e. Monthly Income of the HH from different sources

Particulars	**Fisheries**	**Aquaculture**	**Fish vending**	**Crop farming**	**Business**	**Govt. Service**	**Labour wage**	**Others**
Daily/monthly income(₹)								
Devote how much time in day /week (hrs)								

f. Monthly routine expenses in the HH (₹)

Items	**Before Barge**	**After Barge**	**Items**	**Before Barge**	**After Barge**	**Items**	**Before Barge**	**After Barge**
Food			Entertainment			Education		
Fuel			Utilities bill			House rent		
Clothing			HH Items			Others		
Medical			Social Obligations					

g. Loan amount received

	Amount	**Source**	**Taken on**	**Purpose**	**Repayed amount**
Before Barge					
After Barge					

3. Fishing operations

a. Fishing gears owned (numbers/kg)

	Gill net	Hook and line net	Dragnet	Cast net	Scoop net	Trap	Craft
Before Barge							
After Barge							

4. Catch and disposal before and after movement of barges

Particulars	Q1 (April, May, June)		Q2 (July, Aug, Sept)		Q3 (Oct, Nov, Dec)		Q4 (Jan, Feb, March	
	Before barge	After barge	Before barge	After barge	Before barge	After barge	Before barge	After barge
No. of family members involved in fishing								
Nets & crafts operated								
Hours of fishing/head/ day								
Quantity harvested in each time / trip/head								
Catch per day/ week/head								
Sale (%)								
Home consumption (%)								

Catch Species and price

Particulars	1	2	3	4	5	6	7	8
Q1								
Before barge Major species in catch								
Average sale price Rs/ kg								
After barge Major species in catch								
Average sale price Rs/ kg								
Q2								
Before barge Major species in catch								
Average sale price Rs/ kg								
After barge Major species in catch								
Average sale price Rs/ kg								
Q3								
Before barge Major species in catch								
Average sale price Rs/ kg								
After barge Major species in catch								
Average sale price Rs/ kg								
Q4								
Before barge Major species in catch								
Average sale price Rs/ kg								
After barge Major species in catch								
Average sale price Rs/ kg								

5. Marketing

To whom sale ?

Maketing channel?

labour wage (/day) Man__________________Woman _____________Children________________

6. Impact due to movement of the barges

Particular	Response
Any visible impact on the ecology/ environment of the river?	
In the last one month how many times did you confront the barges while fishing?	
How much fishing hours lost per incident?	
Decrease in catch due to loss of fishing time per incident	
How do you compensate the loss in catch per incident?	By extra fishing ………………hours/incident. Could not compensate the loss/could compensate ……………..%
Any changes in method of fishing, incidence of destruction of nets/crafts in the locality? (in case of destruction of nets/crafts, write name of the fisher, phone no. & date of occurrence)	
Any change in occupation/ incidence of leaving fishing occupation?	
If the barge movement continues for long, say for 5-10 years what will be the impact on livelihood, income and employment?	

7. In case of barge movement to continue, what are your suggestions?

8. Specific observations:

Annexure III : Gazette Notification on hilsa sanctuary

The Kolkata Gazette Extraordinary
Published by Authority

CAITRA 19] TUESDAY, APRIL 9, 2013
[SAKA 1935

PART I-orders and Notifications by the Governor of West Bengal, the High Court, Government Treasury, etc.

GOVERNMENT OF WEST BENGAL
Fisheries Department

NOTIFICATION

No. 719 Fish/C-I /9R-3/20 12 (Part-I).- dated the 4th April, 2013.- In exercise ,of the power conferred by section 19 of the West Bengal Inland Fisheries Act, 1984 (West Ben. Act XXV of 1984) and in supersession of all earlier notification on the subject, the Governor is pleased hereby to make the following amendments in the West Bengal Inland Fisheries Rules, 1985, published in Part-I of the *Calcutta Gazette, Extraordinary,* dated the 6th May, 1985, vide this Department notification no. 1979- Fish/C-I dated, the 29th April, 1985 (hereinafter referred to as the said rules):-

Amendments

In the said rules,-

(1) after sub-rule (2) of rule 46, *insert* the following sub-rules:-

"(3) For the purpose of conservation of hilsa fish stock in the inland open water system, no persons or group of persons or fishers or fisherman or their assistants under no circumstances shall catch hilsa (species group / family: Hilsa shad-Genus / Species: *Hi/sa ilisha* and species group / family: other shads- Genus / Species: other Hilsa species *(renulosa, macrura and todi)* using any kind of monofilament gill net / nets having mesh size below 90 (ninety) millimeter and other nets having mesh size below 40 (forty) millimeter for other fishes.

(4) No person shall transport, market, sell and possess hilsa (species group / family: Hilsa shad- Genus /Species: *Hilsa ilisha* and species group / family: other shads- Genus / Species: other Hilsa species *(tenulosa, macrura and todi)* having length below 23 (twenty three) centimeter and the same is banned.";

(2) after rule 49, *insert* the following rule:-

"50. Declaration of Hilsa Sanctuary and protection of Hilsa.- (I) The riverine area in the river Bhagirathi falling (a) between Lalbagh in Farakka (Murshidabad District), (b) Katwa to Hooghly Ghat (part of Burdwan & Hooghly District), (c) Diamond Harbour to Nischintapur Godakhali and (d) five (5) square kilometer area around the "Sand Bar" located in the river Matla, Roymongal & Thakuran in Sundarbans area and Farakka Barrage are declared as Hilsa Sanctuaries (protected area for Hilsa) .

