ASSESSMENT OF FISH AND FISHERIES OF THE GANGA RIVER SYSTEM FOR DEVELOPING SUITABLE CONSERVATION AND RESTORATION PLAN

(Project Duration : 2016-2020)

(Sanctioned under National Mission on Clean Ganga
vide NGRBA Order No. T-17/2014-15/526/NMCG-Fish and Fisheries dated 13/07/2015)

ICAR-CENTRAL INLAND FISHERIES RESEARCH INSTITUTE
BARRACKPORE, KOLKATA- 700 120

FINAL REPORT

Title of the Project

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Summary

The Holy Ganga has a total length of 2525 kilometres, is not only the sacred river also most populated river basin in India. The drainage area of Ganga River is 8,62,729 km^2 which covers nearly 26% of geographic area of the country. The river supports a rich biodiversity on which thousands of people dependtheir livelihood. But in the recent past, rapid ecological degradation caused by several factors in the river basin is observed and declining of fish production and productivity has become a major concern. Twenty sampling sites along river Ganga covering a total distance of 2525 km were selected for quarterly field samplings.

Exploratory Survey of River Ganga for identification of suitable sampling sites

Study area along river Ganga

- Twenty sampling sites along river Ganga namely Harsil, Tehri, Haridwar, Bijnor, Narora, Farrukhabad, Kanpur, Prayagraj, Varanasi, Buxar, Patna, Bhagalpur, Farakka, Jangipur, Berhampore, Balagarh, Tribeni, Godakhali, Diamond Harbour and Fraserganj covering a total distance of 2525 km were selected. The sites selected were almost equidistant. However, two more stations viz. Tribeni and Jangipur were also sampled from time to time due to their importance from fisheries perspective.

Assessment of Fish and Fisheries of the Ganga River

Fish species richness, abundance and distribution in Ganga River

- A total of 190 fish species (182 native and 8 exotics) distributed among 133 genera, 62 families and 23 orders were recorded during the entire study period from Harshil to Fraserganj. Of these, Cyprinidae was found to be the most species rich (28 spp., 14.28%) family, followed by Danionidae (19 spp., 9.69%), Sisoridae (10 spp., 5.10%) and Bagridae (9 spp., 4.59%) respectively.
- In the present study, the highest number of fish species (107 and 95 each)were recorded at Bijnor and Narora, followed by Farakka (87), Prayagraj (85), Kanpur (83) whereas, Diamond Harbour and Godakhali recorded the least number of fish species (38 and 33 respectively).
- Carps were the most well represented and commercially important group found in all the freshwater stretches of the river. Cypriniformes is the most dominant order, contributing 29% of the total fish species diversity.
- Catfishes (Siluriformes) is the second (22%) most dominant group observed among the total fish group

- Commercially important food fishes shared 60.84% whereas ornamental fish and sport fishes shared 35.44% and 3.7% respectively of the total fish diversity in the river.
- Around 15.26% of the fish species foundinthe river are cosmopolitan in distribution inhabiting freshwater, brackishwater and marine water. Only 18.94% of the fish species belong purely to the brackishwater and 10% of the fish fauna are the inhabitant of both freshwater and brackishwater.

Threatened fishes in river Ganga

In the present study, of the total fish species reported, 10% are categorized as threatened species according IUCN Red List (2020) (15 species as Near Threatened, 2 as Vulnerable and 2 as Endangered). About 73.68% (140) the recorded species are under Least Concerned category which can be comprehensively exploited for fishery.

Abundance of Exotic fishes in river Ganga

Eight different exotic fish species viz. *Ctenopharyngodon idella*, *Hypophthalmicthys molitrix*, *Hypophthalmicthys nobilis*, *Cyprinus carpio* var. *communis*, *Cyprinus carpio* var. *specularis*, *Oreochromis niloticus*, *Clarias gariepinus* and *Pterygopliicthys disjunctivus* are found in the freshwater zone of the river contributing about 3.74% to the total fish diversity. Among the exotics, both common carp and tilapia are ubiquitous along upper and middle stetch of river Ganga. The relative abundance of common carp (44.31 %) and *Oreochromis nloticus* (30.15%) were in agreement with the report of Sarkar et al. 2012 from the entire stretch. The upper stretch (Harsil- Haridwar) was found dominated by *Cyprinus carpio* var. *communis* (19.59 %) and *Cyprinus carpio* var. *specularis* (13.61%).The middle stretch (Haridwar-Varanasi) was recorded with highest abundance of *Cyprinus carpio* var. *communis* (1.46%), *Oreochromis nloticus* (2.01 %) and *Clarias gariepinus* (0.37 %) respectively. Abundance of other exotics like *Ctenopharyngodon idella*, *Hypophthalmicthys molitrix, H. nobilis* was found below 0.10 %. Sites like Kanpur, Prayagraj and Varanasi resulted in high abundance of common carp (7.31%, 16.49%, 4.95%) and tilapia (6.64%,7.36%,4.59%). Dominance of *Cyprinus carpio* var. *communis* (7.68%) and *Oreochromis niloticus* (9.41 %) was noticed at Buxar only in the lower stretch. Availability of other exotic species was noticed sporadically below Bhagalpur to Tribeni stretch of River Ganga.The distribution pattern of exotic fish species in the river denotes that, *C. carpio*, was found omnipresent in ten sampling sites depictingsizeable distribution along the local level.

- Abundance of indigenous fish species like Gangetic carp and catfishes are rapidly declining at the cost of exotics.

Catch Trends and Production

- The native Gangetic Carps or Indian Major Carps which was the major contributor in the Ganga River fishery, have been found reduced to a large extent during the study. This study revealed that total catch (freshwater fish catch) from river Ganga has increased from 3796.57 t (2018-19) to 4263.55 t (2019-20). Maximum fish catch in the river was recorded from the middle stretch (from Prayagraj to Farraka) contributing about 47.5% of total fish catch in 2019-20.

Fishing gears and their sustainable issues

- Existing fishing gears are being modified by the fisherman to exploit maximum fisheries resource, due to which many traditional fishing gears are going into oblivion. Many unsustainable fishing gears of destructive nature especially the zero or small mesh sized gears are common in this river. Common fishing gears like bag net (*Beenti jaal*), Set barrier (*Chaurpata jaal*), Shore seine (*Ber/chat jaal*), etc. should be controlled or banned with suitable alternative livelihood measures to the associated fishers.

Stock Assessment of Selected Fish Species

- The present study indicated that *L. rohita* showed positive allometric growth pattern throughout the period. As per Gulland (1971), the level of exploitation (*E*) was found to be much below from the exploited level (E_{opt}= 0.5) though the continuous recruitment pattern was observed with two major peaks in May (28.98%) and October (18.25%) in the study period.
- *L. catla* indicated isometric growth pattern during the study period. Continuous recruitment pattern was observed for *L. catla* from river Ganga with two major peaks in July (20.08%) and August (20.72%). The exploitation rate for the species was observed to be at optimum level from the river.
- *C. mrigala* indicated positive allometric growth pattern during the present study. Continuous recruitment pattern was observed with two major peaks in July (12.30%) and August (19.60%). The exploitation rate suggests that *C. mrigala* was exploited slightly higher than the biological optimum level.
- *L. calbasu* indicated somewhat isometric growth pattern during the study. Continuous recruitment pattern was observed all over the year with two major peaks in July and August. A much higher exploitation rate of E= 0.71year $^{-1}$ was confronted in case of *L. calbasu* indicating overexploitation of the present stock.

Identification of migratory fishes and their range of migration

Our investigation records thirteen migratory fish species (11 finfish and 2 shellfish) and through the tagging experiment conducted under the project, one hundred Indian Major Carps were tagged and released in river Ganga for studying their migratory behavior.

Assessment of key habitat variables in relation to fish distribution and various biological activity o the fishes

Different Physico-chemical parameters like water temperature, depth, flow transparency, turbidity, pH, dissolved oxygen, alkalinity, calcium, magnesium, total hardness, total solid, total dissolved solid, BOD and other important nutrient parameters and sediment characteristics of River Ganga were analysed.

- Common carp abundance found positive correlation with BOD ($p<0.73$), flow ($p<0.67$) and total phosphate ($p<0.82$) which is a clear indication in the role of anthropogenic pollution behind common carp abundance whereas, negative correlation was found with salinity can also be contributed to the higher abundance in monsoon when salinity is lower.

Water quality status of river Ganga

- Average water temperature in the entire stretch of river Ganga varied from 7.22°C to 29.52°C. During the entire sampling, the lowest water temperature (3.21°C) was observed at Harshil, While the highest temperature of 36.6°C was observed at Buxar-Baliya Stretch of the river Ganga.
- Average depth in the entire river stretch was estimated at 6.34 m. During the study period, lowest average depth of 0.69 m was observed at Harshil in upper hilly stretch, and whereas the highest average depth of 13.36 m was observed at Diamond Harbor, which is a tidal zone of the river.
- River flow in the upper stretch of the river, the highest average flow value of 1.09 m/sec was observed at Harshil, 0.63 m/secin the middle stretch at Narora, and in the lower stretch highest average flow of 1.09 m/sec was observed at Tribeni.
- Average transparency in the entire river was estimated at 43.94 cm during the study period of 2016-2020. The highest average transparency value of 88.20 cm was observed at Tehri in the upper stretch of the river. In the middle stretch, the highest transparency (52.50 cm) was recorded at Buxar and in the lower stretch the highest average transparency (73.75 cm) was observed at Farakka. The lowest transparency value (17 cm)in the entire stretch was observed at Diamond Harbour. Significantly lower transparency was recorded during monsoon months as compared to non-monsoon period.

- The turbidity in the middle and lower stretch ranged from 3.7 NTU to 523 NTU. Average turbidity in the entire river was 99.64 NTU. Highest average turbidity value of 208.06 NTU was recorded at D. Harbour of lower stretch of river Ganga.
- The observed average pH value of water in the entire river is 8.12 and ranged from 7.2 to 9.51 indicates nutral to lightly alkaline condition through out the season. The highest average pH value of 7.9 was recorded at Narora, and the lowest pH value of 7.29 was recorded at Farrukhabad.
- The dissolved oxygen level was above 6 ppm in entire stretch of river Ganga during the study period. The highest average dissolved oxygen value of 9.04 ppm was observed at Harshil in the upper stretch of the river;7.66 ppm in the middle stretch at Prayagraj, and in the lower stretch observed highest dissolved oxygen was 6.64 ppm at Farakka.
- Higher average alkalinity value of 163 ppm was recorded at Buxar-Baliya stretch of the river Ganga and highest average total hardness value of 1095.46 ppm was recorded at Fraserganj describe the low alkaline zone.
- Salinity ranges was recorded from 0.01 ppt to 31.79 ppt in the entire river stretch. Harshil to Tribeni stretch being freshwater zone, salinity ranges 0.01 to 0.15 pptwhereas,0.19 to 2.5 ppt was found at Godakhali and Diamond Harbour stretch considered as brackishwater zone. Highest average salinity value of 28.73 ppt was recorded at Fraserganj as it is an esturine zone of the Ganga river stretch.
- Highest average total dissolved solid (41.40 g/l) and Total Solid value (50.62 g/l) was recorded at Fraserganj. In upper & middle stretch, significant improvement was observed at Haridwar (13.1 %), Narora (17.5%), Kanpur (17.4%), Prayagraj (32.71 %) and Varanasi (7.6 %). In lower stretch, improvement was observed at Buxar (6.9 %), Patna (21.8 %) & Bhagalpur (27.5 %). In estuarine stretch also, improvement was observed at Balagarh (46 %), Tribeni (44.9 %), and Godakhali (26.4 %). However, supersaturated condition of oxygen level was obtained at Buxar, Patna, Balagarh and Tribeni (middle to lower stretch) during pre-monsoon mainly due to *Microcystis* sp. (Blue green algae) bloom formation and at Balagarh and Tribeni in winter due to bloom by the diatom, *Aulacoseira granulata.* During July 2018, a thick scum *Microcystis aerugenosa* bloom was noticed first at Buxar 2245 unit/l and Bhagalpur 1012 unit/l stretch.
- Genus *Aulacoseira* showed higher degree of abundance during winter months from December to January causing difficulties in water treatment plant.
- Highest average total phosphorus value of 0.65 ppm was recorded at Bhagalpur.

- Highest average available nitrogen value of 1.18 ppm was recorded at Varanasi and Highest average Total Nitrogen value of 3.6 ppm was recorded at Godakhali
- Highest average B.O.D value of 3.83 ppm was recorded at Kanpur followed by Varanasi 3.6 ppm and Prayagraj 3.36 ppm due to industrial belt area indicates pollution in Kanpur to Prayagraj stretch of river Ganga.
- Higher average free carbon dioxide value was observed at upper stretches as Harshil, Bijnor and highest of average free carbon dioxide 5.41 ppm was recorded at Haridwar stretch of the river Ganga.
- Average specific conductivity in the entire river was 5.16 mS/cm. Highest average specific conductivity value of 43.12 mS/cm was recorded at Fraserganj. In upper and middle stretch, significant lowering was observed at Harshil (38.16 %), Tehri (31.39 %), Narora (36.3 %), Farrukabad (32.03 %), Kanpur (32.4 %), Prayagraj (31.45 %) and Varanasi (18.33 %). In lower stretch, significant lowering was observed at Buxar (2.7 %) and Farraka (14.3 %) showing the betterment in the health status of the river during the study period.
- Average total chlorophyll in the middle and lower stretch ranges from 0.29 to 42.05 mg/m^3. Highest average chlorophyll content in river water of $16.47 mg/m^3$ was recorded at Tribeni.

Sediment Characteristics of River Ganga

- The sediment pH in the entire stretch of river Ganga ranged from 7.3 to 8.46 through out the season indicates alkaline nature of sediment of Ganga river bed. The highest average soil pH value of 8.46 was recorded at Farrukhabad.
- Average specific conductivity of the sediment in the entire stretch of river Ganga ranged from 0.14 to 5.59 mS/cm. Highest average specific conductivity of 5.59 mS/cm was recorded at Fraserganj as higher range of specific conductivity was found at brackishwater to estuarine zone.
- Highest average available phosphorus value of 6.83 mg/100g was recorded at Tehri.
- The sediment available nitrogen in the entire stretch ranges from 4.9 to 12.56 mg/100g. Highest average available nitrogen value of 12.56 mg/100g was recorded at Tribeni.
- The Free $CaCO_3$ of sediment in the entire stretch ranged from to 4.68 to 10.15%. Highest average Free $CaCO_3$ value of 10.15%. was recorded at Bhagalpur.
- Organic carbon accumulation in sediment was noted in few locations like Bijnor (above barrage; 1.14%) due to partially stagnant water and estuarine zone (like Fraserganj

1.08%) due to mangrove area. On the other hand, slightly acidic sediment pH was noticed in hilly stretch of river Ganga during some occasions (Range 6.55 to 9.01; Average 8.02). Sandification of river bed (>90% sand) is a matter of concern especially upper and middle stretch of river up to Prayagraj (Range 30 to 100 %; Average 76.48%).

Heavy Metal Status along Middle and Lower Stretch of River Ganga

- Heavy metal concentration in river water, sediment, periphyton and fish muscle were analysed during the study. Among the heavy metal concentration *Copper* was found highest (0.039 mg/l) in water at Fraserganj during 2018-2019 and same observation was also reported in next period (2019-2020). However, the other metal concentrations like Zinc, Manganese, Lead and Cadmium in river water were found within safe limit.
- The average concentration of Copper found highest (34.95 mg/kg) at Bhagalpur (Bihar). As per International Joint Commission (1982), US EPA (2002) safe limit of heavy metal in sediment the Copper concentration at Bhagalpur showing the moderately polluted area. The average concentration of Chromium found highest (54.104 mg/kg) at Fraserganj (West Bengal). As per International Joint Commission (1982), US EPA (2002) safe limit of heavy metal in sediment, the Chromium concentration at Fraserganj showing the moderately polluted area.
- Heavy metal in periphytic algae were found at different stretch of river within safe limits.
- Concentration of heavy metals in fish flesh like *R.rita*, *M. cavassius*, *P. conchonius*, *X. cancila*, *O. rubicundus* found within safe limits and other 14 fish species were analysed below detection limit.

Planktonic Status in River Ganga

- A total of 95 genera of phytoplankton, belonging to 13 classes and 7 phyla and 36 genera belonging to 11 classes and 4 phyla of zooplanktons were recorded from entire stretch of River Ganga. Pollution indicator species of Phytoplankton in River Ganga were positively correlated with water nutrient parameters like Total-N, Nitrate-N, Total Phosphate and Silicate during the study.
- However, 93 genus of periphytonic group belonging to 75 genus of phytoplankton and 18 genus of zooplankton were also recorded in the present study.

Benthic status in River Ganga

- The study also showed the availability of 69 macrobenthic species belonging to three different phyla- Mollusca, Arthropoda, and Annelida at Ganga River stretch.

- Amongst the gastropods, *Melanoides tuberculata* belonging to the thiaridae family records a maximum of 23,779 inds/m^2 at Farakka whereas species belonging to the viviparidae family like *Filopalaudina bengalensis* is recorded highest of 4515 inds/m^2 at Patna. *Tarebia granifera*is a commonly available species from Bijnor to Fraserganj showing maximum abundance of 4429 inds/m^2at Balagarh. *Lymnaea acuminate* representing the lymnaeidae family, recorded a maximum individuals of 5719 inds/m^2 at Farakka. *Brotia costula* belonging to the pachychilidae family recorded a highest abundance of 2795 inds/m^2 at Farakka.
- *Parreysia favidens* and *Corbicula striatella* are the two bivalvia species belonging to unionidae and cyrenidae families, shows the highest abundance of 1419 inds/m^2 and 1935 inds/m^2 at Buxar respectively.
- The bioindicating species like *Physella acuta* recorded maximum (890 inds/m^2) at Haridwar, while *Mekongia crassa* belonging to the viviparidae family is found to be maximum (301 inds/m^2) at Farakka. *Parreysia corrugata* is recorded maximum from Kanpur with 600 inds/m^2 whereas, *Indonaia andersoniana* is recorded maximum from Narora.
- Dragonfly nymph is recorded as another pollution indicating insect which is reported from Kanpur showing a maximum abundance of 170 inds/m^2 while, *Anax* sp. is recorded to be abundant at Narora. Chironomid larvae is reported to be one of the potential pollution indicator species recorded maximum of 2451 inds/m^2 from Patna. Phylum Annelida also contributes to the pollution indicator species depicting *Tubifex tubifex* to be one of the most dominant bioindicator primarily at Kanpur with an abundance of 320 inds/m^2.The relativity of pollution indicator benthos species has been influenced by soil parameters like total phosphate, total nitrogen, total chlorophyll, and soil organic carbon.

Studies in Open vs Closed Wetlands of River Ganga

- Present study revealed that river connectivity has an obvious effect on the status of water quality, sediment characteristics, the nutrient profile of water, and sediment of the ecosystem of both the wetlands. The fish species as well as plankton species diversity was found more in open wetland though macro benthic diversity was the same in both the wetlands. The reason behind the diversity differentiation of open and closed wetlands may be the connection with the river. The linkage channel made the freshness environment of open wetland which causes the ecosystem more productive due to hydrological exchanges.

- Fish fauna and benthos community show a positive correlation with whereas plankton has a positive correlation with Nitrate-N Phosphate ($r=0.421$; $p< 0.05$), and Mg^{++} in open wetland. In closed wetland, water parameters didn't exhibit any positive influence to fish, benthos and plankton community.
- Breeding and nursery requirement through studies in Ganga river associates open vs closed wetlands were studied. In the present study, recorded 45 freshwater fish species from open wetland are very common fish species in Ganga River where as 2 exotic fish species as *Hypopthalmicthys nobilis* and *Oreochromis mossambicus* among 23 fish species form closed wetland are found very rare in river. Size class of 5 fish species like *Gudusia chapra, Ailia coila, Botia dario, Botia lohachata* and *Rasbora daniconius* were recored in juvenile stages (<11 cm) specifically monsoon and post monsoon season from open wetland.

Depth and velocity requirement of selected six fishes

- Depth and velocity of entire Ganga stretch were studied during the period. The selected six important fish species as *Schizothorax richardsonii, Tor putitora, Labeo rohita, Labeo catla, Cirrhinus mrigala* and *Labeo calbasu* are fresh water habitat and *Schizothorax richardsonii,* and *Tor putitora* were cold water species recorded from Harshil, Tehri and Haridwar stretch of river Ganga whereas *Labeo rohita, Labeo catla, Cirrhinus mrigala* and *Labeo calbasu* were found from Bijnor to Tribeni stretch of river.
- The depth ranges 0.69 m to 10.77m and flow ranges 0.12 to 1.2 m/sec found suitable for the selected fish species.

Seed Production (In-Situ) of selected fish species and ranching in the depleted river stretches

Seed production of selected commercially important fish species of river Ganga

- Seed production of IMCs (*Labeo rohita, Labeo catla, Cirrhinus mrigala* and *Labeo calbasu*) through induced breeding werestarted since 2017 and the same activity has been continued every year till date for ex-situ conservation of wild fish germplasm of river Ganga.
- A total of 2 crore (approximately) spawn have been produced during 2017-2020 through induced breeding programme.
- Estimates of annual spawn production ranged between 12 lakh/year and 79.4 lakh/year.
- As a part of this programme, ICAR-CIFRI conducted 43 ranching programmes during the project period and released more than 30 lakh of IMC fingerlings produced through

induced breeding of Gangetic brooders and Mahseer in river Ganga in order to conserve and restoration of IMC & Mahseer in the river.

- Ranching programmes were conducted at theriver stretches like Prayagraj, Varanasi, Sahebganj, Maharajpur, Farakka, Balagarh and Barrackpore area where the catch of IMCs decline drastically. Besides these,ranching was also conducted at some major pilgrimage areas like *Rishikesh, Dasashwamedh Ghat, Kumbh mela, Sangam* and *Mayapur*.

Quantitative and Qualitative evaluation of fish spawn

- The average fish spawn production has been estimated to be only 21 ml (435 million) from middle and lower stretch of river Ganga. Qualitative investigation of fish spawn was undertaken in the lower stretch of the river viz. Farakka, Lalgola and Guptipara in West Bengal indicated a total of 46 species belonging to 36 genera, 19 families and 8 orders during the period 2018-19.
- The site Guptipara has been confronted with maximum availability of fish species (0.38%) followed by Farakka (0.36%) and Lalgola (0.25%) respectively.

Juvenile availability of important fish species along Ganga River stretch

- Twelve sampling stations viz. Bijnor, Narora, Farrukhabad, Kanpur, Prayagraj, Varanasi, Buxar, Patna, Bhagalpur, Farakka, Berhampore and Balagarhfrom middle to lower stretches of river Ganga were found more productive than other stations for juveniles of commercially important fishes.
- Very few numbers of juvenile fish species were reported from Harshil, Tehri and Haridwar stretch followed by Godakhali, Diamond Harbour and Fraserganj stretch. The juvenile fish composition obtained from river Ganga was mainly divided into seven major groups such as carps which include major, medium and minor carps; the catfish including large and small sized catfish groups; the miscellaneous which includes fish species of lesser economic importance, growth rate and opportunistic ones and lastly the exotics and their catch percentage have been calculated at each station in the entire river stretch.
- The juvenile fish species was found abundant at Farakka (23) followed by Buxar (21) and Balagarh (16).

Awareness campaign on Sustainable Fisheries and Conservation

- ICAR-CIFRI conducted 46 mass awareness programmes during the project period. A total of 3890 numbers of fishers were sensitized through the awareness campaign in 4 states viz., Uttarakhand, Uttar Pradesh, Bihar and West Bengal including major pilgrimage area like *Rishikesh, Dasashwamedh Ghat, Kumbh mela, Sangam* and *Mayapur*.

- The purpose of the programme was to create awareness among local people including fishers on the detrimental effects of destructive fishing methods like use of zero meshed net and other methods such as poisoning, dynamitting, etc.and were advised not to catch the juveniles and brooders especially during breeding seasons (June-August) for the conservation of fishes in river Ganga. Also, awared about the benefits of closed fishing sesaons in conservation of fishesto the fishermen.

Identification of conservation sites (Aquatic Biosphere/National Aquatic Park) through data generate from thestudy

Protected areas along river Ganga with respect to the sampling sites

- Protected areas include National Park (3), Wildlife Sanctuary (8), Biosphere reserves (2) and one conservation reserve spanning across five different states along river Ganga with respect to oursampling sites were identified as Conservation Sites (Aquatic Biosphere/National Aquatic Park).
- Our investigations revealed the middleandlower stretches of the river Ganga more productive as spawning ground as well as fish juveniles of commercially important fishes during the study. Farakka, Lalgola and Guptipara stretches were found the most suitable sites for fish spawn availability whereas, species richness of fish spawn as well as abundance of juvenile fishes were more along Farakka, Buxar and Balagarh stretches hence, it is suggested that these stretches may be designated as conservation sites of fish species.

Preparation of the Fisheries Conservation and Restoration Plan for the Ganga River System

- A critical analysis was made to determine the commercially important prized fishes of river Ganga which were fished below their maturity length (L_m).
- The data was assessed selectively for 32 fish species combining with length at first maturity parameter of female from the Ganga River Basin.
- The results showed the percentage of Near threatened category fishes like *Harpadon nehereus, Chitala chitala* and *Ompok bimaculatus* were found below the maturity size and the abundance was recorded as 72.22%, 84.44% and 94.11% respectively. This indicates over exploitation of fishes before attaining L_m, thus it leads to growth overfishing of those fish species.

- Similarly, percentage of exploitation rate of small sized fishes remains 65.27 % for Rohu and 51.68 % for Catla in River Ganga.
- Among the major carps, *Labeo calbasu* is caught most extensively in the river stretch showing to its year round availability. The study suggests that gillnet fisheries represent a greater threat along Ganga River threats . Thus, proper management plan should be implemented based on mesh size regulation of gill nets for conservation as well as sustainable fisheries at Ganga River stretches.

Socio-economic status of *Fishermen Co*mmunity along different sites of river Ganga

- Socio-economic study of the Ganga fishers wa**s** carried out in 141 villages involving 1059 fishermen from different stretches of the river. The study revealed that most of the families of the fishers are directly involved in fishing for their livelihood.
- It was also observed that mostof the fishermen belong to the age group of of 40 to 50 years along all the stretches. Participation of youth (15 to 30 years age group) in fisheries or fishing activities was found comparatively less in all the three stretches with the least participation of youth in the upper stretch. Uncertainty of income from riverine fishery may be the main reason behind it.
- Around 21% of the respondents were found just literate in the upper stretch while in the middle and lower stretch around 25% and 23% respondents respectively were found to have attended high school. Of the total respondents, three graduate respondents were found in the middle stretch The survey revealed that theliteracy status of the Ganga fishermen community was poor.
- Fisheries-related activities form a major part of their total income and play a major role in their livelihood. Average monthly income of the fishermen were Rs. 7283, Rs. 5866, and Rs. 4345 in lower, middle and upper stretchof the river, respectively. The arrangement of alternative livelihood option for fishers is vital in the present situation.

SECTION-I

INTRODUCTION

River Ganga extending from 22°18'06.43"N to 31°02'49.31"N and 77°58'47.44"E to 88°30'37.89" E-flows through the heart of the country covering states of Uttarakhand, Uttar Pradesh, Bihar and West Bengal. It is considered to be the largest riverof the country and fifth largest in the world. The river has a total length of 2525 kilometres traversing a long course, emerging from Gangotri, passing through different states and finally drains into the east coast of the country in Bay of Bengal. During its course of flow, the river navigates through a number of growing cities with population of over one lakh. The drainage area in India is 8,62,729 km^2 which is nearly 26% of the total geographical area of the country. Ecologically, river Ganga is a complete assemblage of various spectrums of habitat. The river supports a rich number of fish fauna on which thousands of people depend their livelihood. But in recent past, due to constant ecological degradation caused by man-made hindrances in the river basin there is noticeable decline in both fish production and productivity. Therefore, it is a need of the hour to conserve and restore the Gangetic ecosystem in a sustainable way which will finally add the biotic components as a whole. National Mission for Clean Ganga (NMCG) under Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation is presently monitoring various aspects of the Ganga River System in different states of the country. To conduct, study on the fish and fisheries of the Ganga River System, the Ministry has financially supported a five-years long initiative of ICAR-Central Inland Fisheries Research Institute, Barrackpore (No:T-17 /2014 15/526/NMCG-Fish and Fisheries Dated 13/07/2015). The project was formally launched on 7th July, 2016 in a launching workshop held at ICAR-CIFRI, Barrackpore, West Bengal and its regional centre at Prayagraj, Uttar Pradesh. The result obtained so far is compiled in the present report. Since, the riverine fisheries have also been considered to be one of the important economic activities of the nation, it is worthwhile to assess and link such action plans with the aquatic animals.

OBJECTIVES OF THE PROJECT

- Exploratory survey of river Ganga for identification of suitable sampling sites through experimental cruise
- Assessment of fish and fisheries
- Stock assessment of selected fish species (*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu, Tor putitora* and *Schizothorax richardsonii)*
- Identification of migratory fishes and range of migration through tagging (normal/ satellite) in the entire stretch of Ganga
- Assessment of key habitat variables in relation to fish distribution and various biological activity of the fishes
- Seed production (In situ) of selected fish species (*Tor putitora*, *Schizothorax richardsonii*, *Labeo rohita*, *Labeo catla*, *Cirrhinus mrigala* and *Labeo calbasu*) and ranching in the depleted river stretches
- Awareness campaign on sustainable fisheries and conservation for controlling of destructive fishing methods, mesh size regulation, ban period implementation with community mobilization
- Identification of conservation sites (Aquatic Biosphere/National Aquatic Park) through data generated from the study
- Preparation of the fisheries conservation and restoration plan for the Ganga River System

OBJECTIVE-I

EXPLORATORY SURVEY OF RIVER GANGA FOR IDENTIFICATION OF SUITABLE SAMPLING SITES THROUGH EXPERIMENTAL CRUISE

Study area along river Ganga

Quarterly field campaigns were carried out during January 2016 to October 2020 for sampling of fish, plankton, periphyton, benthos, sediments and water samples from different stations along river Ganga. The sampling sites covered the states of Uttarakhand, Uttar Pradesh, Bihar and West Bengal. The sampling sites of the river are tabulated below (Table 1 and Fig. 1).

Table 1. State and distance wise distribution of sampling stations in river Ganga

River Ganga		
Stations	**State**	**Distance between two stations (Km)**
Harshil	Uttarakhand	0
Tehri		133.09
Haridwar		133.02
Bijnor	Uttar Pradesh	97.09
Narora		182.39
Farrukhabad		214.02
Kanpur		187.57
Prayagraj		261.28
Varanasi		220.03
Buxar	Bihar	129.52
Patna		185.24
Bhagalpur		285.00
Farakka	West Bengal	198.62
Jangipur		54.01
Berhampore		70.07
Balagarh		184.04
Tribeni		26.37
Godakhali		90.66
Diamond Harbour		36.6
Fraserganj		76.6

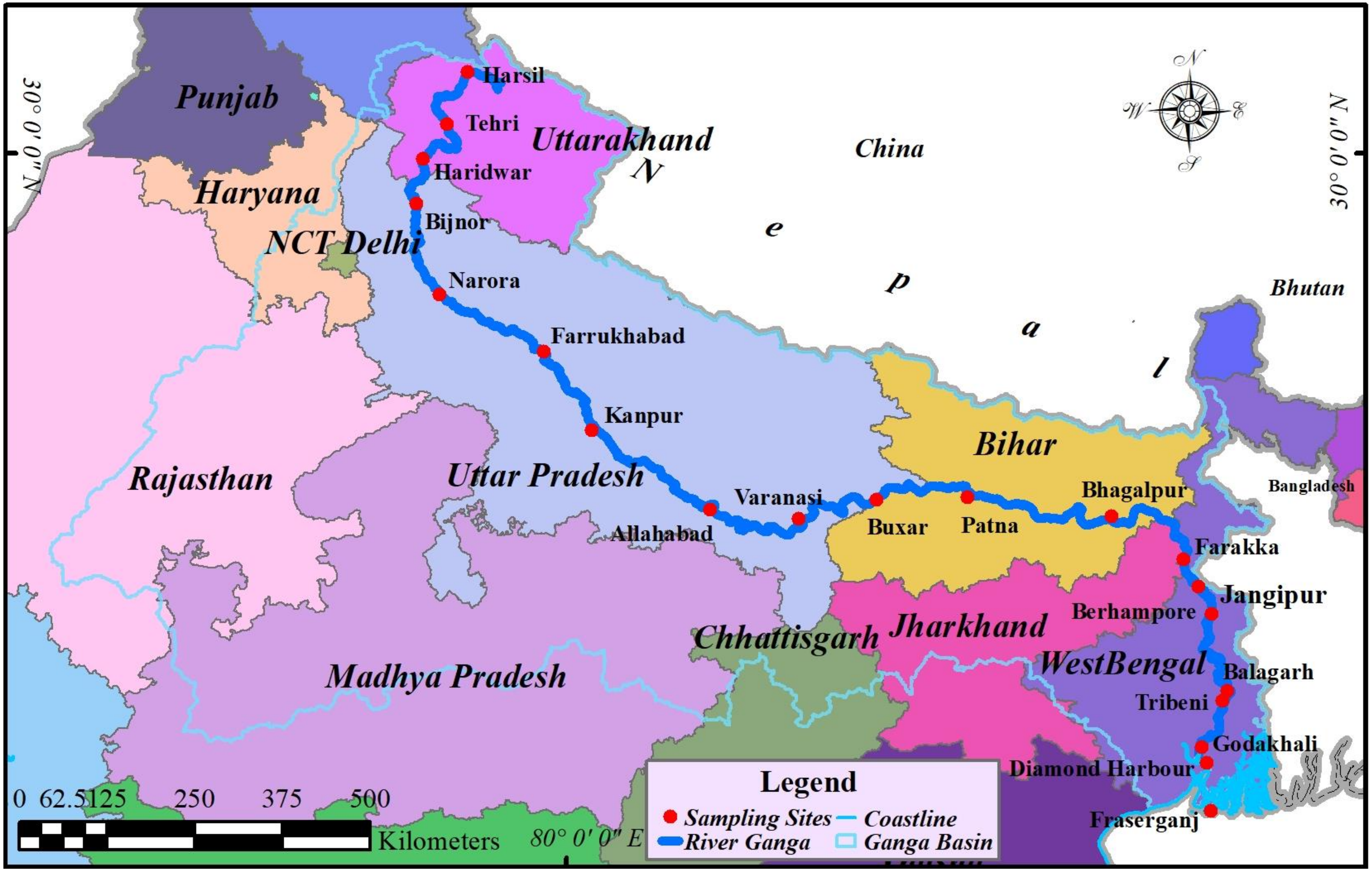


Fig. 1 Study area along river Ganga

SAMPLING METHODOLOGY

Sampling procedure

Twenty sampling sites along river Ganga namely Harsil, Tehri, Haridwar, Bijnor, Narora, Farrukhabad, Kanpur, Prayagraj, Varanasi, Buxar, Patna, Bhagalpur, Farakka, Berhampore, Balagarh, Godakhali, Diamond Harbour and Fraserganj covering a total distance of 2525 km were selected. The sites selected were almost equidistant. However, two more stations viz. Tribeni and Jangipur were also sampled from time to time due to their importance from fisheries perspective. The main river channels as well as adjacent fishing villages/landing centers were sampled for fishes. The various selective and non-selective gears used for the catching the fishes were gill nets, various seine nets, trap nets, barrier and falling nets, cast nets, drag nets, bag nets, etc. The fish samples were collected mainly through experimental fishing and from landing centers within a stretch of 5 km and were identified on spot or preserved in 10% formalin and transported to the laboratory for further analysis. Further, the abundance of species indicative in the observations are the total number of fishes of the individual species collected using various types of gears from various habitat niches within 5 km of each site per sampling.

Estimation of physico-chemical parameters

Water and sedimentquality parameters were assessedwithin 5 km of the fishing sites. Water and sediment samples were collected across the river including the river banks and also from sub-surface layer of the middle of river to obtain composite water and sedimentsamples from each station. Thereafter,water and sedimentsamples were mixed and analyzed following standard methods (APHA, 2015 and 2017) for water and the methods outlined in Piper (1966) and Jackson (1964) for sediment samples.

OBJECTIVE-II

ASSESSMENT OF FISH AND FISHERIES OF THE GANGA RIVER

Methodology

Study area

River Ganga is the most important water channel flowing through the western to the eastern parts of the country stretching across 77°58'47.44''E longitude to 88°30'37.89''E longitude and 22°18'06.43''N latitude to 31°02'49.31''N latitude, travelling a distance of 2525 km. The present report narrows down the broad and vast aspects of the river to focus upon the richness of fish species aggregating at each of the Twentysampling stations distributed over the entire stretch of river Ganges. The study area is concentrated upon thosestations observing the presence of variety of fish species as well as the abundance of fish species at each sampling station. The entire course is divided into four parts: the upper stretch (Harshil to Haridwar), middle stretch (Bijnor to Varanasi), lower stretch (Buxar to Tribeni) and estuarine stretch (Godakhali to Fraserganj).

Data collection

Field campaigns were performed quarterly for the collection of fish faunal data within a span of fouryears from September 2016 to October 2020. The main river channels as well as adjacent fishing villages/landing centers were sampled for fishes. The selected sampling sites were further grouped on the basis of their hydrological characteristics. The various selective and non-selective gears like multi meshed gill nets, various seine nets, trap nets, barrier and falling nets, cast nets, drag nets, bag nets, etc. were utilized for collection of fish samples. The fish samples were collected mainly through experimental fishing and from landing centers within a stretch of five km and were identified on spot or preserved in 10% formalin and transported to the laboratory for further analysis. The specimens were deposited in the Fish Biodiversity Museum of ICAR-Central Inland Fisheries Research Institute, Barrackpore, West Bengal, India.

Habitat quality parameters (water, sediment, plankton, periphyton and benthos) were analyzed from these sites during the same period. Fish samples of selected fish species were collected from the above sites for biological studies. Information on number of boats engaged in fishing and quantity of fishes caught by each boat (CPUE) wererecorded from each landing station. All the boats engaged in commercial fishing were counted along with the quantity of fishes caught, if number of boats is less than thirty. At least 50% of the boats were examined, when number of boats is more than thirty. (If the stations are remote or getting catch and effort data from fishers is difficult, in such case at least the total number of boats engaged in fishing and total IMC's landed during the entire month with number of active fishing days were obtained from auctioneer's data register/fisher friends,etc).

Fig. 2 Experimental fishing at Harsil

Fig. 3 Experimental fishing at Haridwar

Fig. 4 Experimental fishing at Farrukhabad with cast net

Fig. 5 Experimental fishing at Prayagraj with gill net

Fig. 6 Experimental fishing at Varanasi with cast net

Fig. 7 Experimental fishing at Buxar with seine net

Fig. 8 Experimental fishing at Patna with seine net

Fig. 9 Fish catch from bag net at Diamond Harbour

Fish identification

Using the established taxonomic keys (morphometric and meristic characteristics), the collected fish specimens were identified to species level Day (1889), Talwar and Jhingran (1991), Jayaram (1999), Jayaram (2006 & 2010), Nelson et al. (2016) and Froese and Pauly (2021). The taxonomic names and positions are also evaluated by referring Eschmeyer et al. (2021) and FishBase (Froese and Pauly 2021). Global conservation status of the collected fish species was checked and updated following Eschmeyer (2020) and IUCN (2020).

Analysis

Fish species diversity indices and juvenile distribution were also employed using PAST software (Hammer et al., 2015) to analyze and identifythe major diverse areas of the river system. The relationship between length and body weight (LWR) of the fishes (combined group of both the sexes) was calculated by the method of linear regression analysis using the formulae: Log W = Log a + b Log L (Where: W = Body weight (gm), L = Total length (cm (TL) and 'a' is the intercept and 'b' is the slope of the linear regression on the logarithmic value of weight and length. The 'b' values are specified to range between 2.5 to 4 in fishes (Hile, 1936; Martin, 1949). However, in most of the cases, the value diverts from 3Length class frequency distributions of each species were determined using MS Excel office, 2010.

Quantification and estimation of invasion index of fish species have been a useful method for determining the impact of fishes in the respective water body. The methodology behind the determination of Invasion index (Ix) was calculated to assess the rate of impact. The invasion index assesses the rate up to which a particular alien species has invaded in particular system (Singh et al., 2013). The Index (I_x) is calculated on the basis of exotic abundance (En) with respect to other native riverine fish species (N). Value less than '0' depicts lesser loss of native fish diversity, while value above 1 result in higher rate of loss. The index has been assessed (2017-2020) for the most two common invaded species Common carp and Tilapia in the river.

RESULTS

Fish diversity

A total of 190 fish species (182 native and 8 exotics) distributed among 133 genera, 62 families and 23 orders were recorded during the entire study period from Harshil to Fraserganj. In a total of the 62 families.Of these, Cyprinidae was found to be the most species rich (28 spp., 14.28%) family, followed by Danionidae (19 spp., 9.69%), Sisoridae (10 spp., 5.10%) and Bagridae (9 spp., 4.59%) respectively.. In the present study, the highest number of fish species (107 and 95 each)were recorded at Bijnor and Narora, followed by Farakka (87), Prayagraj (85), Kanpur (83) whereas, Diamond Harbour and Godakhali recorded the least number of fish species (38 and 33 respectively). Carps were the most well represented and commercially important group found in all the freshwater stretches of the river. Cypriniformes is the most dominant order, contributing 29% of the total fish species diversity. Catfishes (Siluriformes) is the second (22%) most dominant group observed among the total fish group. Commercially important food fishes shared 60.84% whereas ornamental fish and sport fishes shared 35.44% and 3.7% respectively of the total fish diversity in the river. Of the total fish species reported, 10% are categorized as threatened species according IUCN Red List (2020) (15 species as Near Threatened, 2 as Vulnerable and 2 as Endangered). About 73.68% (140) the recorded species are under Least Concerned category which can be comprehensively exploited for fishery. However, as perthe threatened status of freshwater fishes of India compiled by NBFGR (2010), 11 species are Near Threatened and 19 are Vulnerable species among the total fish species from the river (Table 2). Representation of threatened category based on the current state of knowledge needs to be further developed for the Gangetic fish fauna as the risk assessment status of 12.10% of the indigenous species are yet to be established. River Ganga is also known to inhabited by diverse zoogeographical fish species of varied hydrological regimes. The investigation has also further classified 55.78% of the species to be solely freshwater inhabitants. Around 15.26% of the fishes of the river are cosmopolitan in distribution inhabiting freshwater, brackishwater and marine water ecosystems which includes 17 families and 26 genera. Subsequently, only 18.94% of the species belong purely to the brackishwater and marine water habitat (24 families and 34 genera). Out of the total species diversity, 10% of the fish fauna are the inhabitants of both freshwater and brackishwater environments that consists of 14 families and 15 genera. As many as eight different exotic fish species (viz. *Ctenopharyngodon idella*, *Hypophthalmicthys molitrix*, *Hypophthalmicthys nobilis*, *Cyprinus* *carpio* var. *communis*, *Cyprinus carpio* var. *specularis*, *Oreochromis niloticus*, *Clarias gariepinus* and *Pterygopliicthys disjunctivus*) are found in the freshwater zone of the river contributing about 3.74% to the total fish diversity. Among the exotics, both common carp and tilapia are ubiquitous along upper and middle stetch of river Ganga. The relative abundance of common carp (44.31%) and *Oreochromis niloticus* (30.15%) were in agreement with the report of Sarkar et al. 2012 from the entire stretch. The upper stretch (Harsil- Haridwar) was found dominated by *Cyprinus carpio* var. *communis* (19.59%) and *Cyprinus carpio* var. *specularis* (13.61%). The middle stretch (Haridwar-Varanasi) was recorded with highest abundance of *Cyprinus carpio* var. *communis* (1.46%), *Oreochromis nloticus* (2.01%) and *Clarias gariepinus* (0.37%) respectively. Abundance of other exotics like *Ctenopharyngodon idella*, *Hypophthalmicthys molitrix*, *H. nobilis* was found below 0.10 %. Sites like Kanpur, Prayagraj and Varanasi resulted inhigh abundance of common carp (7.31%, 16.49%,4.95%) and tilapia (6.64%,7.36%,4.59%). Dominance of *Cyprinus carpio* var. *communis* (7.68%) and *Oreochromis niloticus* (9.41%) was noticed at Buxar only in the lower stretch. Availability of other exotic species was noticed sporadically below Bhagalpur to Tribeni stretch of River Ganga. The distribution pattern of exotic fish species in the river denotes that, *C. carpio*, was found omnipresent in ten sampling sites depicting sizeable distribution along the local level.

From the previous studies by various workers in the main channel of the Ganga River, there were no report on the significant loss of fish diversity from the river. The earlier works were mainly focused on the fish faunal diversity, distribution and abundance either of the entire river basin or some selected stretches of the river or of its tributaries.Therefore, the present study gives a very systematic and comprehensive account of the fish diversity in the entire river stretch which is not comparable with previous studies.

Table 2. Records of fish diversity in the Ganga River reported by various sources

Sl No.	Stretch of Ganga Basin	Number of fish species recorded	Information available from (Ref.)
1.	Entire GangaRiver	271	Hamilton (1822)
2.	Indo Gangetic Plain	207	Menon (1974)
3.	AlaknandaRiver (i) Upper Ganga River, Garhwal (ii)Prayagraj stretch (iii) KosiRiver(Tributary) (iv) Patna stretch (v) Fresh water zone from Alakananda to Padma (Bangladesh).	41 54 30 103 56 162	Singh,Badola&Dobriyal (1987) -Do- Payne et al. (2004) Khan & Kamal (1980) Payne et al. (2004) Payne, Sinha, Singh & Huq (2004)
4.	Stretch from upper Ganga to Gangetic (Hooghly) estuary	172	Jhingran (1991)
5.	Indo Gangetic plain	266 (Freshwater: 158, Marine: 108)	Talwar and Jhingran (1992)
6.	Gangamain channel (considered only on economically important species)	110	Sinha, De and Jha (1998)
7.	Gangotri to Kolkata (Armenian Ghat)	141(Recorded 10 exotics)	Sarkar et al. (2012)

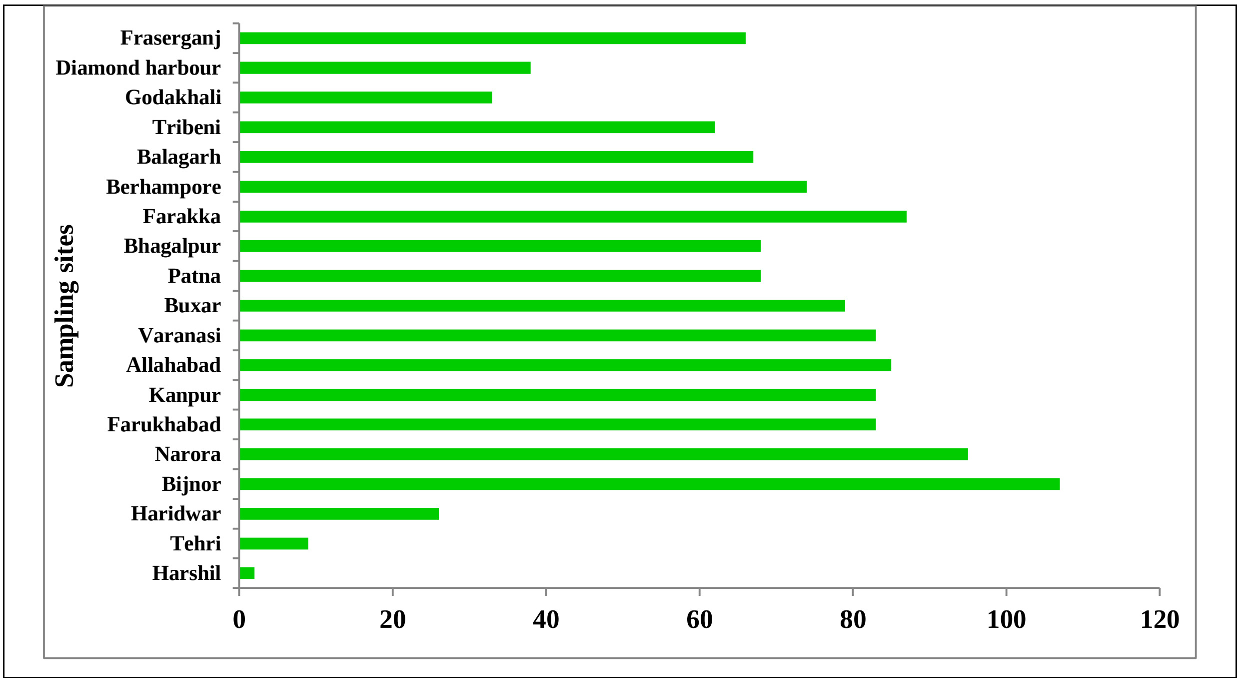


Fig. 10 Site-wise fish species distribution in river Ganga

Fig. 11 Hilsa catch at Godakhali, West Bengal

Fig. 12 Assorted catch atBhagalpur, Bihar

Fig. 13 Assorted catch at Berhampore, West Bengal

Fig. 14 Prized Murrel catch at Patna, Bihar

Fig. 15 Valuable Gobbid catch at Balagarh, West Bengal

Fig. 16 Croakers catch at D. Harbour, West Bengal

Fig. 17 Hilsa catch at Farakka, West Bengal

Threatened fishes in river Ganga

The status of fishes being threatened is a major concern nationwide particular in Ganga River. From the present investigation, out of the total 190 fish species recorded from river Ganga 18 fish species belongs to 8 orders and 12 families were recorded under IUCN red list (Version 2020-2.) (Table 3.). Native fish species viz. *Bagarius bagarius*, *Bagarius yarrelli, Chitala chitala*, *Labeo pangusia*, *Ompok pabo*, *Ompok pabda*, *Schizothorax richardsonii* and *Tor putitora* belong to the threatened category of IUCN Red List (Version 2020-2.). Family Synodontidae contributed highest (53.8%) followed by Cyprinidae (16.68%) and Siluridae (13.94%) in the present study. The number of threatened fishes like *Ailia coila*, *Ompok bimaculatus and Wallago attu* were highly significant ($p<0.05$) at Bhagalpur where as *Tor putitora* ($p<0.05$) at *Tehri*, *Schizothorax richardsonii* ($p<0.05$) at Haridwar, *Bagarius yarrelli* ($p<0.05$) found ($p<0.05$) at Buxar, *Parambassis lala* ($p<0.05$) at Farakka, Bagarius bagarius ($p<0.05$) at Balagarh, Chitala chitala ($p<0.05$) at Behrampore and *Harpadon nehereus* ($p<0.05$) at Fraserganj stretch of river Ganga.