(2) In order to facilitate spawning, all types of fish catching are banned in the Hilsa Sanctuaries during June to August and October to December every year.

(3) Fishing of hilsa is prohibited within five (5) square kilometer of the Farakka Barrage round the year to protect the hilsa species and facilitate brooders spawning in the area.

(4) For the purpose of conservation of juveniles hilsa Gatka / khoka ilish) migrating downstream towards sea, use of bag net, scoop net, lift net and small meshed gill nets {mesh size below one (1) inch} for catching hilsa below 23.0 centimeters in the inland open water system (including estuarine area) is totally prohibited during February to April every year."

By order of the Governor,

S. K. DAS

Addl. Chief Secy. to the Govt. of West Bengal.

Annexure IV: Some Photographs of Socioeconomic Survey

Interaction with fishermen in upper stretch

Interaction with fishermen in middle stretch

Interaction with fishermen in lower stretch

Group discussion with stakeholders in upper and middle stretch

Annexure V: Energy conservation calculations

I) *Calculation of consumption of High Speed Diesel in transportation of 1 MTPA of imported coal from Haldia to Farakka by IWT*

a.	Distance between Haldia & Farakka through NW-1	: 560 km
b.	Effective capacity of barges of Jindal ITF Ltd.	: 1600 tonne
c.	Average fuel consumption of barges of Jindal ITF Ltd.	: 100 litre/hr
d.	Average speed of barges in upstream direction	: 12 km/hr
e.	Average speed of barges in downstream direction	: 18 km/hr
f.	Time taken in upstream journey (Sagar to Farakka)	: 47 hours
g.	Time taken in downstream journey (Farakka to Sagar)	: 31 hours
h.	Total time taken in one round voyage (f+g)	: 78 hours
i.	Therefore, total fuel consumption in one round trip (c × h)	: 7800 litres
j.	**Hence, total Fuel consumption in transportation of 1 MTPA of coal from Haldia to Farakka by IWT**	**: 4875 KL [X]**

$$\frac{\mathbf{7800\ liters \times 1000000\ tonnes}}{\mathbf{1600\ tonnes \times 1000\ litres}}$$

(The fuel consumption of Barge in upstream and downstream direction will not be the same as the barge will not be loaded in downstream journey and there is advantage of water current also)

II) *Calculation of consumption of HSD in transportation of 1 MMT of imported coal to Farakka Thermal power plant from Haldia and Paradip by Railways*

a.	Distance between Haldia & Farakka by Railways	: 423 km
b.	Distance between Paradip & Farakka By Railways	: 781 km
c.	30% of coal (i.e. 0.3 MTPA) to be transported from Haldia and 70% of coal (i.e. 0.7 MTPA) from Paradip	
d.	Hence total tonne km moved by Railways $[0.3 \times 10^6 \times 423 + 0.7 \times 10^6 \times 781]$	: 673 Million ton-km
e.	One litre of HSD transports 85 t km by railways	:
f.	**Hence, consumption of HSD (in KL) in transportation of 650 million tkm = (673 Million ton-km/85 ton- Km) × 1000 litres**	**: 7918 KL *[Y]***

III) <u>Calculation of fuel saving</u>

a.	Hence, saving of HSD in transporting 1MTPA of coal by waterway as compared to by Railways = [X – Y]	: 3043 KL
b.	Or, saving of HSD in transporting 3MTPA of coal by waterway to Farakka thermal power plant by IWT as compared to Railways	: **9129 Kilo Litres** OR **9.1 Million Litres per year** OR **Rs 45 Crore per year**

Note: Even this huge saving is calculated on conservative side since while both ways actual fuel consumption (and empty run of barges downstream) have been taken in case of waterways, only one side movement has been considered in case of Railways.

Annexure VI: Initiatives taken by IWAI under Jal Marge Vikas Project

The following measures have been taken under Jal Marg Vikas Project:

1. Proposed use of modern inland water vessels, low draft vessels with natural gas (LNG/CNG) as fuel will reduce emission of SOx (50%), NOx (70%), Particulate Matter (95%) and CO_2 (25%). Low draft vessels will be designed to reduce disturbance of benthic flora and fauna.

2. LNG/CNG engines on inland vessels will have lower noise level than diesel engines, reducing noise pollution substantially.

3. Provision of aids to navigation, such as channel markings, day and night navigational aids, including deployment of GPS, river maps and electronic navigation charts for navigation.

4. Provision of River Information System (RIS) and Vessel Traffic Management System (VTMS) with the ability to generate electronic navigation chart, which can be share to fishermen to avoid disturbance of fishing activities.

5. Bank protection works at the sites of the Farakka Feeder Canal.