Table 3. Threatened fish species under IUCN Red List from river Ganga

Order	Family	Species	IUCN, 2020	CAMP, 1998	
Cypriniformes	Cyprinidae	*Tor putitora* (Hamilton 1822)	EN	EN	EN
	Cyprinidae	*Schizothorax richardsonii* (Gray 1832)	VU	VU	NA
	Cyprinidae	*Labeo pangusia* (Hamilton 1822)	NT	LRnt	NA
Siluriformes	Sisoridae	*Bagarius bagarius* (Hamilton 1822)	NT	VU	NA
	Sisoridae	*Bagarius yarrelli* (Sykes 1839)	NT	NA	EN
	Ailiidae	*Ailia coila* (Hamilton 1822)	NT	VU	NA
	Ariidae	*Arius gagora* (Hamilton,1822)	NT	NA	NA
	Siluridae	*Ompok bimaculatus* (Bloch 1794)	NT	EN	NA
	Siluridae	*Ompok pabda* (Hamilton,1822)	NT	EN	NA
	Siluridae	*Ompok pabo* (Hamilton,1822)	NT	NA	EN
	Siluridae	*Wallago attu* (Bloch & Schneider 1801)	VU	LRnt	NA
	Clariidae	*Clarias magur* (Hamilton,1822)	EN	VU	NA
Perciformes	Ambassidae	*Parambassis lala* (Hamilton,1822)	NT	NA	NA
Osteoglossiformes	Notopteridae	*Chitala chitala* (Hamilton,1822)	NT	EN	NA
Anguilliformes	Anguliidae	*Anguilla bengalensis* (Gray 1831)	NT	EN	NA
Aulopiformes	Synodontidae	*Harpadon nehereus* (Hamilton 1822)	NT	NA	NA
Myliobatiformes	Dasyatidae	*Pastinachus sephen* (Fabricius 1775)	NT	NA	NA
Carcharhiniformes	Carcharhinidae	*Scoliodon laticaudus* (Müller & Henle 1838)	NT	NA	NA

*NE: Not Evaluated, LRnt: Lower risk near threatened, NT: Near Threatened, VU: Vulnerable, EN: Endangered; NA-Not assessed

Fish species not recorded in the present study

The present investigation could not record18 fish species which were reported by the earlier workers from the Ganga basin (Talwar &Jhingran, 1991). Barring few, majority of them are considered as trash fishes. The non-available fish species in the present study are as follows:

Order: Cypriniformes

- **Family: Cyprinidae**

1. *Labeo nandina* (Ham, 1822)
2. *Pethia guganio* (Ham, 1822)
3. *Puntius puntio* (Ham, 1822)
4. *Puntius vittatus* (Day, 1865)
5. *Tor tor* (Ham, 1822)
6. *Tor mosal* (Ham, 1822)
7. *Amblypharyngodon microlepis* (Bleeker, 1853)
8. *Schizothoraichthys progastus* (McClelland, 1839)
9. *Puntius terio* (Ham, 1822)

- **Family: Nemachelidae**

10. *Schisturas caturigina* (McClelland, 1839)

Order: Beloniformes

- **Family: Belonidae**

11. *Strongylura strongylura* **(**van Hasselt, 1823)

Order: Siluriformes

- **Family: Bagridae**

12. *Batasio tengana* (Ham, 1822)

- **Family: Aillidae**

13. *Clupisoma montana* (Hora, 1937)

- **Family: Sisoridae**

14. *Conta conta* (Ham, 1822)
15. *Erethistes jerdoni* (Day, 1870)
16. *Nangra nangra* (Ham, 1822)

Order: Perciformes

- **Family: Anabantidae**

17. *Anabas cobojius* (Ham, 1822)

- **Family: Toxotidae**

18. *Toxotes chatareus* (Ham, 1822)

Fish assemblage structure of river Ganga

The study recorded a total of 56 commercially significant indigenous fish species which fetches high market value. Bijnor was recorded with the highest number (107) of fish species followed by 95 fish species at Narora stretch. The reach between Harshil to Haridwar is found to be inhabited by hill streams fish species. The prominent characteristic species are the Barb, Baril and minnows. The keystone species of the hilly stretch are Mahaseer (*Tor putitora*) and Snow trout (*Schizothorax richardsonii*). Downward of Haridwar to the plains up to Bhagalpur marks the appearances of commercially important fish groups of carps and catfishes. Species having higher economic value are *Labeo rohita*, *L. catla*, *Cirrhinus mrigala*, *L. calbasu*, *Sperata aor*, *S. seenghala*, *Wallago attu*, *Chitala chitala*, *Rita rita*, *Eutropiicthys vacha* and *Clupisoma garua*. Historically, the region from Kanpur to Varanasi has been one of the major hotspots of pollution loading in the river; however, the present study hadrevealed 76 fish species which is slightly higher in comparison to the earlier reports. The lower Ganga zone from Varanasi (Uttar Pradesh) to Tribeni (West Bengal) of the river is comparativelyrich inbiodiversity. The region supports 101 native fish species with two exotic fishes- *Cyprinus carpio* and *Oreochromis niloticus* in sizeable population.This finding on fish species distribution will in turn support the endangered National Aquatic Animal of India (*Platanista gangetica gangetica*) in the protected stretch of the river located at Vikramshila Ganges River Dolphin Sanctuary near Bhagalpur, Bihar. Farakka stretch of the river Ganges in West Bengal has highest diversity (87 fish species) in the lower part of the river, Hilsa fishery below Farakka barrage is the prime fishing activity of the stretch owing to its huge commercial value. Moreover, as the river passes from Tribeni through the metropolitan city of Kolkata, by the time it reaches Godakhali located only about 30 kms down the city, the pollution and contamination level in the water can support fewer degrees of fish species. Estuarine stations of Godakhali and Diamond Harbour indicated dominance of euryhaline species like *Tenualosa ilisha*, *Polynemus paradiseus*, *Arius* sp., *Otolithoides pama, Odontamblyopus rubicundus* and *Setpinna* sp.

To assess the species richness complying three different seasons (pre-monsoon, monsoon and post-monsoon seasons) in different sites of river Ganga, a mathematical expression has been applied which is a commonly used information statistics index for aquatic environment. As evident from the graphical representation (Fig 18 & 19.) maximum number of species were recorded from Bijnor (N=107) followed by Narora (N=95) at Uttar Pradesh. Though Harsil to Tehri stretch is practically a non-fishing zone,the fish species diversity in the region is found comparatively low. Whereas, species eveness have been found almost similar. Sites from Haridwar to Narora have comparatively uneven distribution of fish species, though the sites have reflected highest diversity levels.

In the present study, diversity has been measured by the number of species richness and evenness. Thus, in lower stretch of Ganga such as Farakka (species richness 87; eveness 0.21) and Berhampore (species richness 74; eveness 0.22), which have low environmental stress shows high species richness as well as evenness. Water quality parameters in the spots have rendered optimum levels as well. In the middle stretch, extending from Buxar to Bhagalpur species evenness is found more or less equal than the richness level (5.31 to 5.77). Sites viz. Kanpur, Diamond Harbour and Godakhali species were not as evenly distributed. Presence of certain dominant species (exotics in Kanpur) might have been the influencing factor.

Table 4. Diversity Indices of fish species of river Ganga

Sampling stations	No. of taxa	Shanon index (H')	Evenness (J')	Margalef's richness index
Harsil	2	0.08	0.54	0.15
Tehri	9	0.03	0.11	0.66
Haridwar	26	2.60	0.51	3.33
Bijnor	107	2.24	0.08	6.20
Narora	95	2.17	0.09	6.19
Farrukhabad	83	2.64	0.16	6.56
Kanpur	83	1.23	0.04	5.58
Prayagraj	85	1.95	0.08	5.33
Varanasi	83	1.97	0.08	6.28
Buxar	79	2.59	0.17	5.77
Patna	68	2.77	0.23	5.23
Bhagalpur	68	2.73	0.22	5.31
Farakka	87	2.93	0.21	6.50
Berhampore	74	2.79	0.22	6.28
Balagarh	67	2.61	0.20	5.19
Tribeni	63	2.16	0.13	5.05
Godakhali	33	1.59	0.14	2.34
Diamond Harbour	38	1.61	0.13	2.58
Fraserganj	66	1.61	0.07	4.20

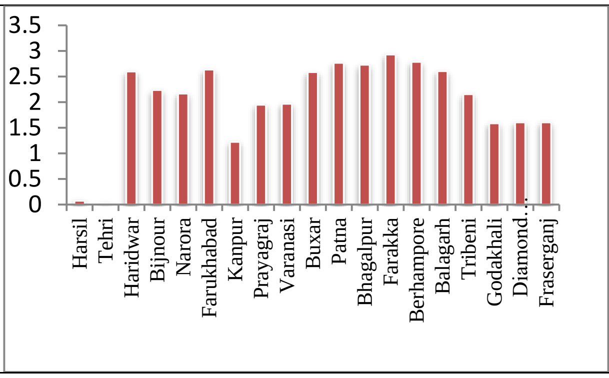


Fig. 18 Diversity richness (H') in different sites of Ganga

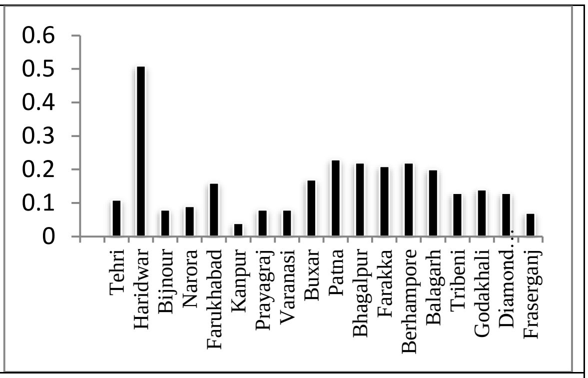


Fig. 19 Species eveness (J') in different sites of Ganga

Equitability (evenness) analysis

Total of 190 species of fish were recorded during the study from the diverse habitats. The number of fish species ranged more than 40 in the disturbed site (lower stretch) to more than 80 at the reference site (upstream and middle stretch). Equitability index for each site with fish indicated that middle stretch of river Ganga from Buxar to Balaghar having higher score and indicating that the similar kind of fish distribution.

Commercially Important fish Species Available from River Ganga

Out of 190 species recorded from the river, 58 species are reported to have commercial importance. Following species are known for their high commercial value:

Table 5. Commercially Important fish species of river Ganga

Fish species	Common english name	Habitat	Commercial importance	Percent contribution (by no.)
Ailia coila	Gangetic Ailia	Freshwater	Food fish	28.41
Amblypharyngodon mola	Mola carplet	Freshwater	Food/Ornamental fish	48.15
Anabas testudineus	Climbing perch	Freshwater	Food /Ornamental fsh	7.93
Anodontostoma chacunda	Chacunda gizzard shad	Brackishwater	Food fish	6.28
Bangana dero	Kalaban	Freshwater	Food fish	6.49
Bariliusbendelisis	Indian Hill Trout	Freshwater	Food/Sport fish	2.64
Botialo hachata	Reticulate loach	Freshwater	Ornamental fish	6.99
Cabdio morar	Morari	Freshwater	Food/Ornamental fish	44.19
Channa marulius	Great snakehead	Freshwater	Food fish	1.24
Channa punctata	Spotted snakehead	Freshwater	Food fish	16.11
Chitala chitala	Humpback featherback	Freshwater	Food / Ornamental fish	0.96
Cirrhinus mrigala	Mrigala	Freshwater	Food fish	11.78
Clupisoma garua	Garua batcha	Freshwater	Food fish	17.20
Coilia dussumieri	Goldspotted grenadier anchovy	Freshwater	Food fish	31.40
Eutropiicthys vacha	Vacha	Freshwater	Food fish	55.59
Gagata cenia	Indian Gagata	Freshwater	Ornamental fish	3.26
Glossogobius giuris	Tank goby	Freshwater	Food fish	29.21
Gonialosa manmina	Ganges river gizzard shad	Freshwater	Food fish	24.33

Gudusia chapra	Indian river shad	Freshwater	Food fish	34.98
Harpadon nehereus	Bombay Duck	Marinewater/Brackishwater	Food fish	7.12
Heteropneusteus fossilis	Asian Stinging catfish	Freshwater	Food/Ornamental fish	11.08
Johnius coitor	Amphidromous croaker	Freshwater	Food fish	42.97
Labeo calbasu	Kalbasu	Freshwater	Food fish	26.98
Labeo catla	Katla	Freshwater	Food fish	18.97
Labeo gonius	Kuria Labeo	Freshwater	Food fish	5.45
Labeo rohita	Rohu	Freshwater	Food fish	16.20
Macrognathus pancalus	striped spiny eel	Freshwater	Food / Ornamental fish	56.97
Mastacembelus armatus	Tire-track spiny eel	Freshwater	Food / Ornamental fish	3.16
Mystss cavasius	Gangetic mystus	Freshwater	Food/Ornamental fish	5.13
Mystus gulio	Long whiskers catfish	Brackishwater	Food fish	2.46
Nandus nandus	Gangetic leaf fish	Freshwater	Food / Ornamental fish	2.16
Nemapteryx caelata	Engraved catfish	Brackishwater	Food fish	1.94
Notopterus notopterus	Silver bronze featherback	Freshwater	Food / Ornamental fish	2.90
Odontamblyopus rubicundus	Rubicunduseelgoby	Brackishwater	Food fish	42.07
Ompok bimaculatus	Butter catfish	Freshwater	Food/Ornamental fish	3.26
Opsarius barna	Barnabaril	Freshwater	Food/Sport fish	8.64
Osteobrama cotio	Cotio	Freshwater	Food/Ornamental fish	39.14
Otolithoides pama	Gangetic sciaenid	Brackishwater	Food fish	13.29
Pethia conchonius	Rosy barb	Freshwater	Food/Ornamental fish	59.80
Polynemus paradiseus	Paradise threadfin	Brackishwater	Food fish	52.18
Puntius sophore	Spot-fin swamp barb	Freshwater	Food/Ornamental fish	64.15
Rasbora daniconius	Slender Rasbora	Freshwater	Ornamental fish	3.29
Rhinomugil corsula	Corsula mullet	Freshwater/Brackishwater	Food fish	29.87
Rita rita	Rita	Freshwater	Food/ Sport fish	10.77
Salmophasia bacaila	Large razorbelly minnow	Freshwater	Food fish	18.16
Schizothorax richardsonii	Snow trout	Freshwater	Sport fish	16.15
Setipinna phasa	Gangetic hairfin anchovy	Freshwater	Food fish	25.43
Setipinna tenuifilis	Common hairfin anchovy	Brackishwater	Food fish	2.22
Sperata aor	Long-whiskered catfish	Freshwater	Food/Sport fish	16.18
Sperata seenghala	Giant river catfish	Freshwater	Food/Sport fish	28.18
Systomus sarana	Olive barb	Freshwater	Food/Sport fish	9.78
Tariqilabeo latius	Gangetic latia	Freshwater	Food fish	15.06
Tenualosa ilisha	Hilsa shad	Freshwater/Brackishwater	Food fish	33.26
Tor putitora	Golden Mahseer	Freshwater	Food/Sport fish	33.45
Wallago attu	Freshwater shark	Freshwater	Food/Sport fish	8.69
Xenentodon cancila	Freshwater garfish	Freshwater	Food /Ornamental fish	5.14

Exploited total length (TL) frequency of few commercially important fish species of river Ganga

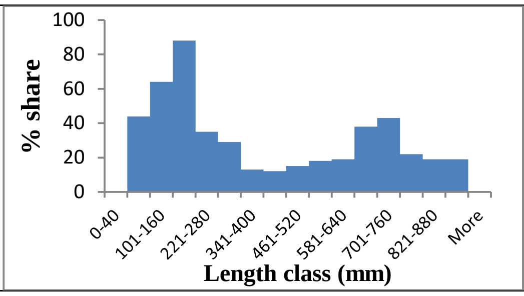


Fig. 20a *Labeo rohita* (N=478)

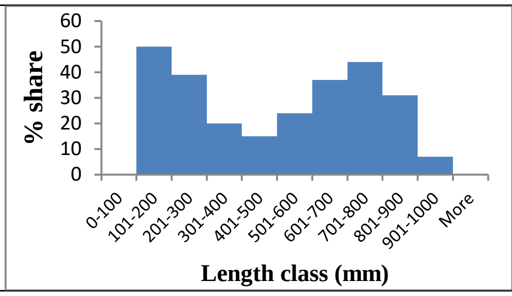


Fig. 20b *Labeo catla* (N=267)

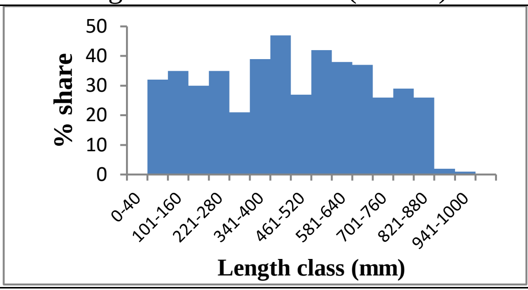


Fig. 20c *Cirrhinus mrigala* (N=467)

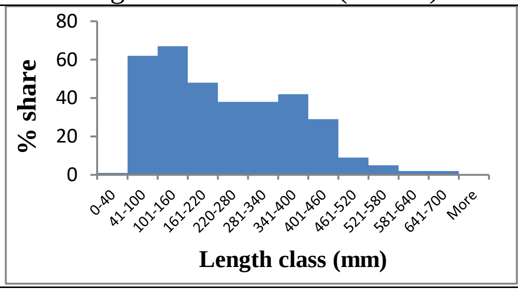


Fig. 20d *Labeo calbasu* (N=343)

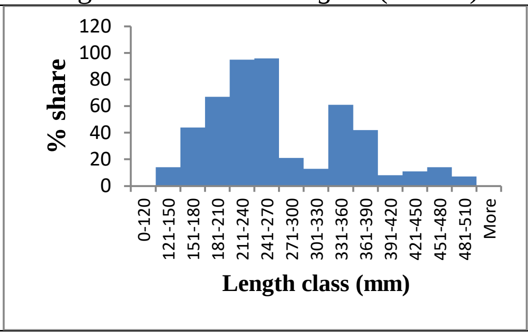


Fig. 20e *Tor putitora* (N=343)

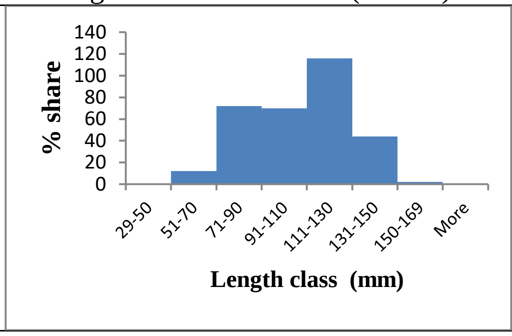


Fig. 20f *Gudusia chapra* (N=316)

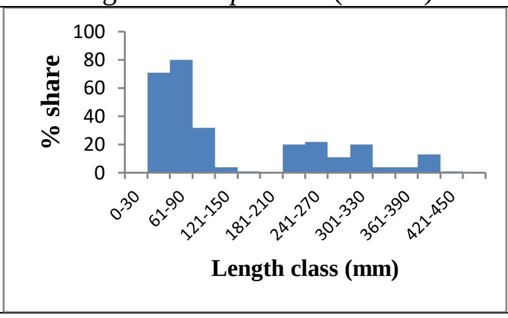


Fig. 20g *Tenualosa ilisha* (N=276)

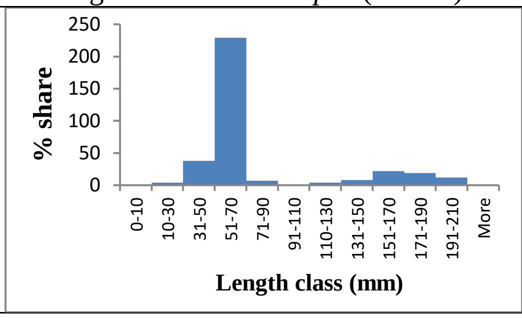


Fig. 20h *Polynemus paradiseus* (N=250)

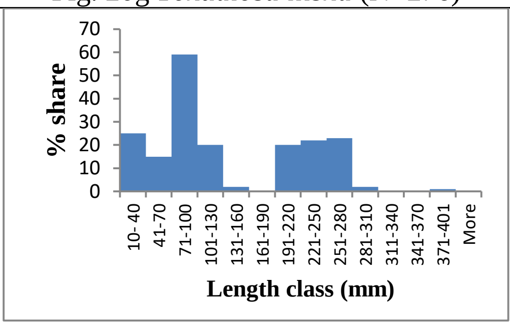


Fig. 20i *Otolithoides pama*(N=190)

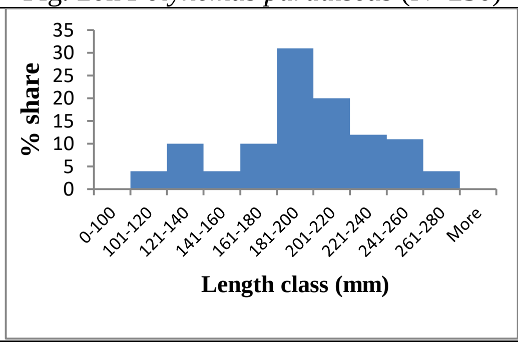


Fig. 20j *Notopterus notopterus* (N=106)

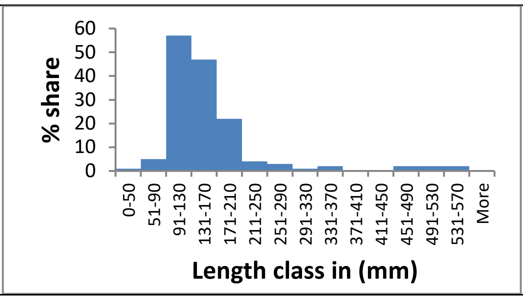


Fig. 20k *Ailia coila* (N=277)

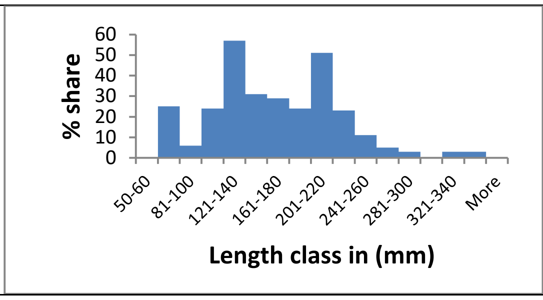


Fig. 20l *Clupisoma garua* (N=319)

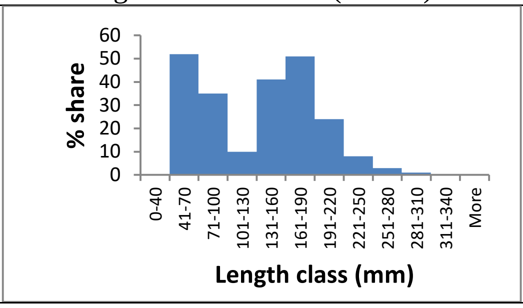


Fig. 20m *Eutropiicthys vacha* (N=225)

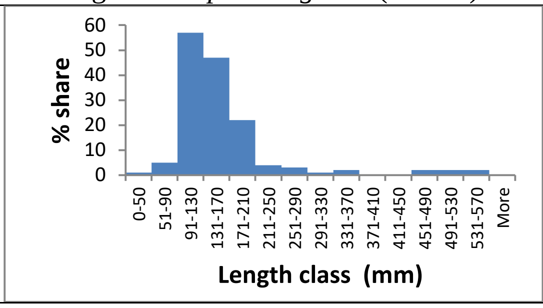


Fig. 20n *Rita rita* (N=198)

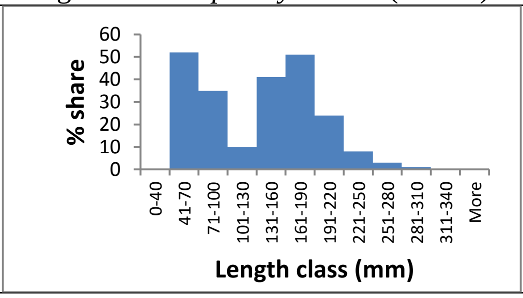


Fig. 20o *Mystus cavasius* (N=168)

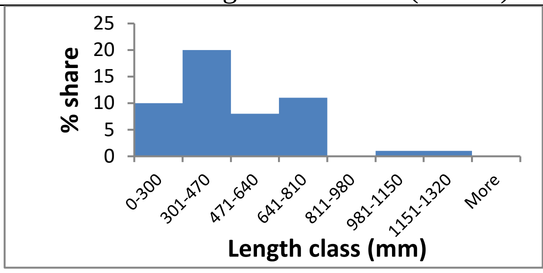


Fig. 20p *Wallago attu* (N=152)

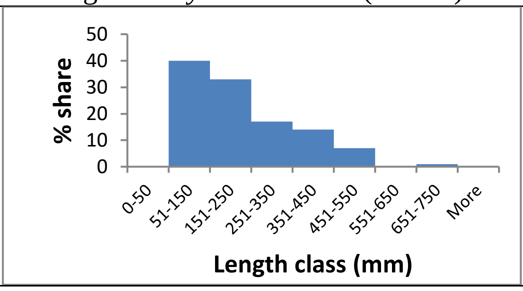


Fig. 20q *Sperata seenghala* (N=115)

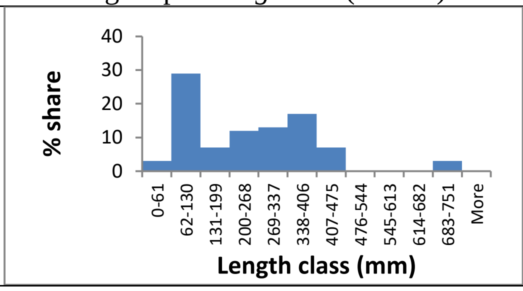


Fig. 20r *Sperata aor* (N=190)

Fig. 20 a-r Exploited total length (TL) frequency of commercially important fish species of river Ganga

A critical analysis was made to determine the commercially important prized fishes of river Ganga caught below their maturity length (L_m). The data was assessed for selective 32 fish species combining with various length at first maturity parameters of female from the GangaRiverbasin. The result showed significant variations in Near threatened designated fishes like *Harpadon nehereus*, *Chitala chitala* and *Ompok bimaculatus* where the percentage caught below the maturity size is 72.22%, 84.44% and 94.11% respectively. This indicates over exploitation of fishes below its maturity length thus creating growth overfishing. Similarly, exploitation rate of India Major Carps in terms of maturity length is 65.27%

(Rohu), 51.68% (Catla), 32.97% (Mrigala) and 61.22% (Calbasu). Among all the major carps, *Labeo calbasu* is caught extensively in the river stretch owing to its year-round availability. Table 6. depicts the fishes of river Ganga caught much below their maturity length.

Table 6. Fishes of river Ganga caught below first length of maturity

Sl. No	Species	Length at first maturity (L_m)	Source	% caught below L_m from Ganga	Gear used for targeting juveniles
1.	*Labeo rohita*	579 mm	Chondar, 1999	65.27	Gill net, Seine net
2.	*Labeo catla*	550 mm	Natarajan, 1963	51.68	Gill net, Seine net
3.	*Cirrhinus reba*	135 mm	Hossain et al., 2013	62.17	Gill net, Seine net
4.	*Cirrhinus mrigala*	349 mm	Hanumantharao, 1971	32.97	Gill net, Seine net
5.	*Labeo calbasu*	278 mm	Dwivedi et al., 2009	61.22	Gill net, Seine net, Hook & line
6.	*Labeo gonius*	200 mm	Choudhury, 2003	98.16	Gill net, Seine net, Hook & line
7.	*Sperata seenghala*	770 mm	Saigal, 1982	94.73	Gill net, Seine net, Hook & line
8.	*Sperata aor*	840 mm	Saigal, 1964	81.04	Gill net, Seine net, Hook & line
9.	*Mystus cavasius*	100 mm	Bhatt, 1971	34.52	Gill net, Seine net
10.	*Mystus tengara*	90 mm	Gupta, 2015	28.64	Gill net, Seine net
11.	*Mystus gulio*	82 mm	Jhingran V.G, 1969	47.87	Gill net, Seine net, Hook & line
12.	*Rita rita*	300 mm	Rahaman et al., 2013	92.51	Seine net, Hook & line
13.	*Chitala chitala*	700 mm	Chonder, 1999	84.44	Seine net, Hook & line
14.	*Notopterus notopterus*	238 mm	Hamza, 1980	74.52	Seine net, Hook & line
15.	*Gudusia chapra*	80 mm	Hossain et al., 2010	82.53	Gill net
16.	*Gonialosa manmina*	80 mm	Azadi (2008)	88.73	Gill net
17.	*Anabas testudineus*	80 mm	Hora & Pillay, 1962	32.60	Gill net, Seine net
18.	*Tor putitora*	330 mm	Pathani& Das, 1980	57.55	Gill net, Hook & line
19.	*Schizothorax richardsonii*	324 mm	Agarwal et. al, 2010	61.47	Cast net, Trap
20.	*Tenualosa ilisha*	341 mm	De (1986)	89.75	Gill net, Bag net and lift net

21.	*Polynemus paradiseus*	160 mm	Gupta, 1968	89.24	Gill net, Bag net
22.	*Clupisoma garua*	171 mm	Hasan et al., 2020	50.16	Gill net, Hook & line
23.	*Eutropiicthys vacha*	140 mm	Hossain et al., 2012	45.33	Gill net, Hook & line
24.	*Johnius coitor*	114 mm	Sarkar et al., 2017	70.12	Gill net, Seine net
25.	*Mastacembelus armatus*	362 mm	Alam et al., 2020	67.21	Hook & line, trap & seine net
26.	*Macrognathus pancalus*	131 mm	Pathak et al., 2013	73.91	Drag net, trap & seine net
27.	*Heteropneustes fossilis*	120 mm	Khan, 1972a	54.43	Drag net, trap & seine net
28.	*Ompok bimaculatus*	232 mm	Mishra et al., 2013	94.11	Seine net, Hook and line, drag net
29.	*Channa punctata*	120 mm	Prasad et al., 2011	57.70	Seine net, Hook and line, drag net
30.	*Channa marulius*	300 mm	Chacko, 1956	55.55	Seine net, Hook and line, drag net
31.	*Harpadon nehereus*	145 mm	Ghosh, 2014	72.22	Bag net, Gill net
32.	*Systomus sarana*	250 mm	Alikhuni, 1957	87.66	Gill net

Abundance of major fish group in river Ganga

The total fish species as obtained in the present investigation from respective centres of river Ganga have been categorized and their catch percentage have been calculated at each centre as well as in the entire stretch. In the upstream zones of Haridwar, Bijnor and Narora the carps shared more or less equal amount (54%, 24 % and 23 % respectively) in comparison to catfish and miscellaneous groups. However, the trend declined to further middle and downstream reaches where a major decline in the carps and a considerable increase in miscellaneous fish groups were noticed. In centres, viz. Varanasi, Patna, Bhagalpur, Balagarh and Tribeni, the major carp had a sharp decline (22%, 22%, 23%, 18% and 15%) respectively in comparison to miscellaneous fish groups (27%, 31%, 23%, 52% and 58%) respectively. Thus, the proportion of carps (major, medium and medium) fell considerably with respect to the entire river stretch where it constitiuted of only 2.3% of the total catch and a considerable increase of the miscellaneous or trash fish group (43%).

Table 7. Abundance of major fish group in river Ganga

MAJOR GROUPS	UPPER STRETCH	MIDDLE STRETCH	LOWER STRETCH
	(HARSIL-HARIDWAR)	(BIJNOR- BHAGALPUR)	(FARAKKA-FRASERGANJ)
Mahseer	1	0	0
Trout	1	0	0
Major carp	0	4	4
Medium Carp	2	1	1
Minor Carp	1	5	3
Large Cat fish	0	8	12
Small Cat fish	4	17	23
Shads	0	3	5
Miscellaneous	6	71	112
Exotic Fish	3	7	6
Total Species (stretch wise)	18	116	166

* **Mahseer:** *Tor putitora* **Trout:** *Schizothorax richardsonii***, Major carps:** *Labeo catla, Cirrhinus mrigala, Labeo calbasu, Labeo rohita,* etc. **Medium carps:** *Cirrhinus reba, Labeo bata, Labeo gonius, Labeo dero,*etc. **Minorcarps:** *Puntius conchonius, Puntius sophore, Labeo angra, etc.* **Large cat-fish:** *Sperata* sp., *Wallago attu, etc.* **Small cat-fish:** *Mystus* sp., *Ompok pabda* etc. **Shads:** *Gudusia chapra, Tenualosa ilisha* etc. **Miscellaneous:** *Xenentodon cancila., Monopterus cuchia, Barilius barila*, etc. **Exotic Species:** *Cyprinus carpio, Oreochromis niloticus, Clarias gariepinus, H. nobilis, H. molitrix, P. disjunctivus*

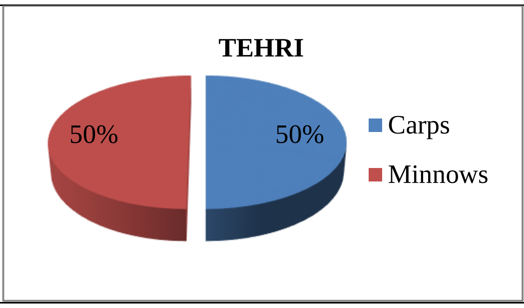


Fig. 21a

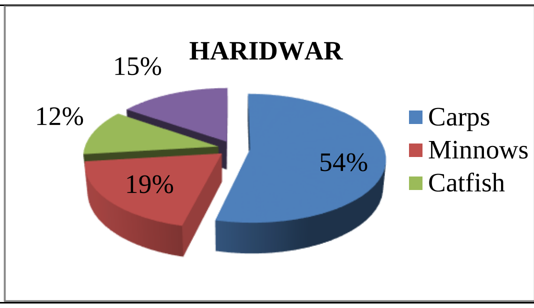


Fig. 21b

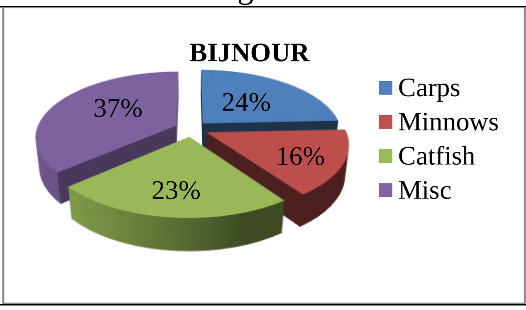


Fig. 21c

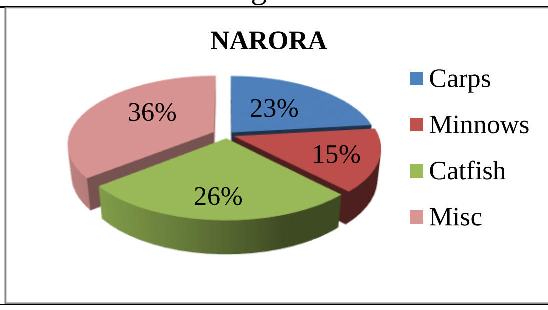
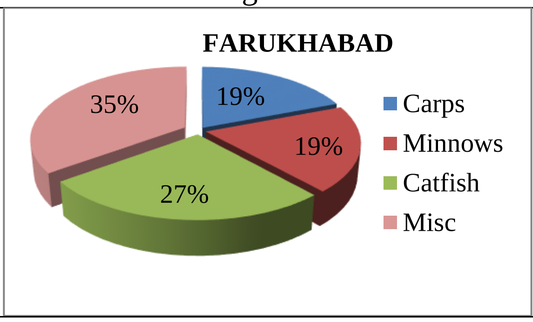


Fig. 21d



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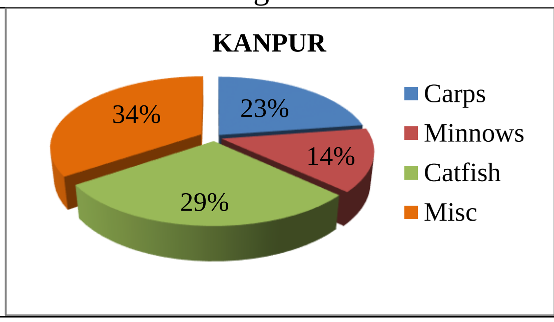
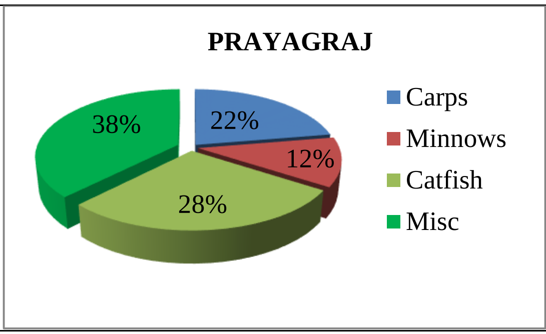


Fig. 21f



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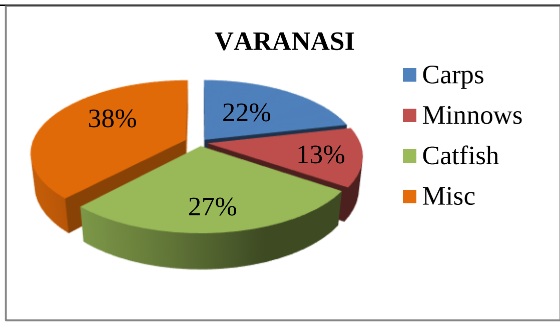

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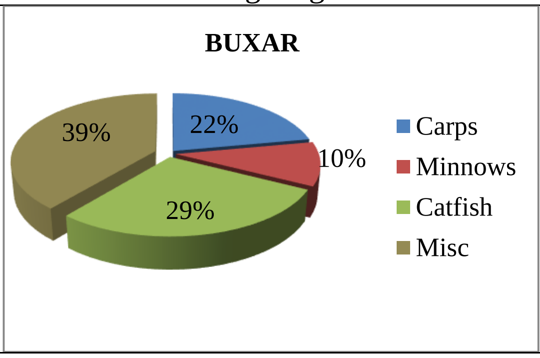


Fig. 21i

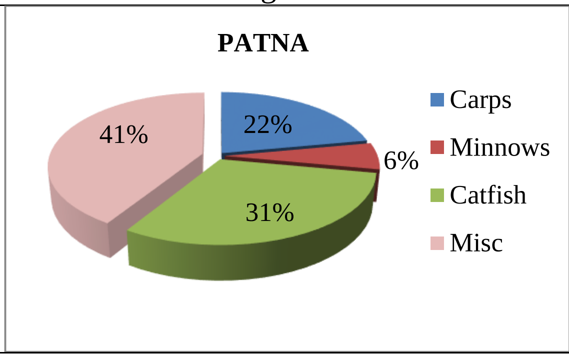


Fig. 21j

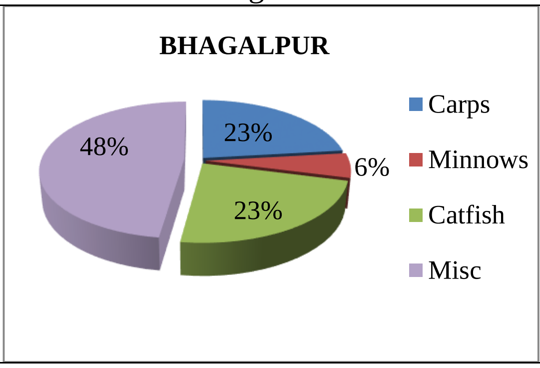


Fig. 21k

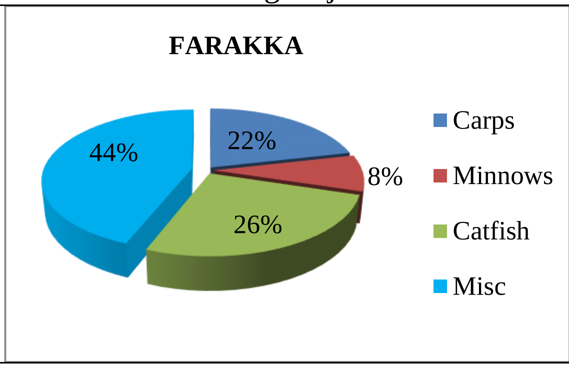


Fig. 21l

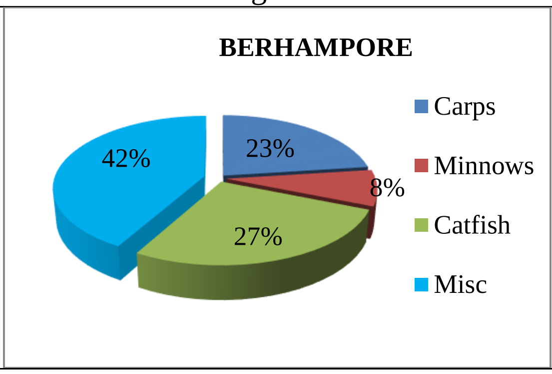


Fig. 21m

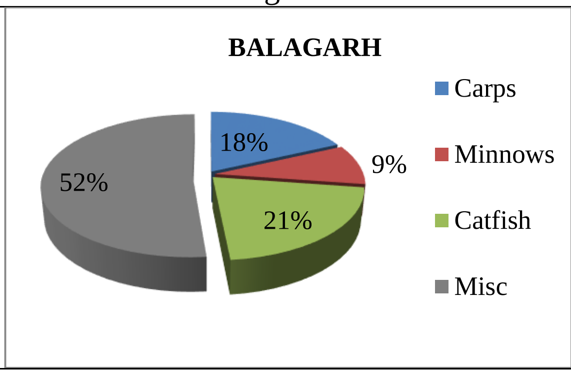


Fig. 21n

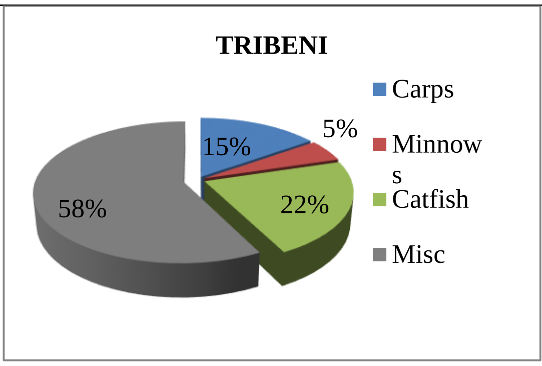
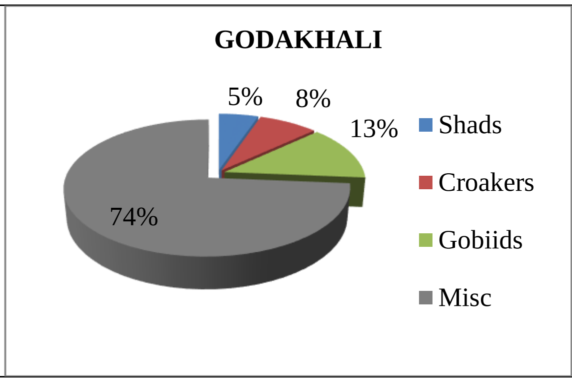


Fig. 21o



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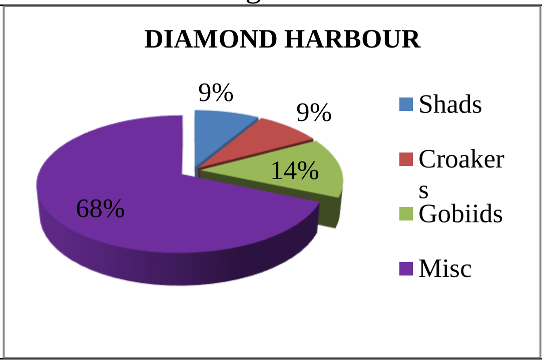


Fig. 21q

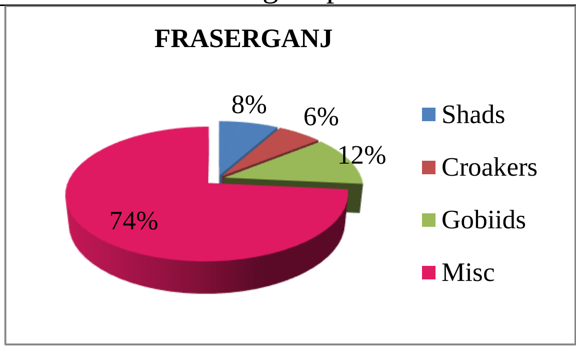


Fig. 21r

Fig. 21(a-r) Graphical representation of major fish groups at various stations along river Ganga

Monthly variations of catch (family wise percentage) in river Ganga

Differences in variation in fish species can be largely studied by its monthly abundance. Fishes of commercial importance of Ganga are targeted selectively by the fisher folks for their livelihood generation. Therefore, assessment of the major family groups is required to understand their availability pattern (seasonwise) in the river. Five major freshwater family groups have been presented below comprising of Clupeidae (*Gonialosa manmina*, *Gudusia chapra*, *Tenualosa ilisha* and *Corica soborna*), Cyprinidae (*Labeo* spp., *Cirrhinus* spp., *Puntius* spp., etc.), Bagridae (*Mystus* spp., *Sperata* spp., etc.), Aillidae (*Clupisoma garua*, *Ailia coila*, *Eutropiicthys vacha* etc.) and others. Similarly, the estuarine section of the river has been grouped into Clupeidae (*Gonialosa manmina*, *Gudusia chapra*, *Tenualosa ilisha*, *Corica soborna* and *Anodontostoma chacunda*), Engraulidae (*Setipinna* spp., *Ilisha* spp., *Pellona ditchella*), Sciaenidae (*Otolithides pama*, etc.) and others. However, in the stations, Diamond Harbour and Fraserganj, additional families namely Polynemidae (Threadfins) Synodontidae (*Harpadon nehereus*) has been taken into consideration in the catch estimationdue to its high commercial value.

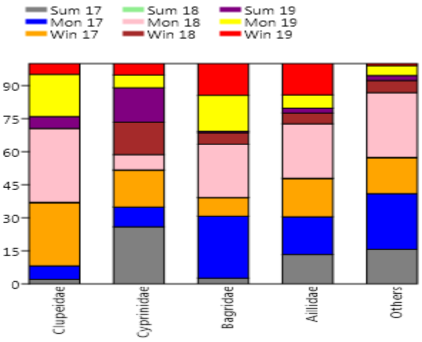


Fig. 22a Monthly abundance variation at Buxar

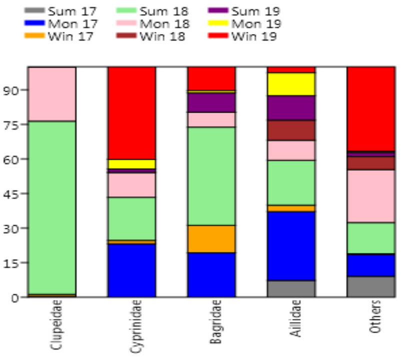


Fig. 22b Monthly abundance variation at Patna

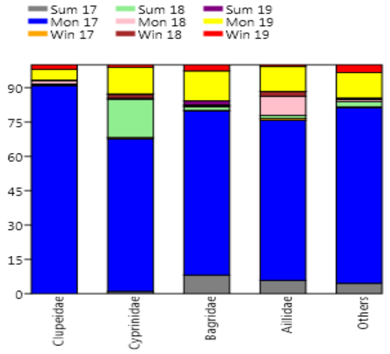


Fig. 22c Monthly abundance variation at Bhagalpur

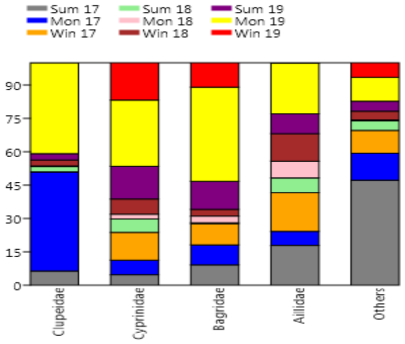


Fig. 22d Monthly abundance variation at Farakka

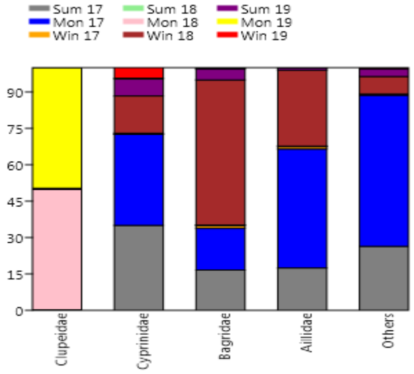


Fig. 22e Monthly abundance variation at Berhampore

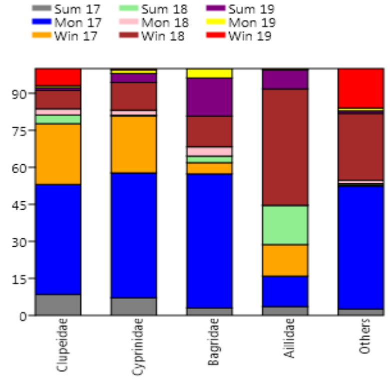


Fig. 22f Monthly abundance variation at Balagarh

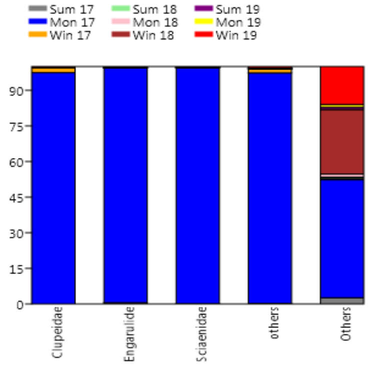


Fig. 22g Monthly abundance variation at Godakhali

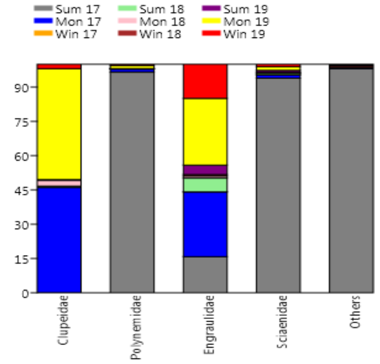


Fig. 22h Monthly abundance variation at D.Harbour

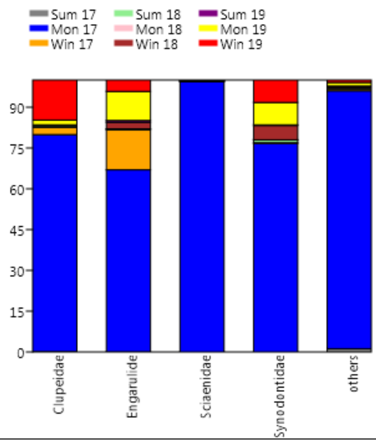


Fig. 22i Monthly abundance variation at Fraserganj

Fig. 22 (a-i) Monthly variations of catch (family wise percentage) in river Ganga

In the lower estuarine zone of the river, dominance of Clupeids has been noticed during the entire monsoon of 2017 and 2018 contributing to 27.5% and 62.2% respectively to the total fish catch. Hilsa was observed as the major catch of the season. Likewise, during winter months (Dec-Feb) of 2017, it was also observedof the increasing share (47%) of clupeids to the total catch. Single species fishery, especially threadfins and croakers were also recorded in abundance during a certain period of a year. *Polynemus paradiseus* contributed 21.7% during summer while 36% of the total catch during monsoon 2017. In 2019, the production of threadfin came down to 3.92% and 25.9% in summer and winter months respectively. This might be due to the effect of recruitment overfishing of the species where small size fishes are caught as bycatch in bag net (*Beenti jaal*) in the region. Prized Bombay duck (*Harpadon nehereus*) with avg. TL 111 mm is only caught in Diamond Harbour during summer months (March-June) as the average salinity of the river water reaches 6.37 ppt which is ideal for its breeding movement. However, juveniles of the same are noticed during July month in the area with average total length (TL) of 90 mm.

Status of Major Carp resources in river Ganga

Previous studies have revealed that ecological degradation of the river caused by various anthropogenic hindrances or activities resulted in noticeable decline in overall fish production especially for major carps and Hilsa shad (Jhingran and Ghosh, 1978). Impact is more visible on indigenous fish fauna of the river like Indian Major Carps which have been reduced to a large extent. Severe decrease in precipitation, water abstraction in river Ganga has resulted in the modification of the water flow and turbidity in breeding seasons which in turn has caused failure of natural recruitments (Das et al., 2013). Prayagraj stretches of river Ganga have witnessed substantial decrease of major carp landings from 41.4 to 8.3 % during the period of

1958-62 to 1996-97. On the other hand, contribution of miscellaneous fish has increased drastically from 27.1% in 1958-62 to 63.4 % by 1996-97 (Vass et al., 2009). Interestingly, almost during similar period share of catfish species in river Ganga have shown an increase from 21% to 24.6% (Dey, 1999). Besides, analyzing the population pattern of IMC, the criteria for the selection of site also included on the basis of less abundance of predators and congenial aquatic parameters (Chen, 2003). Moreover, in the middle stretches of the river, fish species landings have widely shifted from major carps and large catfishes to a more diverse assemblage including catfishes, minor cyprinids, shads, croakers and spiny eels during the period of 1950s and 1960s (Payne et al., 2003). Recent studies indicate that, at Prayagraj, the yield rate of Indian Major Carp came down from 90.85 ton from 1955-67 to 27.39 tons for the present 2015-16 with a drastic decline in catches of major carps from 38.09 % to 16.04 %. However, the catches of smaller species remained at the level of the past with slight changes in catch composition.

Deteriorated and modified river often helps exotic fishes like Common carp, Tilapia, etc. which have already established in middle and lower stretch of river Ganga and are contributing significantly in the total catch. As rising exotic stock of fish trigger severe menace to the important native Gangetic species like Indian Major Carps and large catfishes (Jha et al., 2016), therefore care was also taken before hand to avoid ranching in zones with reported exotics (Roshith et al., 2013). Species like *Labeo rohita* (Rohu) was observed to be relatively high in catch percentages in Nabadwip compared to the other three carp species. However, sites like Balagarh and Barrackpore reflected increased catch amount of *Labeo calbasu* throughout the season. Monsoon forms to be the important season for IMC's where the flooding results in breeding in adjacent bays and sheltered areas. In such cases, contribution of species like *Labeo rohita* and *L. calbasu* may rise up to 4.55 % and 3.63 % respectively (Roshith et al., 2013). Production trend of Indian Major Carp (kg per Km) in different sites from 1960's to 1990's showed unanimous variation. The average production of Major carp is presented below.

Indian Major Carp landings (avg. t) in different time period of river Ganga (site wise)

Table 8. Indian Major Carp landings (avg. t) in different time period of river Ganga

Sites	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1972-80	1981-90	1991-2000	2001-07	2015-16	2018-19	2019-20
Prayagraj	11.7	16.3	19.9	23.5	20.8	28.5	21.4	21.4	16.8	19.1	31.09	35.82	6.65	NA	16.12	7.08	13.06
Varanasi	2.9	3.6	1.2	0.9	0.9	1.2	3.4	2.5	1.2	1.2	NA	NA	NA	NA	NA	NA	NA
Buxar	30.4	16.7	NA	NA	3.1	2.9	6.7	4.7	1.3	3.3	2.89	3.25	NA	NA	NA	43.7	50.9
Ballia	13.4	12	7.4	3.3	7	NA	NA	7	6	6.4	NA	NA	NA	NA	NA	NA	NA
Patna	12.7	11.5	17.9	20.6	11.9	12.6	13.5	11.2	8.5	9.2	NA	7.1	NA	NA	NA	39.4	69.4
Bhagalpur	3.5	3.7	4.1	6	4.2	6.9	10	7.3	11	9.8	11.7	5.98	NA	0.865	NA	24.8	37.6
Lalgola	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.876	32.08	NA	NA	29.7	40.34

Overview of climate change and impact on IMC recruitment

Global rise in atmospheric temperature has led to rise temperature resulting in abnormalities of the heat budget of the river systems. Erratic precipitation, severe floods and increase drying of the river are few of the consequences. Prediction through climate models have indicated rising trend of mean annual temperature of 1–4℃ in Ganga River basin up to 2050 (Moors et. al, 2011). Generally, the entire Ganga river basin receives heavy rainfall (80%) during the period from June to September with average of 1200 mm (Nandargi et al., 2018). However, recent studies have indicated decrease of rainfall by 56% over 133 districts along entire Ganga basin largely due to climate change (Bera, 2017). Natural recruitment of IMC's in the Ganga River System is largely affected by these environmental impacts. It affects the reproductive cycle and thus resulting in decrease in fish spawning. Studies have indicated that, contribution of wild IMC spawn in the period 2005-2009 have shown a decreasing trend (10%) compared to other fish stocks (90%), (Das et al., 2013). On the other hand, considerable decline in fish seed availability have been noticed from 78.82 % (1960's) to 34.48% (2004) (Vass et al., 2009).

Catch trends and production

The important fish species landed from the river Ganga were identified and commercially important fish grouped as Major carp (IMC), Large Catfish, Hilsa, Exotics and local major and miscellaneous fishes. Total fish catch of river Ganga have been estimated during the study period. It was noticed that total fish catch or landing from river Ganga has increased from 3796.57 t (2018-19) to 4263.55 t (2019-20). The total fish landing in the middle stretch (from Prayagraj to Farraka) have contributed 47.5% of total fish catch during 2019-20.

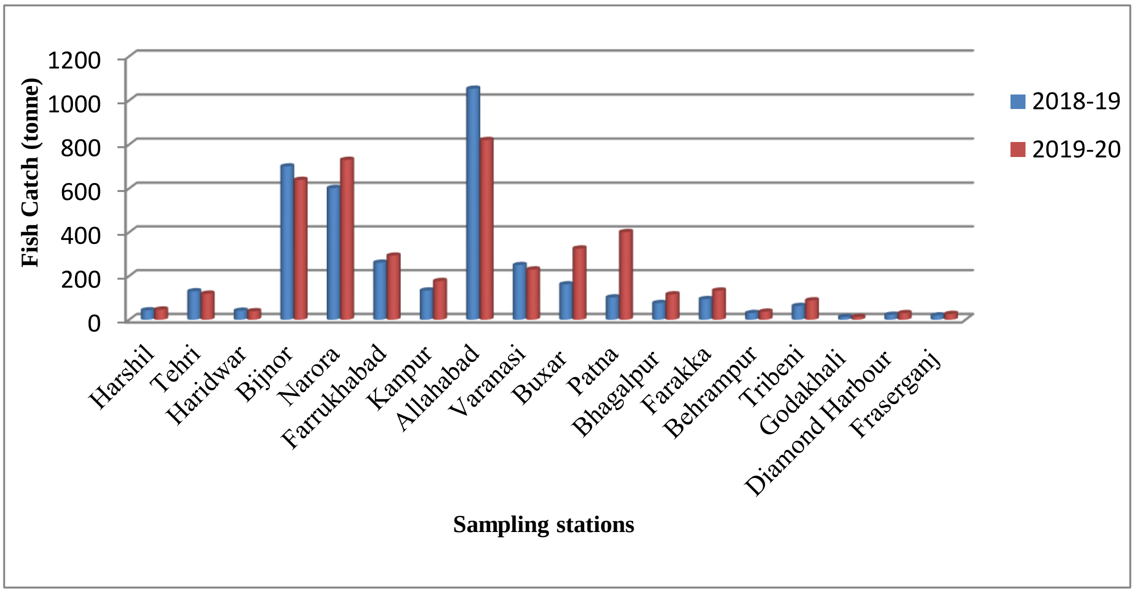


Fig. 23 Catch trends of fish catch from river Ganga

The annual fish yield was observed maximum at Patna (1803.3 kg per km) and minimum at Bhagalpur (781.5 kg per km). A genuine structural variation in fisheries of the river in different stretches was noticed with major carp domination in Kanpur to Prayagraj stretch. Similarly, the other sites of the river such as Varanasi, Patna and Bhagalpur also showed considerable variations.

Present average production of small indigenous fish species and other miscellaneous fishes is around 30.19 tons. The yield of major carps reduced from 28.2 to 3.26 tons in 1985 with present scenario of 49.56 tons. Large catfishes showed the maximum increase and were almost double of the sixties (7.34 tones) to 28.02 tons in 1981 with present production 39.5 tons.

Table 9. Production of major carp and other major varieties of fishes (in tones) from river Ganga (1969-2020)

Station	Species Name	1975-1980	1980-1985	2016-2020
Buxar	IMC	5.81	14.44	4.03
	Catfish	36.36	36.98	9.9
	Hilsa	3.42	4.95	0
	Exotic	NA	NA	19.6
	Misc.	72.6	97.71	13.79
	Total	**118.19**	**154.08**	**47.32**
Patna	IMC	NA	16.51	2.16
	Catfish	NA	33.87	8.06
	Hilsa	NA	0.27	0
	Exotic	NA	0	0.08
	Misc.	NA	80.03	17.69
	Total	**NA**	**130.65**	**27.99**
Bhagalpur	IMC	43.12	22.49	1.98
	Catfish	90.39	83.57	6.49
	Hilsa	0.72	2.16	0
	Exotic	NA	0	0
	Misc.	191.83	193.94	11.45
	Total	**326.06**	**302.16**	**19.92**
Farakka	IMC	9.18	1.62	1.34
	Catfish	19.73	2.11	7.9
	Hilsa	45.41	15.98	10.39
	Exotic	NA	0	0
	Misc.	67.51	17.65	25.53
	Total	**141.83**	**37.36**	**45.16**

Rarely recorded fish species in river Ganga

Name : *Chaca chaca* Kingdom: Animalia, Phylum: Chordata Class: Actinopterygii, Order: Siluriformes Family: Chacidae: Genus: Chaca Species: *Chaca chaca* **Location: Bijnor**	**Name : *Erethistes pusillus*** Kingdom: Animalia, Phylum: Chordata Class: Actinopterygii Order: Siluriformes Family: Erethistidae Genus: *Erethistes* Species: *Erethistes pusillus* **Location: Varanasi**

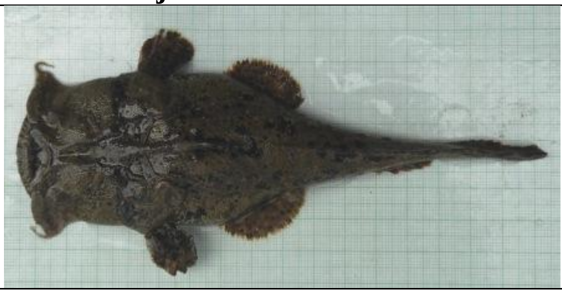
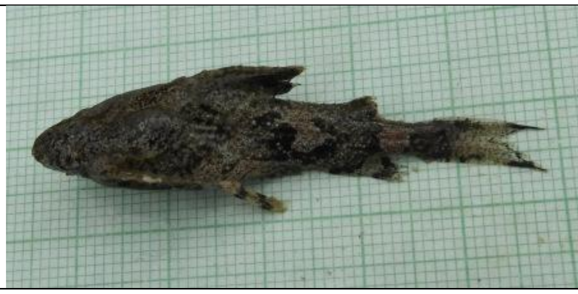
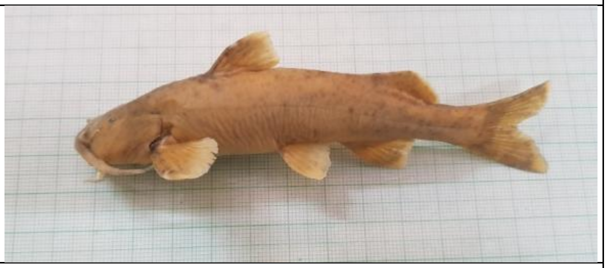

	

Fig. 24a	Fig. 24b
Name : *Pethia gelius*(Golden barb**)** Kingdom: Animalia Phylum: Chordata Class: Actinopterygii Order: Cypriniformes Family: Cyprinidae Genus: *Pethia* Species: *Pethia gelius* **Location: Bijnor**	**Name : *Glyptothorax garwali*** Kingdom: Animalia Phylum: Chordata Class: Actinopterygii Order: Siluriformes Family: Sisoridae Genus: *Glyptothorax* Species: *Glyptothorax garwali* **Location: Haridwar**
	
Fig. 24c	Fig. 24d
Name : *Opsarius tileo*(ray-finned fishes**)** Kingdom: Animalia Phylum: Chordata Class: Actinopterygii Order: Cypriniformes Family: Cyprinidae Genus: *Opsarius* Species: *Opsarius tileo* **Location: Bijnor**	**Name : *Bengala elanga* (Bengala barb)** Kingdom: Animalia Phylum: Chordata Class: Actinopterygii Order: Cypriniformes Family: Cyprinidae Genus: *Megarasbora* Species: *Megarasbora elanga* **Location: Bijnor**

	
Fig. 24e	Fig. 24f
Name : *Oreichthys cosuatis* Kingdom: Animalia Phylum: Chordata Class: Actinopterygii Order: Cypriniformes Family: Cyprinidae Genus: *Oreichthys* Species: *Oreichthys cosuatis* **Location: Bijnor**	**Name : *Glyptothorax dakpathari*** Kingdom: Animalia Phylum: Chordata Class: Actinopterygii Order: Siluriformes Family: Sisoridae Genus: *Glyptothorax* Species: *Glyptothorax dakpathari* **Location: Haridwar**
	
Fig. 24g	Fig. 24h
Fig. 24 a-h New record of fish species at specific stretch of river Ganga	

New maximum length record of fish species

Name : *Securicula gora* Kingdom: Animalia, Phylum: Chordata Class: Actinopterygii Order: Cypriniformes; Family: Cyprinidae Genus: *Securicula* Species: *gora* New length recorded:28.2cm Length on fishbase:24.5cm	**Name : *Johnius coitor* (Coitor croaker)** Kingdom: Animalia, Phylum: Chordata Class: Actinopterygii, Order: perciiformes Family: Sciaenidae: Genus: *Johnius* Species: *coitor* New length recorded:16.9cm Length on fishbase:16.0cm
	
Fig. 25a	Fig. 25b
Name : *Corica soborna* (Ganges river sprat) Kingdom: Animalia, Phylum: Chordata Class: Actinopterygii, Order: Clupeiformes Family: Clupeidae: Genus: *Corica* Species: *soborna* New length recorded:8.2cm Length on fishbase:5.3cm	**Name : *Gogangra viridescence*** Kingdom: Animalia, Phylum: Chordata Class: Actinopterygii, Order: Siluriformes Family: Sisoridae: Genus: *Gogangra* Species: *viridescence* New length recorded:11.2cm Length on fishbase:8.5cm

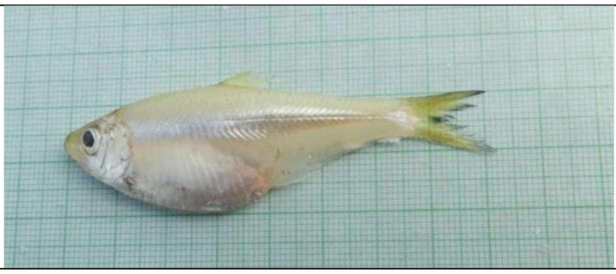


Fig. 25c	Fig. 25d

Fig. 25 a-d New maximum length record of fish species

Exotic fishes of river Ganga

Eight exotic fish species namely *Hypophthalmichthys molitrix* (Silver carp), *Hypophthalmichthys nobilis* (Big head carp), *Ctenopharyngodon idella* (Grass carp), *Cyprinus carpio* (Common carp), *Cyprinus carpio* var. *specularis* (Common carp), *Pterygoplichthys disjunctivus* (Vermiculated sailfin catfish), *Clarias gariepinus* (African Sharptooth Catfish), and *Oreochromis niloticus* (Nile tilapia) were recorded during the study period. Maximum landing of the exotic fish species has been recorded from the middle stretch of the river extending from Varanasi to Buxar. Few of the sites namely Bijnor (U.P.), Berhampore (W.B) and Balagarh (W.B) have also been observed as an area inhabited byexotic fish species. Overall Repeatability Index of Common carp and Tilapia in river Ganga werecalculated as 26.8 and 24.09 respectivelyin the middle stretches. Maximum annual Invasive Index (Ix) of both common carp and Tilapia with respect to other native riverine fish species (N) were 0.28 and 0.15 respectively indicating that the invasion has moderately impacted the biodiversity. Sudden landing of common carp (*Cyprinus carpio communis*) from river Ganga at Patna was noticed during monsoon months (July-August), 2019 with an estimated landing of 2.16 tonnes.

Salient Identifying Characters of Exotic fishes Recorded from Ganga riversystem

Fig. 26 *Cyprinus carpio* (Linnaeus, 1758)

1. Body robust, more or less compressed, abdomen rounded
2. Mouth small, terminal and protrusible; lips thick and fleshy
3. Barbels 2 pairs, one pair each of rostral and maxillary; maxillary pair longer than rostral
4. Dorsal fin very long with 3 spines and 18 to 20 rays, dorsal spine stout and serrated
5. Caudal fin deeply emarginated
6. Lateral line straight with 30 to 40 scales
7. Colour: Sides of the body golden-yellow, fins tinged with reddish or golden
8. Exotic carp

Fig. 27 *Cyprinus carpio* var. *Specularis* (Linnaeus, 1758)

1. Varieties of common carp
2. Body partially covered with scales

Fig. 28 *Hypophthalmichthys nobilis* (Richardson, 1845)

1. Body stout and compressed
2. Head large, snout short and broad
3. Mouth terminal and oblique
4. Abdomen round, post-ventral part of abdomen with a keel
5. Dorsal fin short, inserted behind origin of pelvic fins. Dorsal with 9 finrays (7 branched)
6. Anal with 14 fin rays (11 branched)
7. Scales small, lateral line with 115 scales

Fig. 29 *Hypophthalmichthys molitrix* (Valenciennes, 1844)

1. Abdomen strongly compressed with a sharp keel from throat to vent
2. Mouth terminal, lower jaw slightly longer than upper
3. Barbel absent
4. Dorsal fin short, inserted behind pelvic fins, or above tip of pectoral finswith 10 rays (7 branched)
5. Anal fin with 14 to 17 rays(12 to 14 branched)
6. Scales small, lateral line with 110 to115 scales
7. Body silvery white, fins dark. Body with some red spots

Fig.30 *Oreochromis niloticus* (Valenciennes,1844)

1. Jaws equal; mouth does not reach vertical from anterior border of eye; outer teeth rather broad,
2. 3 rows of scales on cheek
3. Scales cycloid; pectoral fin pointed; pelvic, dorsal and anal fins blunt
4. Caudal well scaled

Fig. 31 *Pterygoplicthys disjunctivus* (Weber, 1991)

1. Head is covered with strong bony casing, supra occipital process is absent
2. The caudal fin is emarginated in nature, attributed by extended lower lobe and subsequently pointed at the terminal
3. Body is covered with tuff and large bony plates with small spines extending over lateral line (29)
4. The dorsal surface of the head exhibits dark vermiculation while the entire body

Fig. 32 *Clarias gariepinus* (Burchell, 1822)

1. Slender bodies, large eel-like, a flat bony head
2. Terminal mouth with four pairs of barbels
3. Usually of dark gray or black coloration on the back, fading to a white belly
4. A large, accessory breathing organ composed of modified gill arches. Only the pectoral fins have spines

Invasion index of exotic fish species on native fish fauna of river Ganga

Table. 10 Invasion Index of exotic fish species on native fish fauna of river Ganga

Sl no.	Sites	Index value (I_x) Common carp	Remarks	Index value (I_x) Tilapia	Remarks
1.	Haridwar	0.06	Less impacted	-	-
2.	Bijnor	0.09	Less impacted	0.002	Less impacted
3.	Narora	0.07	Less impacted	0.06	Less impacted
4.	Farrukhabad	0.16	Less impacted	0.28	Less impacted
5.	Kanpur	0.40	Moderately impacted	0.60	Moderately impacted
6.	Prayagraj	0.85	Moderately impacted	0.28	Less impacted
7.	Varanasi	1.73	Highly impacted	0.45	Moderately impacted
8.	Buxar	1.25	Highly impacted	0.21	Less impacted

Potential impact of common carp (exotic fish species) on native fish fauna of river Ganga

Tehri Lake having the surface area of 4200 ha is situated at Garhwal region of Uttarakhand, India, which is formed after the construction of world's highest Tehri dam on confluence of the Bhagirathi and Bhilangana rivers. Catch data collected from two landing centres of Tehri lake namely Dobrachatti and Tipri revealed that catch composition comprises of mainly two species i.e., *Tor putitora* and *Cyprinus carpio*. Landing data shows that average percentage composition of Golden mahseer is higher (69.40%) as compared to common carp (30.59%). This might be due to the usage of more numbers of fishing net for Golden mahseer. Mean catch per unit efforts (CPUE) is significantly more ($P<0.05$) (18.33±6.06 kg/hr/boat) for common carp as compare to CPUE of Golden mahseer (12.22±3.07 kg/hr/boat).

Likewise, *Cyprinus carpio* was observed to be the most dominating fish species encountered from the river stretch of Balia and Buxar reflecting overwhelming dominance with 33.85% (avg.) by weight of the total catch. The annual average yield per day was estimated 19.17 kg day^{-1}, which is almost at par with the yield from Prayagraj stretch (Tripathi et al., 2017). The species was confronted in all three seasons with its peak extending from August to November during which the catch may rise up to 43.67%. The population of the catch was dominated by the size range of 20.1-32.4cm. In analogy with the indigenous fishes, almost proportionate contribution of common carp was noticed in the year 2017 (30.07%) and 2018 (29.06%) while sharp increase of 13.38% in common carp landing was observed in 2019 (42.44%) in comparison to the preceding year. The invasion index of common carp indicated moderate impact of the exotic in the stretch with the average value of 1.25 during 2017-2020.

Fig. 33 Common carp at Tehri Lake, Uttarakhand

Fig. 34 Common carp haulatBuxar, Bihar

Correlation between selected parameters and C. carpio productions

A correlation was established between the exotic carp production and water quality parameters (>0.75 positive or negative). Therefore, nine environmental variables viz. water temperature, depth, flow, turbidity, dissolved oxygen, biochemical oxygen demand, salinity, total phosphate and total nitrogen were selected to correlate with *C. carpio* production and distribution in the study area. Table 11. depicts that four parameters viz. water flow, BOD, salinity and total phosphate are the major influencing factors for *C. carpio* seasonal catch. Positive correlation with BOD and TP is a clear indication intherole of anthropogenic pollution behind common carp abundance. Higher abundance of common carp during monsoon might be due to its bottom dwelling habit and also found less impacted by increased flow in monsoon. Negative correlation with salinity can also be contributed to the higher abundance in monsoon when salinity is lower.

Table 11. Major influencing factors for *C. carpio* seasonal catch variations

	Water Temp	Depth	Flow	Turbidity	Dissolved Oxygen	Biological Oxygen Demand	Salinity	Total Phosphate	Total Nitrogen
C. carpio	0.49	-0.29	0.67*	0.33	-0.31	0.73*	-0.78*	0.82*	0.09

* Marked correlations are significant at $p < .05$

Length class and season wise availability of Common carp and Tilapia in river Ganga

❖ ***Distribution and availability in River Ganga of C. carpio***

Among all other invasive carps reported from the river, common carp is the most ubiquitous as it is recorded in almost all the sites of middle stretch (Uttar Pradesh and Bihar) of the river throughout the year.

❖ ***Maximum length recorded of C. carpio***

79.5 cm (TL) (♀; wt. 8.0 kg) during post monsoon months from Prayagraj (December, 2019)

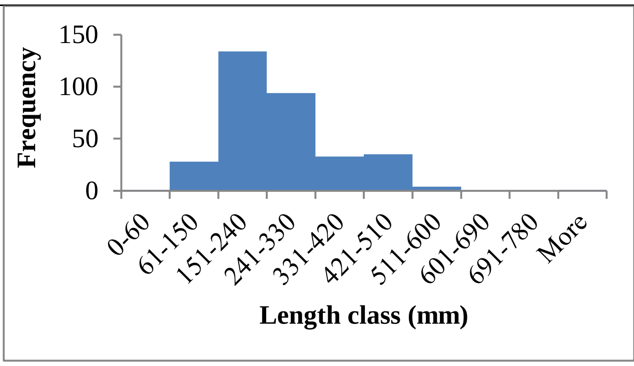


Fig. 35 Length class frequency distribution of C. carpio available in river Ganga

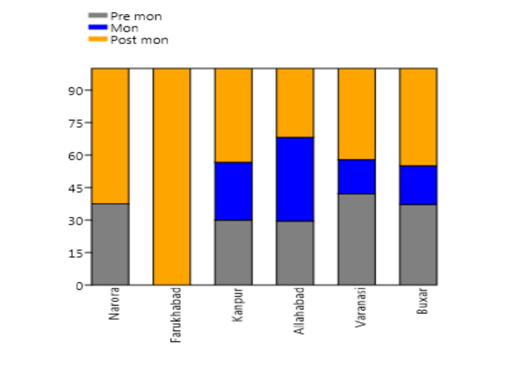


Fig. 36 Season wise (%) Juvenile availability of C.carpioin river Ganga

❖ ***Length weight relationship***

During the period of investigation, a total of 338 representative samples of *Cyprinus carpio* having size range of 9.1-79.5 cm (TL) were collected from the study site to assess LWR. The estimated 'b' value is within the expected range (2.5 to 3.5) for the species (Froese, 2006) exhibiting its isometric growth pattern in the river.

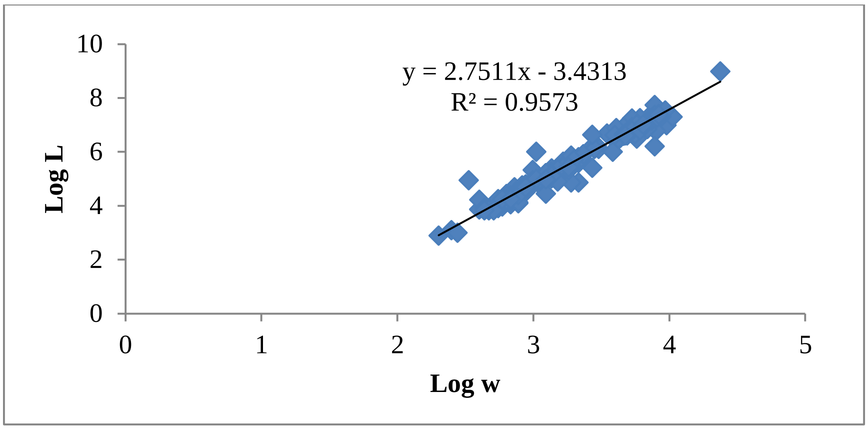


Fig. 37 Length weight relationship of *Cyprinus carpio*

- ***Length class and juvenile availability in river Ganga***

The available length class of *Cyprinus carpio* in the middle Ganga resides between 150-570 mm with maximum abundance from 210-330 mm indicating its wide range of the fishsize. Highest abundance of *C. carpio*has been confronted mostly during monsoon season from the entire stretch. Kanpur to Buxar zone has exhibited maximum availability with 33% (avg.) round the year.

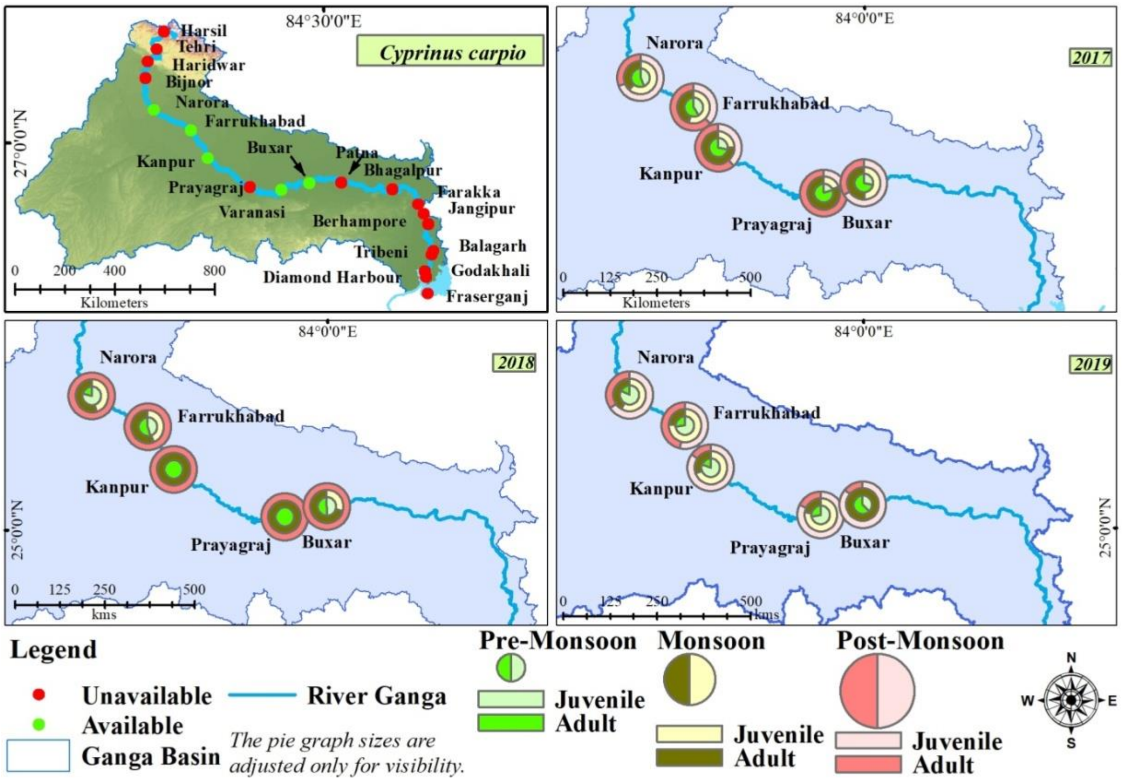


Fig. 38 Season wise distribution of *C. carpio* juveniles in different sites of Ganga

Nile Tilapia (*Oreochromis niloticus*) is a major threat to the Ganga River System. The species was introduced in India as an important aquaculture fish serving as important food fish due to its fast growth and wide environmental tolerance. The species has established its population in the river system and contributes about 7% of the total fish landing in the middle stretch.

❖ ***Distribution and availability in River Ganga of Tilapia:***

The Tilapia is reported to be distributed in the freshwater habitats like lakes, ponds and irrigation channel. The species is reported Haridwar to Buxar available throughout the year.

❖ ***Maximum length recorded of O.niloticus:***

44.5 cm (TL) (♂; wt. 1.268 kg) during post monsoon months from Kanpur (December, 2018)

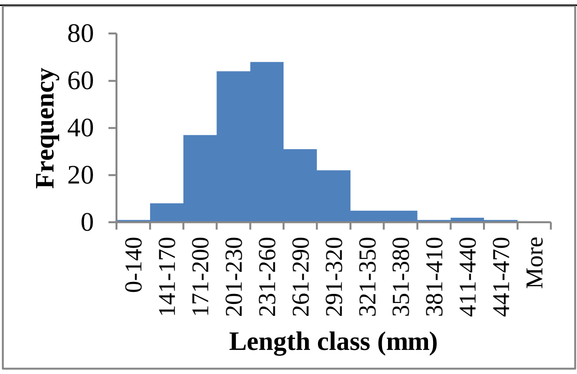


Fig. 39 Length class frequency distribution of *O. niloticus* available in river Ganga

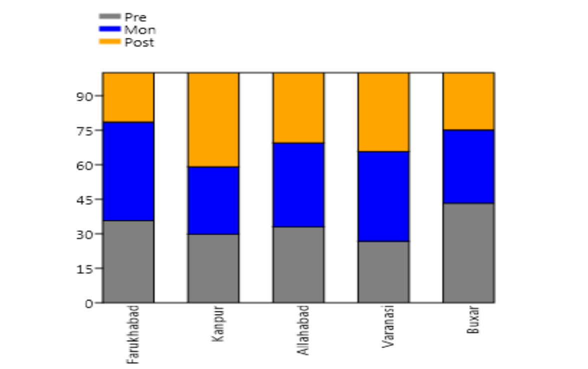


Fig. 40 Season wise (%) Juvenile availability of *O. niloticus*in river Ganga

❖ ***Length weight relationship of Tilapia***

During the period of investigation, a total of 245 representative samples of *O. niloticus* having size range of 14-44.5 cm (TL) were collected from the study site to assess LWR. The estimated 'b' value is within the expected range (2.5 to 3.5) for the species (Froese, 2006) exhibiting its isometric growth pattern in the river.

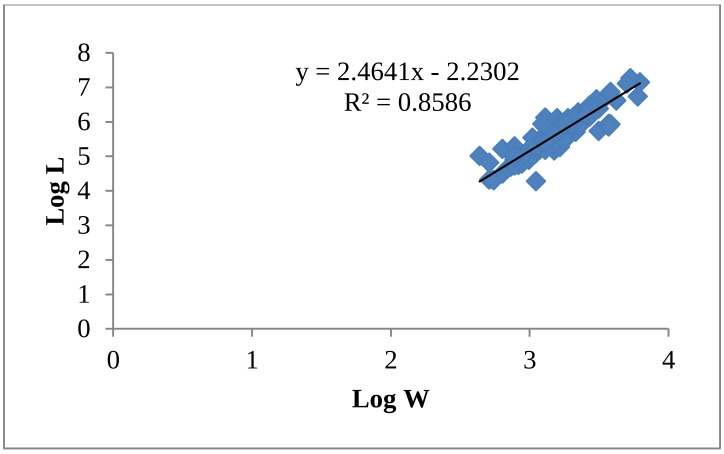


Fig. 41 Length weight relationship of *Oreochromis niloticus*

❖ ***Length class and Juvenile availability of Tilapia in river Ganga:***

O. niloticus reaches sexual maturity is at 3-6 months depending on temperature, and attains weight about 30 g. As reported, reproduction occurs only when temperatures are over 20°C. The dominant length class of *O. niloticus* in Gangais 201-260 mm. Maximum abundance of Tilapia juveniles have been confronted during monsoon months from Farrukhabad to Prayagraj.

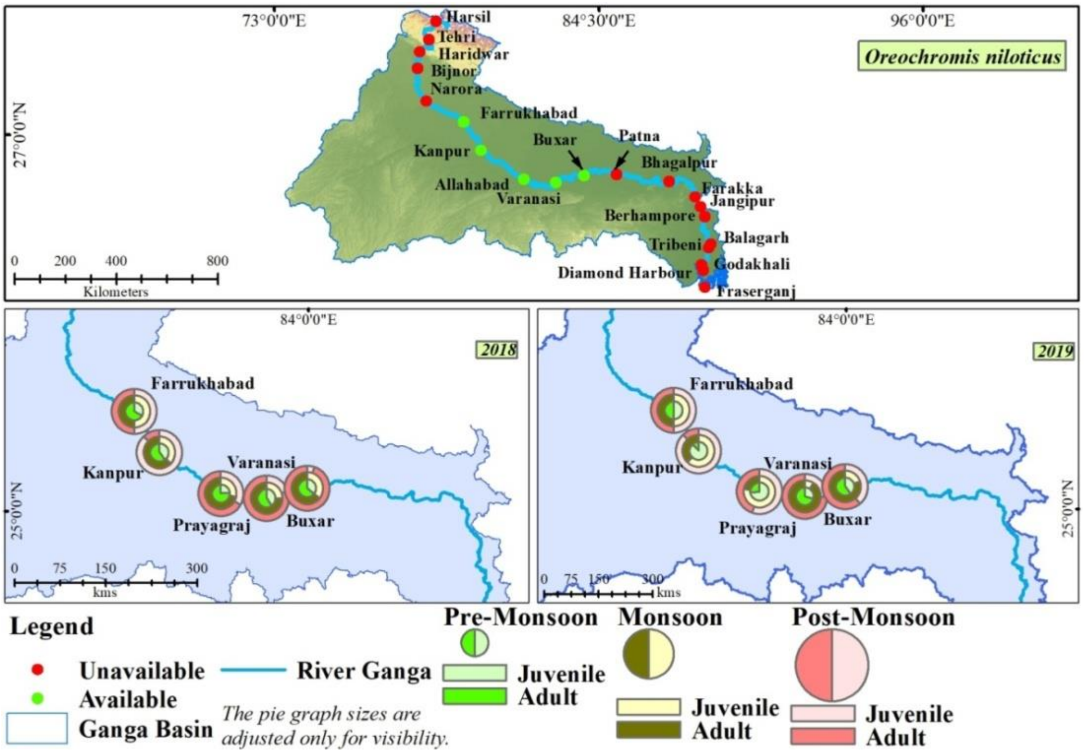


Fig. 42 Season wise distribution of *O. niloticus* juveniles in different sites of Ganga

Assessment of biotic integrity (Index of Biotic Integrity)

Investigation was conducted along 2515 km stretch of the main channel of the river Ganga for assessment of the Index of biotic integrity (IBI) (Karr, 1981) during 2016-2020 in sixteen sampling sites viz., Bijinor (S1), Narora (S2) Farrukhabad (S3), Kanpur (S4), Prayagaraj (S5) and Varanasi (S6) in the upper stretch, Buxar (S7), Patna (S8) and Bhagalpur (S9) in the middle stretch and Farrakka (S10) Berhampore (S11), Balaghar (S12) and Triveni (S13) in the lower stretch, Godakhali (S14), Diamond harbour (S15) and Fraserganj (S16) in the estuarine stretch of the river. Following the method applied for the central Indian rivers (Ganasan and Hughes, 1998) where the most desirable metric values obtained at the least disturbed site was used as the reference condition. The metrics adapted were based on the modifications successfully tested in tropical and sub tropical rivers Mexico, Namibia, Venezuela and India (Lyons et al., 1992; Hocutt et al., 1994; Gutierrez, 1994; Ganasan and Hughes, 1998; Das and Samanta, 2006).

Table 12. Parameters used in assessment of fish communities from the original IBI and corresponding metrics adapted for the study in river Ganga

Original metrics	Adapted metrics
No. of fish species	No. of native species No. of native families
No. of intolerant species	No change
No. of darter species	No. of Demarsalspecies
No. of sunfish species	No. of Pelagic fishes species
No. of sucker species	No. of Benthopelagic fishesspecies
% of individuals as Green sunfish	% individual as tolerant species
% of individuals as omnivores	No change
% of individuals as invertivores	% individual as herbivores
% of individuals as piscivores	% individual as Carnivore
No. of individuals	No change
% of individuals as hybrids	No. of Moderate species

Table 13. Criteria for scoring of IBI for river Ganga

Category	Metric	Traditional scoring criteria		
		5 (best)	3	1 (worst)
Taxonomic richness	No. of native species	>80	40-80	<40
	No. of native families	>30	15-30	<15
Habitat composition	Pelagic fishes	>10	5-10	<5
	Benthopelagic fishes	>44	22-44	<22
	Demarsal fishes	>36	18-36	<18
	No. of intolerant species	>24	12-24	<12
	No. of Individuals as tolerant	>30	15-30	<15

	species			
	No. of Individuals as Moderate species	>36	18-36	<18
Trophic composition	No. of Individuals omnivores	>30	15-30	<15
	No. of Individuals herbivores	>30	15-30	<15
	No. of Individuals top carnivores	>40	20-40	<20
	Total no. of Individuals	>80	40-80	<40

IBI and IBI metrics

The number of native species and families in the reference site is more than that observed in the stressed zone.All IBI metrics showed high values at sites 1 and 2 with high habitat quality. Site 6, 7, 8 and 13 showed the high values only occurred when habitat quality was high. Data for number of native adults appeared unrelated to habitat quality. The remaining metrics increased constantly with increased habitat quality. The trophic composition of the fishes also showed significant alteration in the stressed sites. The metric percentage of individual as omnivores, carnivores and herbivores decreased in sites S5, S6, S9 and S14 compared to the reference sites. The IBI is lower at the sites S13, S14 and S15 which are disturbed. The qualitative evaluation of the IBI at the six sites indicated that lower stretch of river Ganga from Site13 to Site15 found to be Impaired and upper stretch sites S 1, S 2 and middle stretch S10 to be acceptable.

FISHING METHODS OF RIVER GANGA AND ASSOCIATED SUSTAINABILITY ISSUES

Fishing methods followed in a particular stretch of a river depend on the habitat condition and targeted fish species among the available fish species in the area. Survey in river Ganga has revealed huge diversity of fishing methods orfishing gears which are categorically sub-divided under different heads depending upon their mode of operations as given below.

Classification of fishing gears observed in river Ganga

Sub-divisions of the recorded fishing gear have been performed depending upon their operational methods (Von Brandt, 1984). A total of 82 different types of fishing gears were recorded from entire stretch of river Ganga,which can be divided into the following 12 broad groups as given below. Maximum diversity was recorded in case of Gill nets (26 types), followed by Fishing traps (18 types) and bag nets (12 types). A total number of 26 different types of baits under 07 categories were recorded in line fishing. Among those baits, earthworm and small-sized prawns were observed to be ubiquitous. Six varieties of fish species and four types of insects used as bait are found to be prevalent for catching carnivorous fishes. Five specially modified indigenous types of bait moulded with fish attractants were also documented.

Table 14. Categorization of fishing methods of river Ganga

Sl.	Category	Sl.	Category
1.	Without gear (1 type)	7.	Gill netting (26 types)
2.	Grappling and wounding gear (4 types)	8.	Drive-in net (2 types)
3.	Stupefying devices (1 type)	9.	Falling gear (2 types)
4.	Line fishing (7 types)	10.	Lift nets (3 types)
5.	Fishing trap (18 types)	11.	Bag nets (12 types)
6.	Arial Fishing trap (1 type)	12.	Dragged gear (5 types)

Table 15. List of fishing methods of river Ganga

Sl.		Category	Sub-category	Local name
1		**Without gear**		
	1a		Mudskipper fishing by hand	*Dakur maach dhora*
2		**Grappling and wounding gear**		
	2a		Curved metal rod to catch mud crab	*Sink/Beri*
	2b		Bamboo tongs to catch mud crab	*Chimtey*
	2c		Multi-pronged bamboo spear	*Ballam*
	2d		Multi-pronged metallic spear	*Kand*
3		**Stupefying devices**		
	3		Chemical stupefying	*Bis diye maach dhora*
4		**Line fishing**		
	4a		Line without hook	*Sutiaara*
	4b		Hand lines, single hook	*Hat Borshi*
	4c		Set line with 7 hooks	*Tuka-Feka*
	4d		Bottom set long lines, multiple hooks	*Hajari Bansi*
	4e		Pole and line fishing, single hook	*Bonshi/Chhip*
	4f		Pole and line fishing, 2 hooks	*Borshi/Bonshi*
	4g		Set line from small twigs	*Nolborshi*
5		**Fishing with Fishing**		

		traps		
	5a		Brush Fishing trap	*Komor*
	5b		Barrier Fishing trap	*Chaurpata/ Khalpata*
	5c		Box Fishing trap - Truncated cone	*Duar*
	5d		Box Fishing trap - rectangular cuboidal	*Ghuni*
	5e		Box Fishing trap - rectangular cuboidal	*Pizara*
	5f		Box Fishing trap - Barrel shaped	*Dhol britti*
	5g		Box Fishing trap- Truncated cone	*Jhangi*
	5h		Box Fishing trap - Cylindrical	*Dhol duar*
	5i		Box Fishing trap - Half cylindrical	*Britti*
	5j		Box Fishing trap - Cylindrical	*Aanta*
	5k		Box Fishing trap- large cylindrical	*Duari Britti*
	5l		Box-Fishing trap- Dome shaped	*Pinjra*
	5m		Box Fishing trap-Domru shaped	*Chak Jaal*
	5n		Box Fishing trap-Domru shaped	*Gogh Jaal*
	5o		Box Fishing trap- Double domru shaped	*Chak Jaal*
	5p		Box Fishing trap- Extended cylindro conical	*Aarsi*
	5q		Box Fishing trap- cylindro-conical	*Woka*
	5r		Box-Fishing trap-cuboidal, net made	*Jhinga Jaal*
6		**Arial Fishing trap**		
			Arial Fishing trap	*Thoopa Jaal*
7		**Gill netting**		
			Drift Gill net – 32mm mesh	*Aungthasi Jaal*
			Drift Gill net – 20-30 mm mesh	*Fasla Jaal*
			Drift Gill net – 25mm mesh	*Sutri Jaal*
			Drift Gill net – 26mm mesh	*Vachaili Jaal*
			Drift Gill net – 18-26mm mesh	*Piyali Jaal*
			Drift Gill net – 30-35mm mesh	*Chelwa Jaal*
			Drift Gill net – 95-122mm mesh	*Bekra Jaal*
			Drift Gill net – 126mm mesh	*Bhasha Jaal*
a.	**7a**		Drift Gill net – 100-220 mm mesh	*Cot/Sele Jaal*
b.	**7b**		Drift Gill net – 200-220 mm mesh	*Songaila Jaal for Bagarius*
c.	**7c**		Drift Gill net – 220 mm mesh	*Daak Kele Jaal* for IMC
d.	**7d**		Drift Gill net – 210 mm mesh	*Pangas Jaal*
e.	**7e**		Drift Gill net - 170 mm mesh	*Chapa Jaal*
f.	**7f**		Drift Gill net - 160 mm mesh	*Dora Jaal*
g.	**7g**		Drift Gill net - 115 mm mesh	*Current Jaal*
h.	**7h**		Drift Gill net - 95-120 mm	*Chinese Jaal*
i.	**7i**		Drift Gill net - 80-100 mm mesh for IMC	*Naga Jaal*
j.	**7j**		Drift Gill net - 80 mm-120 mm mesh	*Fash Jaal*
k.	**7k**		Drift Gill net - 60-105 mm mesh Bhola, Phasa, Hilsa	*Fans jaal, Sata Jaal*
l.	**7l**		DriftGill net - 45-50 mm mesh	*Phasa Jaal*
m.	**7m**		Drift Gill net - 40-46 mm mesh	*Bhola Jaal*
n.	**7n**		Drift Gill net - 40- 50 mm mesh	*Fasla/Current/Nagin*

				Jaal/Patti jaal/ Dharmu Jaal
o.	**7o**		Drift Gill net - 40-110 mm mesh	*Hilsa Jaal*
p.	**7p**		Drift Gill net - 37 mm mesh	*Vacha/Ghoura Jaal*
q.	**7q**		Drift Gill net – 30-60 mm mesh	*Tilantare Jaal/Ketaki Jaal*
r.	**7r**		Drift Gill net - 20,26,28,30 mm mesh	*Topse Jaal*
s.	**7s**		Drift Gill net – 22 mm mesh	*Chalhati Jaal*
t.	**7t**		Drift Gill net - 20 mm mesh	*Chela Jaal*
u.	**7u**		Drift Gill net - 14-26 mm mesh	*Khoyra Jaal*
v.	**7v**		Drift Gill net - 18 mm mesh	*Khorsula Jaal*
w.	**7w**		Drift Gill net - 18- 34 mm mesh	*Piyali/Raikhoira/Puti Jaal*
x.	**7x**		Drift Gill net - 14-25 mm mesh	*Pituli bele Jaal/Gule Jaal/Ailia coila Jaal*
y.	**7y**		Drift Gill net - 16-18 mm mesh	*Kukri Jaal*
z.	**7z**		Drift Gill net - 15-20 mm mesh	*Fasla Jaal*
8		**Drive-in net**		
	8a		Drive-in net	*Chilwan*
	8b		Drive-in net	*Khunche Jaal*
9		**Falling gear**		
	9a		Cast net	*Fekka Jaal, Khepla jaal, Jhiguri jaal, Fekua jaal,*
	9b		Cone-shaped falling gear	*Chabi jaal*
10		**Lift nets**		
	10a		Hand lift nets	*Jhatka jaal*
	10b		Mechanized lift nets (fixed)	*Gyanra vessal*
	10c		Mechanized lift nets (boat installed)	*Nouka vessal*
11		**Bag nets**		
	11a		Scoop nets without handle, circular	*Gunri jaal*
	11b		Scoop nets with handle	*Chhekuni jaal*
	11c		Skimming net	*Thela jaal*
	11d		Skimming net	*Hatu jaal*
	11e		Skimming net	*Dhebti jaal*
	11f		Small bag net, fixed type	*Chingri jaal*
	11g		Dragged scoop net, rectangular	*Meen jaal*
	11h		Multiple bag net	*Kona jaal*
	11i		Large bag net, surface set	*Thor jaal*
	11j		Large bag net, bottom set	*Beenti jaal*
	11k		Large bag net, with barrier (Stow net)	*Patan jaal*
	11l		Closable bag nets	*Sangla jaal*
12		**Dragged gear**		
	12a		Small shore seine with zero mesh net	*Choti jaal*
	12b		Large Shore seine with zero mesh net	*Ber jaal*
	12c		Boat seine with zero mesh net	*Chot jal, Masahri Jaal, Maha jal*

	12d		Boat seine with meshed net	*Ghaar jaal, Chelhwari Jaal, Chhanta Jaal, Jholi jal, Ghai jal, Samiya jal, Saraila jal, Ghai jal, Ghanali jal*
	12e		Bottom trawl	*Katni jaal, Moi jal*

Table 16. Station wise distribution of fishing gearalong with major target species (upper and middle stretch, Haridwar to Varanasi)

District/ Centre	Type of Gear	Local Name	Mesh Size (mm)	Target Species
Haridwar	Gill net	*Current Jaal*	80 - 160	*Tor putitora, Schizothorax richardsonii, Silonia silondia, Glossogobius giuris, Cyprinus carpio*
	Cast net	*Fekka Jaal*	20 - 40	*Tor putitora, Labeo dyocheilus, Botia lohachata, Cyprinus carpio*
Bijnor	Gill net	*Patti Jaal*	40	*Labeo rohita, Cirrhinus mrigala, Salmophasia bacaila, Labeo dyocheilus, Puntius sarana, Gonialosa manmina, Wallago attu, Cabdio morar, Tor putitora*
		Current Jaal	20-120	
		Tilantare Jaal	40-60	
	Cast net	*Fekka Jaal*	20 - 40	*Labeodyocheilus, Tor putitora, Labeodyocheilus, Cyprinus carpio.*
Bulandsahar (Narora)	Gill net	*Fasla Jaal*	20-120	*Cirrhinus reba, Labeo bata, Cirrhinus mrigala, Salmophasia bacaila, Labeo dero, Labeo rohita, Cabdio morar, Wallago attu, Notopterus notopterus.*
		Mosquito Jaal	01	
Farrukhabad	Gill net	*Sata Jaal*	30-80	*Labeo rohita, Wallago attu, Mastacembelus armatus, Cirrhinus mrigala, Labeo bata*
		Fasla Jaal	20-100	
		Current Jaal	30-140	
	Cast net	*Fekua Jaal*	20-40	*Wallago attu, Rita rita, Bagarius bagarius*
	Drag net	*Chelhwari Jaal*	40-80	*Wallago attu, Rita rita,* Gunguna, *Cyprinus carpio*
Kannauj	Gill net	*Ketaki Jaal*	30-50	*Labeo rohita, Mastacembelus armatus, Cirrhinus mrigala, Labeo calbasu*
		Dharmu Jaal	40-60	
		Current Jaaal	40-120	
Kanpur	Drag net	*Chhanta Jaal*	50	*Rita rita, Wallago attu, Cyprinus carpio, Sperata* sp., *Mystus* sp.
		Chelhwari Jaal	20-60	
	Gill net	*Current jaal*	30-120	*Labeo rohita, Mastacembelus armatus, Cirrhinus mrigala, Labeo bata*
		Fasla Jaal	20-120	
	Cast Net	*Fekka Jaal*	20-40	*Sperata* sp., *Mystus* spp., *Wallago attu, Rita rita, Bagarius bagarius*
Unnao	Cast Net	*Jhiguri Jaal*	20	*Speratasp., Mystusspp., Wallago attu, Rita rita, Bagariusbagarius*
Fatehpur	Drag Net	*Jholi Jaal*	20-50	*Rita rita, Wallago attu, Cyprinus carpio, Sperata* sp., *Mystus* spp.
		Ghai Jaal	20-40	
	Gill net	*Sata Jaal*	50	*Labeo rohita, Mastacembelus armatus, Cirrhinus mrigala, Labeo bata*
		Fasla Jaal	20-160	
	Cast Net	*Jhiguri Jaal*	20-40	*Sperata* sp., *Mystus* spp., *Wallago attu, Rita rita, Bagarius bagarius*
Kaushambi	Drag Net	*Ghai Jaal*	20-40	*Wallago attu, Cyprinus carpio, Rita rita, Bagarius bagarius, Sperata* sp., *Mystus* sp., *Cirrhinus mrigala*
		Jholi Jaal	30-50	
		Samiya Jaal	20-60	
Prayagraj	Drag Net	*Saraila Jaal*	20-40	*Wallago attu, Cyprinus carpio,* Rita, Gonch, *Sperata* sp., *Mystus* spp., *Cirrhinus mrigala*
		Ghai Jaal	20-30	

		Ghanali Jaal	20-30	
		Maha Jaal	20-40	
	Gill net	*Current Jaal*	20-120	*Labeo bata*, *Cirrhinus reba*, *Cirrhinus mrigala*, *Clupesoma garua*, *Eutropiichthys vacha*, *Labeo rohita*, *Mastacembelus armatus*
	Mosquito Net	*Masahri Jaal*	01	*Cabdio morar*, *Cyprinus carpio*
Mirzapur	Fishing trap	*Evert pattern Jaal*	40-50	Prawn, *Cabdiomorar*, *Rhinomugilcorsula*
	Drag Net	*Chanta Jaal*	40	*Rita rita*, *Cyprinus carpio*, *Sperata* sp., *Mystus* spp., *Wallago attu*, *Cyprinus carpio*
		Saraila Jaal	30-50	
		Ghai Jaal	20-30	
	Mosquito Net	*Masahri Jaal*	01	*Cabdio morar*, *Cyprinus carpio*
	Gill net	*Current Jaal*	20-120	*Labeo bata*, *Cirrhinus reba*, *Clupesoma garua*, *Eutropiichthys vacha*, *Cirrhinus mrigala*, *Labeo rohita*, *Mastacembelus armatus*
Varanasi	Drag Net	*Maha Jaal*	15-30	*Rita rita*, *Wallago attu*, *Cyprinus carpio*, *Notopterus notopterus*, *Bagarius bagarius*
		Saraul Jaal	20-30	
		Ghanaili Jaal	20	
	Gill net	*Chote Jaal*	20-40	*Labeo bata*, *Cirrhinus mrigala*, *Sperata* sp., *Mystus* spp., Tilapia, *Clupisoma garua*, *Eutropiichthys vacha*
		Fasla Jaal	60-120	
	Mosquito Net	*Mashahri Jaal*	01	*Cabdio morar*, Tilapia, *Cyprinus carpio*, *Cyprinus carpio*
		Machhardani Jaal	01	
	Cast Net	*Jhiguri Jaal*	20-30	*Sperata* sp., *Mystus* spp., *Wallago attu*, *Rita rita*, *Bagarius bagarius*

Table 17. Station wise distribution of fishing gear along with major target species (lower and estuarine stretch, Buxar to Fraserganj)

District/ Centre	Type of Gear	Local Name	Mesh Size (mm)	Target Species
Buxar	Hook & line fishery	*Tuka-Feka*	--	IMC, Common carp (*Cyrinus carpio*)
	Gill net	*Chalhati jaal*	22	*Gudusia chapra*, *Gonialosa manmina*
	Drive-in gear	*Chilwan*	01	Miscellaneous freshwater fishes of varying size length
	Lift net	*Chitwa jaal*	5-6	*Rhinomugil corsula*
	Fishing trap	*Woka*	01	Prawns (*Macrobrachium* sp.)
	Boat seine	*Ghar*	01	Small and large catfishes, Eels etc.,
	Drag net – Shore seine	*Ber/chat jaal*	01	Miscellaneous freshwater fishes of varying size length
	Gill net	*Fasla jaal*	140	*Wallago attu*, *Sperata* sp., *L. calbasu*
	Gill net	*Bekra jaal*	20-30	*Clupisoma garua*, *E. vacha*
	Gill net	*China jaal*	95-122	*Cyprinus carpio*
	Gill net	*Chalhati jaal*	22	*O. cotio*, *Puntius sophore*, *S. phasa* etc.
	Gill net	*Songaila jaal*	100-150	IMC and Large catfishes
	Cast net	*Jhingura*	65	*Cyprinus carpio*
	Gill net	*Aungthasi jaal*	32	*Gudusia chapra*, *M. pancalus* etc.
Patna	Fishing trap	*Jhangi (1.5*1 ft)*	-	*Sperata* sp., *Mastacembelus armatus*, *Rita rita*
	Hook & line	*Banshi*	--	*Rita rita*, *Sperata* sp., etc.
	Gill net	*Bhasha jaal*	126	IMC, *Notopterus notopterus*, *Bagarius bagarius*
	Gill net	*Dora jaal*	160	IMC, *Bagarius bagarius*,*Sperata* sp.
	Gill net	*Sutri jaal*	25	*Ailia coila*
	Gill net	*Bekra jaal*	25-38	*Clupisoma garua*

	Gill net	*Vachaili jaal*	26	*E. vacha*
	Gill net	*Gochail jaal*	140	IMC, *Chitala chitala, Notopterus notopterus*
	Drag net – Shore seine	*Ber/chat jaal*	01	Miscellaneous freshwater fishes of varying size length
Bhagalpur	Fishing trap	*Pinjra*	--	*Puntius* spp., *M. armatus* etc.
	Fishing trap	*Aarsi*	--	Small Indegenous Fishes (SIF), prawn etc.
	Fishing trap	*Jhinga jaal*	--	Freshwater prawn
	Hook & line	*Banshi*	--	*Channa* spp., *Rita rita*, *Sperata* sp., etc.
	Gill net	*Current jaal*	55	Rohu, *Rita rita*, *Sperata* sp., *L.calbasu*
	Drag net – Shore seine	*Ber/chat jaal*	01	Miscellaneous fishes of varying size length
	Gill net	*Current jaal*	105	Rohu, Catla, Mrigal and Calbasu
	Gill net	*Current jaal*	15	*P. atherinoides*, *Ailia coila*, *X. cancila* etc.
	Gill net	*Chelwa jaal*	30-35	*Crossochelius latius, O. cotio, Gudusia chapra* etc.
Farakka	Fishing trap	*Dholbitti (3*2 ft)*	--	*Macrobrachium* sp., *Rita rita, E. vacha*
	Hook & line	*Barshi*	--	*Mastacembelus armatus, Wallago attu, Channa* spp., *Rita rita*, *Sperata* sp., etc.
	Fishing trap	*Britti (1.5*2 ft)*	--	*Macrobrachium* sp., *Mystus* sp., *Sperata* sp., etc
	Gill net	*Pangas jaal*	150-200	*Pangasius pangasius;* Large catfishes
	Gill net	*Nagin jaal*	45	*Clupisoma garua, E. vacha, Silonia silondia*
	Gill net	*Ghaura jaal*	25-40	*Clupisoma garua, E. vacha*
	Gill net	*Piyali jaal*	18-26	*Cabdio morar, Johnius coitor*etc.
	Gill net	*Hilsa jaal*	55-110	*Tenualosa ilisha*
	Gill net	*Kukri jaal*	10-12	*Glyptothorax telchitta*
	Bag net	*Dhebtijaal*	20-30	*Tenualosa ilisha*
	Bag net	*Kona jaal*	80-Upper;30-end	IMC, *Pangasius pangasius, Bagarius bagarius, Sperata* spp.
	Bag net – Purse type	*Sangla jaal*	75-110	*Tenualosa ilisha*
	Fishing trap	*Duar (3.6*3.5 ft)*		*Macrobrachium* sp., *Mystus* sp., *Sperata* sp., etc.
	Drag net – bottom trawl	*Katni / Moi jaal*	12-21	Freshwater prawn, *Glossogobiusgiuris* etc.
	Drag net – Shore seine	*Ber/chat jaal*	01	Miscellaneous freshwater fishes of varying size length
Jangipur	Fishing trap	*Duar (3.6*3.5 ft)*	--	*Macrobrachium* sp., *Mystus* sp., *E. vacha,* etc.
	Fishing trap	*Ghooni*	--	*Macrobrachium* sp., *Mystus* sp.,*M.armatus* etc.
	Fishing trap	*DuariBritti*	--	*Macrobrachium* sp., *Mystus* sp., *M. armatus ,Gagata* spp. etc.
	Hook & line	*Barshi*	--	*Mastacembelus armatus, Wallago attu, Channa* spp., *Rita rita*, *Sperata* sp., etc.
	Gill net	*Ghaura jaal*	20-40	*Clupisoma garua, Eutropiicthys vacha* etc.
	Gill net	*Hilsa jaal*	55-110	*Tenualosa ilisha*
	Gill net	*Songaila jaal*	100-150	*Bagarius bagarius*
	Gill net	*Piyalijaal/Rai Khoira/ Puti jaal*	18- 34	*Cabdio morar, Cirrhinus reba, Puntius* spp.
	Gill net	*Puti jaal*	18-20	*Puntius* spp., *Macrognathus pancalus* etc.
	Gill net	*Pangas jaal*	150-200	*Pangasius pangasius;* Large catfishes
	Drag net – Shore seine	*Ber/chat jaal*	01	Miscellaneous freshwater fishes of varying size length
Rejinagar	Fishing trap	*Duar*	--	*Macrobrachium rosenbergii*
	Fishing trap	*DholDuar*	--	Prawn, *Wallago attu* etc.,
	Hook & line	*Barshi*	--	*Mastacembelus armatus, Wallago attu, Channa* spp., *Rita rita*, *Sperata* sp., etc.
	Gill net	*Hilsa jaal*	55-90	*Tenualosa ilisha*
	Gill net	*DaakKele Jaal*	22-30	IMC, Large catfishes
	Gill net	*Piyali jaal/Rai*	18- 34	*Cabdio morar, Cirrhinus reba, Puntius* sp.

		Khoira/ Puti jaal		
	Drag net – bottom trawl	*Katni / Moi jaal*	12-21	Freshwater prawn, *Glossogobius giuris* etc.
Nabadwip	Hook & line	*Nolborshi*	--	*Channa* sp.
	Hook & line	*Barshi*	--	*Mastacembelus armatus, Wallago attu, Rita rita*, etc.
	Fishing traps	*Brush Fishing trap (Komorjaal)*		IMC
	Fishing trap	*Ghuni*	--	Prawn
	Gill net	*Hilsa/ Chadi jaal*	55-90	*Tenualosa ilisha*
	Gill net	*Fashjaal*	125-140	IMC, Large catfishes
	Falling gear	*Cast net (Kheplajaal)*	40-50	*Puntius* spp., *Macrognathus pancalus* etc.
	Falling gear	*Chaba jaal*	80-100	Indian Major Carps (IMC)
	Drag net	*Shore seine (Ber jaal)*	01	Miscellaneous freshwater fishes of varying size length
Balagarh	Stupefying devices	*Fishing with poison*	-	Prawn
	Hook & line	*Barshi*	--	*Mastacembelus armatus, Wallago attu, Channa* spp., *Rita rita*, *Sperata* sp., etc.
	Gill net	*Fash jaal*	80-140	IMC, *Rita rita*
	Gill net	*Hilsa/Dholi jaal*	80-110	*Tenualosa ilisha*
	Gill net	*Ghaura jaal*	30-40	*Clupisoma garua, E. vacha* etc.
	Gill net	*Chela jaal*	12	*Salmostoma bacaila*
	Gill net	*Gulej aal*	14-20	*Apocryptes bato*
	Cast net	*Khepla jaal*	30-35	Miscellaneous
	Bag net	*Patan jaal*	70	IMC, *Pangasius pangasius, Tenualosa ilisha*
	Drag net – bottom trawl	*Katni / Moi jaal*	12-21	Freshwater prawn, *Glossogobius giuris* etc.
Triveni	Stupefying devices	*Fishing with poison*	--	Prawn
	Hook & line	*Multiple hooks (Hajari borshi)*	--	*Clupisoma garua, Bagarius bagarius*
	Arial Fishing trap	*Thoopa jaal*	5-6	*Rhinomugilcorsula*
	Gill net	*Hilsa/Chadi/Dholi jaal*	55-110	*Tenualosa ilisha*
	Gill net	*Ghaura jaal*	30-40	*Clupisoma garua, E. vacha* etc.
	Gill net	*Ghaura/Vach ajaal*	37-40	*Eutropiichthys vacha*
	Gill net	*Khorsula Jaal*	18	*Rhinomugil corsula*
	Gill net	*Gule jaal*	25	*Apocryptes bato*
	Set barrier net	*Char ghera*	01	*Pangasius pangasius, Lates calcarifer, Setipinna* sp.
	Drive-in gear	*Khunchni jaal*	8-11	*Apocryptes bato, Odontamblyopus rubicundus*
	Cast net	*Khepla jaal*	45-55	Miscellaneous fishes
	Lift net	*Nouka vessal*	10-11	*Tenualosa ilisha* (juvenile), *Salmophasia bacaila* etc.
Barrackpore	Hook & line	*Long line; 2 hooks per pole*	--	*Rita rita*
	Hook & line	*Barshi*	--	*Mastacembelus armatus, Rita rita, Sperata* sp., etc.
	Gill net	*Ghaura jaal*	30-40	*Clupisoma garua, E. vacha* etc.
	Gill net	*Hilsa/Chadi jaal*	60-100	*Tenualosa ilisha*
	Gill net	*Khoira jaal*	12-14	*Gudusia chapra*, Juveniles of *T. ilisha*
	Lift net	*Nouka vessal*	10-11	*Tenualosa ilisha* (juvenile), *Salmophasia bacaila* etc.
	Fishing trap	*Chakjaal targeting catfish*	35-40	*Arius gagora*
	Hook & line	*Barshi*	--	*Macrobrachium rossenbergii, Arius* sp., *Clupisoma garua* etc.

Godakhali	Gill net	*Hilsa jaal*	60-110	*Tenualosa ilisha*
	Gill net	*Phasa jaal*	45-50	*Setpinna* sp.
	Gill net	*Bhola jaal*	40-46	*Otolithoides pama*
	Cast net	*Khepla jaal*	35-45	*Puntius* spp., *C. garua* etc.
	Bag net	*Thela jaal*	01	Juveniles of *Macrobrachiumrosenbergii*
	Bag net, large, surface set	*Bhasa Beenti jaal*	65-01 (upper to lower)	*Corica soborna*, Juveniles of Hilsa, *S. phasa*, *Polynemus paradiseus* etc.
	Bag net, large, bottom set	*Thor jaal*	60-01 (upper to lower)	Prawn, Gobiids (*A. bato, O.rubicundus* etc.)
D.Harbour	Fishing trap	*Gogh jaal*	01	*Mystus gulio*, *Arius* sp., *O. rubicundus*, prawn etc.
	Hook and line (line fishing)	*Barshee*	--	*Arius* sp.
	Set barrier net	*Char ghera*	01	*Pangasius pangasius, Lates calcarifer, Polynemus* sp., etc.
	Gill net	*Hilsa jaal*	70-110	*Tenualosa ilisha*
	Gill net	*Bhola jaal*	40-50	*Otolithoides pama*
	Gill net	*Topsey jaal*	25-30	*Polynemus paradiseus*
	Gill net	*Sele jaal*	150-160	*Leptomelanosoma indicum*
	Cast net	*Khepla jaal*	30-35	Misscelanous fishes
	Bag net, small, fixed type	*Chingri jaal*	01	Juveniles and adults of *M. rossenbergii*
	Bag net, drag rectangular,	*Meen jaal*	01	Juveniles of *M. rossenbergii*
	Bag net, large, bottom set	*Thor jaal*	60-01 (upper to lower)	Prawn, Gobiids (*A. bato, O. rubicundus* etc.), *Polynemus paradiseus* etc.
Fraserganj	Without gear	*Dakur dhora*	-	Mudskipper
	Grappling gear	*Curved metallic rod*	-	Mud crab
	Grappling gear	*Bamboo tongs*	-	Mud crab
	Fishing trap	*Barrier Fishing trap (Chaurpata)*	01	Prawn, Misc
	Fishing trap	*Chak jaal*	01	Mud crab
	Gill net	*Chinese jaal*	95-100	*Pampus* sp., *Setipinna* sp., *Cynoglossus* spp. etc
	Gill net	*Hilsa jaal*	90-110	*Tenualosa ilisha*
	Cast net	*Khepla jaal*	45-50	Gobbids, Silver belly
	Bag net	*Guri jaal*	10-15	Prawn and Gobiids
	Bag net	*Chekuni jaal*	10-15	Mud crab
	Bag net	*Hatu jaal*	8-11	Prawn and Gobiids
	Bag net	*Meen jaal*	01	Juveniles of *P. monodon* etc.
	Bag net, large, bottom set	*Thor jaal*	65/70-01 (upper to lower)	Prawn, *Harpadon nehereus, Trichurius lepturus, Polynemus paradiseus* etc.

Pictorial view of different categories of Fishing gear in entire stretch of river Ganga

1. Fishing without gear

1. Fishing by hand

2. Grappling and wounding device

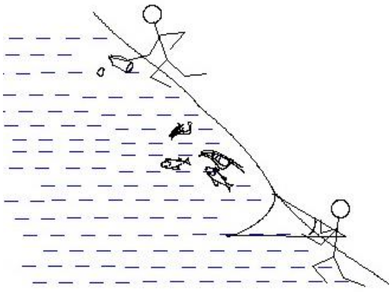
2a. Curved metal rod to catch mud crab

2b. Bamboo-made tongs to catch mud crab

2c. Multi-pronged bamboo spear

2d. Multi-pronged metallic spear

3. Stupefying devices



3. Fishingby poisoning

4. Line fishing

4a. Line without hooks

4b. Hand line without pole

4c. Line without pole, 7 hooks

4d. Multiple set line

4e. Pole and line, 2 hooks

4f. Set line from small twigs

5. Fishing with Fishing traps (18 types)

5a. Brush park

5b. *Chaurpata Jaal*

5c. *Duar*

5d. *Ghuni*

5e. *Pizara*

5f. *Dhol*

5g. *Jhangi*

5h. *Dhol Duar*

5i. *Britti*


5j. *Aanta*


5k. *Duari Britti*


5l. *Pinjra*


5m. *Chak Jaal* for crab fishing


5n. *Gogh jaal*


5o. *Chak Jaal* targeting catfish


5p. *Woka*


5q. *Woka*


5r. *Jhinga Jaal*

6. Arial Fishing trap


6a.*Thoopa Jaal*

7. Gill nets


7a. *Cot Jaal/Sele jaal*


7b. Pangas Jaal


7c. *Current jaal* targeting crab

7d. *Hilsa Jaal* targeting Hilsa

7e.*Phasa Jaal*

7f. *Bhola Jaal*

7g. *Vacha /Ghoura Jaal*

7h. *Tilantare Jaal*

7i. *Topsey Jaal*

7j. *Chela Jaal*

7k. *Khoira Jaal*

7l. *Punti Jaal/Piyali Jaal*

7m. *Gule Jaal*

7n. *Kukri Jaal*

7o. *Jaal* (15-20 mm)

8. Drive-in gears

8a. *Chilwan*

8b. *Khunchni Jaal*

9. Falling gears


9a. *Khepla Jaal*


9b. *Chabi Jaal*

10. Lift nets (3 types)


10a. *Jhatka Jaal*


10b. *Gyanra vessal/Sarail*


10c. *Nouka vessal*

11. Bag nets


11a. *Guri Jaal*


11b. *Chhekuni Jaal*


11c. *Thela Jaal*


11d. *Hatu Jaal*


11e. *Dhebti Jaal*


10f. *Chingri Jaal*, bag type, fixed


10g. *Meen Jaal*, bag type, drag


10h. *Kona Jaal*


10i.*Thor Jaal*


10j. *Beenti Jaal*


10k. *Patan Jaal*


10l. *Sangla Jaal*

12. Drag nets


11a. *Choti Jaal*


11b. *Ber Jaal*


11c. *Chot Jaal*


11e. *Ghaar Jaal*


11d. *Katni/Moi Jaal*

Fig. 43 (1a-11d) Pictorial view of different categories of Fishing gear in entire stretch of river Ganga

Sustainability issues related to net-based fishery

- Replacement of biodegradable cotton twine with non-biodegradable synthetic twine as net material leading to ghost fishing by discarded net material in river water. Also, these discarded nets are causing plastic pollution in the river.
- Operation of zero mesh big-sized shore seine (locally called *Chot jaal/Moshari/ Ber Jaal*) was found prevalent in entire middle and lower stretch of the river catching small size

fish seed of prized fishes causing growth overfishing and ultimately leading to severe depletionof fish stock

- Similarly, Bag net (*Binti Jaal/Thor Jaal*), Set barrier (*Chaurpata Jaal*) and Shooting nets (Meen jaal/Chingri Jaal) are causing huge destruction of fish seed of valuable estuarine fish species such as *Tenualosa ilisha* (Hilsa), *Polynemus paradiseus* (Topse), etc. in estuarine zone.
- Recruitment overfishing was observed in the estuarine mouth when matured hilsa brooders are targeted during their breeding migration.

Fig. 44 Indiscriminate destruction of juvenile fishes by zero-meshed *Chot/Ber Jaal* in freshwater zone

Fig. 45 Destruction of prized fish juveniles by bottom and surface set bag net in estuarine zone

Sustainability issues related to hook and line fishery

- Oil extracted from Gangetic Dolphin (*Platanista gangetica*) locally called *ghorboch* is still in use as a major attractant in bait preparation at the entire Bihar stretch of river Ganga.
- Gangetic River Tortoise (*Nilsonnia gangetica*) is also found to be very susceptible to hook and line fishing. Once theyget hooked, they are sold in local markets at high price instead of releasing back to the river.
- Berried Freshwater Giant Prawn *Macrobraciumrosenbergii* is caught indiscriminately in estuarine stretch using wheat ball during breeding migration causing recruitment overfishing.
- In the face of rising demand, small-sized fishes are also targeted through hook and line; *Eutropiichthys vacha* with ranging from 90to 120 mm are observed to be caught in Bally-

Uttarpara stretch of river Ganga in West Bengal, whereas, the requisite length for attaining maturity for such fishes were reported to be 131 mm to 140 mm.

Sustainability issues related to Fishing trap Fishery in River Ganga

- Bamboo screen of Fishing traps is gradually being replaced with zeromeshed net like *Aanta, Aarsi, Britti, Woka*, etc. which are not allowing larvae or small sized fishes to escape from the Fishing trap. This must be regarded as a matter of great concern relating to sustainable fisheries as fishing traps are mostly operated along the shoreline where density of fish larvae/juveniles is higher during post-spawning period. Replacement of bamboo screen with zero mesh net must be discouraged to sustain the fisheries in river Ganga.

Like other Indian rivers, river Ganga also observed colossal change in qualitative as well as quantitative abundance of available fish species caused by significant changes in flow pattern as well as overall water quality. Abundance of indigenous fish species like Gangetic carp and catfishes are rapidly declining at the cost of exotics. Fishing gears are also being modified accordingly with many original traditional gears are going into oblivion. Many unfriendly fishing gears with huge destruction capability especially gears with zero or small mesh sizes are in use in River Ganga. Those fishing gears like bag net (*Beenti Jaal*), Set barrier (*Chaurpata Jaal*), Shore seine (*Ber/Chat Jaal*), etc should be controlled/banned with suitable alternative livelihood to the dependent fishers.

OBJECTIVE-III

STOCK ASSESSMENT OF SELECTED FISH SPECIES

Fish stock assessment may be described as determination of exploitation level which is necessary for estimation of maximum sustainable yields from the fish resources. The study of stock assessment is necessary to understand the present level of exploitation or the status of exploited stock for maintenance of yield at sustainable level. Inland fisheries are often considered as multispecies multigear fisheries and most of the catches are categorized under small scale fisheries.

Population Characteristics of IMC (*L. rohita, L. catla, C. mrigala*) and *L. calbasu* were analyzed in the present study.

Estimation of growth parameters of *L. rohita, L. catla, C. mrigala* and *L. calbasu*

Important growth parameters viz. Length weight relationship, Asymptotic Length (L_∞), Growth Coefficient (K), Growth performance index (ϕ), Natural mortality (M), Exploitation rate (E), Total mortality (Z), Fishing mortality (F), Recruitment pattern and Yield per recruit *of L. rohita, L. catla, C. mrigala* and *L. calbasu* were analyzed of during the study period.

***Labeo rohita* (Ham, 1822)**

The average total length (min: 48 mm; max: 920 mm) and weight (min: 1.524 g; max: 12000 g) of *L. rohita* was computed to be 404.391 mm (± 272.81). The present study indicated dominant range of size group from 161-220 mm followed by 101-160 mm in the studied river stretch (Fig. 46). Kamboj et al., 2020 has estimated maximum size length of 320 mm from Haridwar stretch of the river. Similarly, Khan et al., 2011 has reported a maximum length of 1600 mm from the Ganga river stretch. Length weight relationship ($W= 0.012 L^{3.14}$, $R^2 = 0.985$) calculated for the species indicated somewhat positive allometric growth pattern from the river. The growth parameter of *L. rohita* such as asymptotic length (L_∞) was found 735 mm and growth coefficient (*K*) was 4.5 during the study. The values of three different mortality rates viz. natural mortality (M), fishing mortality (F) and total mortality (Z) of *L. rohita* was observed as 1.92 $year^{-1}$, 1.48 $year^{-1}$ and 2.37 $year^{-1}$ respectively. Growth performance index (ϕ) was obtained as 6.38 during the present investigation. The level of exploitation (*E*) was found to be 0.43 $year^{-1}$ for *L. rohita* much below the exploited level (E_{opt}= 0.5) as per Gulland (1971). Continuous recruitment pattern was observed all over the year with two major peaks in May (28.98%) and October (18.25%) (Fig. 47). The Y'/R and

B'/R curve (Fig. 48) for different exploitation rates was calculated in the case of *L. rohita* The value of max E were found to be 0.428 year^{-1} while the values obtained for E10 and E50 were 0.35 year^{-1} and 0.27 year^{-1} respectively.

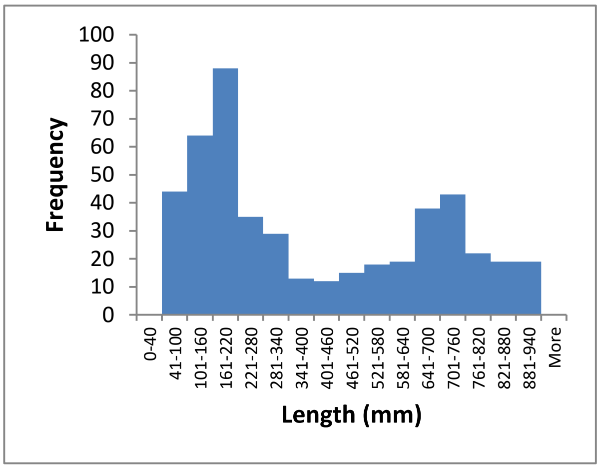


Fig. 46 Length frequency histogram of *L. rohita* obtained from river Ganga

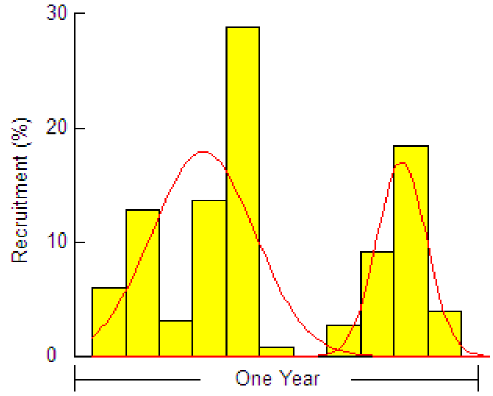


Fig. 47 Annual recruitment pattern of *L. rohita* in river Ganga

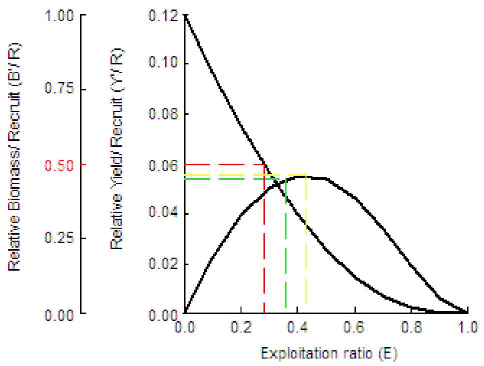


Fig. 48 Relative biomass recruitment of *L. rohita* in river Ganga

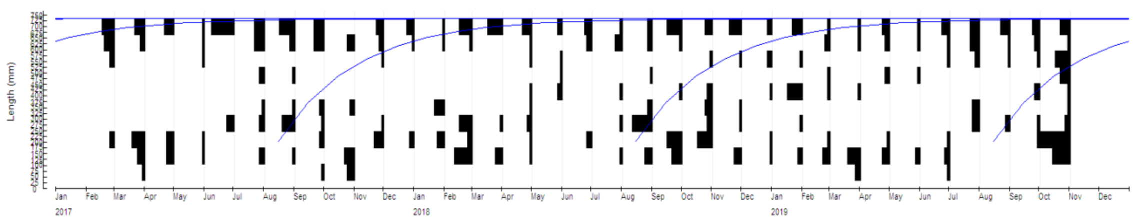


Fig. 49 Growth curve of *Labeo rohita* over three years (2017-19) from river Ganga

***Labeo catla* (Ham, 1822)**

The average total length (min: 118 mm; max: 970 mm) and weight (min: 17.45 g; max: 18000 g) of *L. catla* was computed to be 504 mm (± 259.72). The present study indicated dominant range of size group from 101-200 mm followed by 701-800 mm from the entire river stretch (Fig. 50). Khan et al., 2011 has reported a maximum length of 1450 mm from the Ganga river stretch. The growth parameters like asymptotic length (L_∞) and growth coefficient (K) of *L. catla* were analyzed as 879 mm and 0.96. Mortality rates as natural mortality (M), fishing mortality (F) and total mortality (Z) of *L. catla* was observed as 1.26 year^{-1}, 0.3 year^{-1}and 1.56 year^{-1} respectively. Growth performance index (ϕ) was obtained as 5.87. Length weight relationship (W= 0.011 L $^{3.08}$, R^2 = 0.952) calculated for the species indicated somewhat isometric growth pattern from the river. Continuous recruitment pattern was observed for *L. catla* from river Ganga all over the year with two major peaks in July (20.08%) and August (20.72%) (Fig. 51). The level of exploitation (E) was found to be 0.49 year^{-1} for *L. catla* which was found almost at par with the exploited level (E_{opt}= 0.5) as per Gulland (1971). The Y'/R and B'/R curve (Fig. 52) for different exploitation rates was calculated in the case of *L. catla*. The value of E max were found to be 0.410 year^{-1} while the values obtained for E10 and E50 were 0.305 year^{-1} and 0.267 year^{-1} respectively.

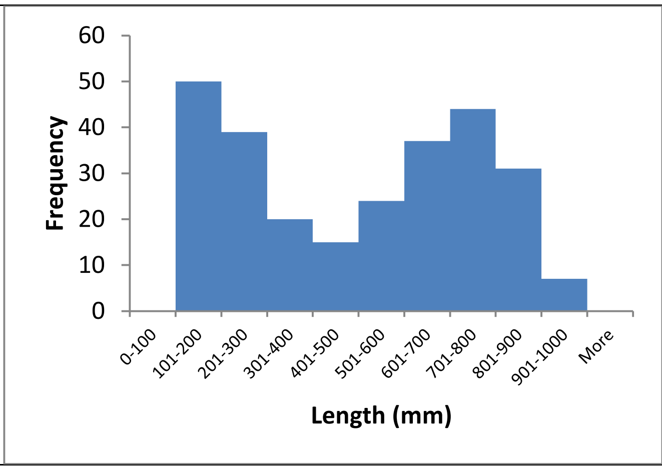


Fig. 50 Length frequency histogram of *L. catla* obtained from river Ganga

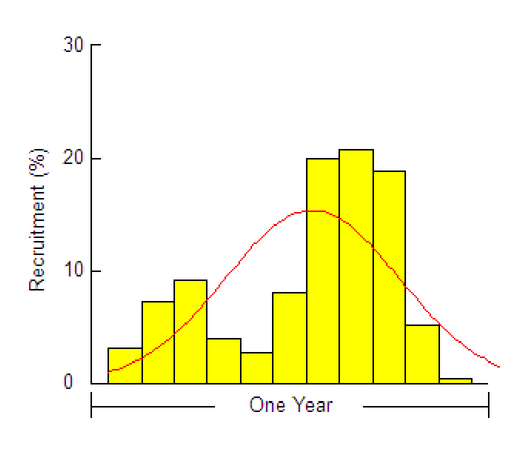


Fig. 51 Annual recruitment pattern of *L. catla* in river Ganga

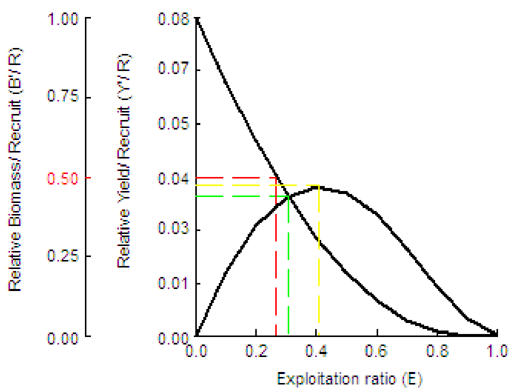


Fig. 52 Relative biomass recruitment of *L. catla* in river Ganga

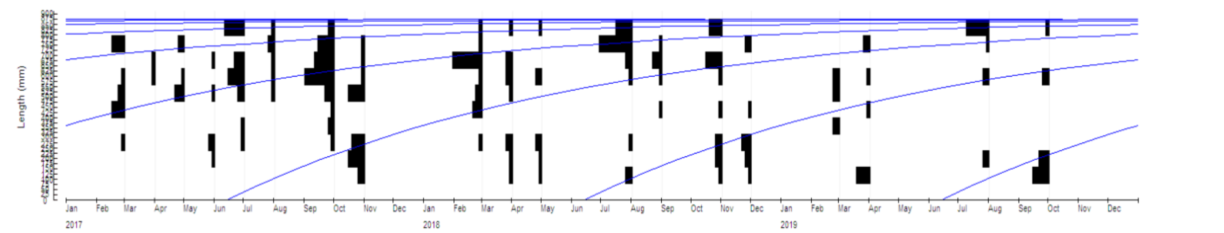


Fig. 53 Growth curve of *Labeo catla* over three years (2017-19) from river Ganga

Cirrhinus mrigala **(Ham, 1822)**

The average total length (min: 42 mm; max: 1000 mm) and weight (min: 3.072 g; max: 1300 g) of *C. mrigala* was computed to be 458.89 mm (± 237.35). The present study indicated dominant range of size group from 401-460 mm followed by 521-580 mm in the studied river stretch (Fig. 54). Jhingran 1959 estimated maximum size of 1016 mm for both pooled sexes from river Ganga at Buxar, Bihar. Similarly, Kamal 1969 described maximum length of *C. mrigala* to be 960 mm from river Yamuna (tributary of Ganga). The growth parameters like asymptotic length (L_∞) and Growth coefficient (K) of *C. mrigala* were estimated to be 987 mm (TL) and 1.5 year^{-1} respectively during the present study. The growth performance index (ϕ) for the species was found to be 6.61 during the present investigation. The annual mortality rates M, F and Z of *C. mrigala* from river Ganga was estimated to be 1.64, 3.35 and 1.71 respectively. The exploitation level (E) was computed to be 0.51 year^{-1}. Length weight relationship (W= 0.001 L $^{3.14}$, R^2 = 0.955) calculated for the species indicated positive allometric growth pattern from the river. Continuous recruitment pattern was observed all over the year with two major peaks in July (12.30%) and August (19.60%) (Fig. 55). The Y'/R and B'/R curve (Fig. 56) for different exploitation rates was calculated in the case of *C. mrigala*. The value of max E were found to be 0.420 year^{-1} while the values obtained for E10 and E50 were 0.35 and 0.27 respectively.

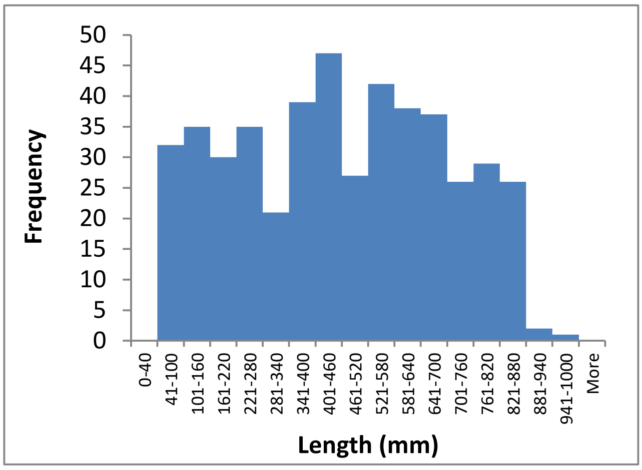


Fig. 54 Length frequency histogram of *C. mrigala* obtained from river Ganga

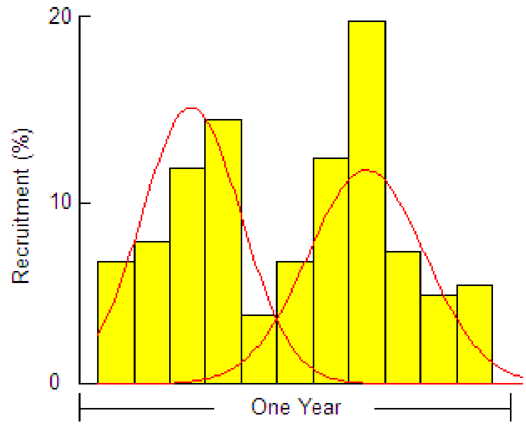


Fig. 55 Annual recruitment pattern of *C. mrigala* in river Ganga

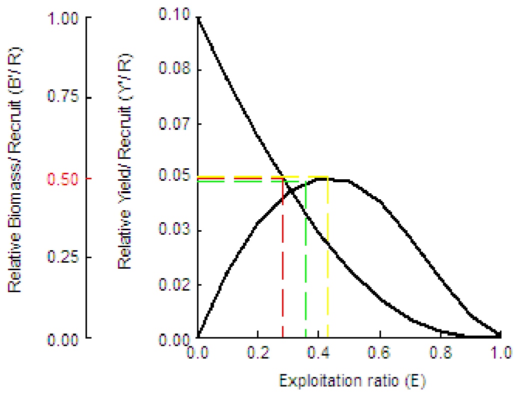


Fig. 56 Relative biomass recruitment of *C. mrigala* in river Ganga

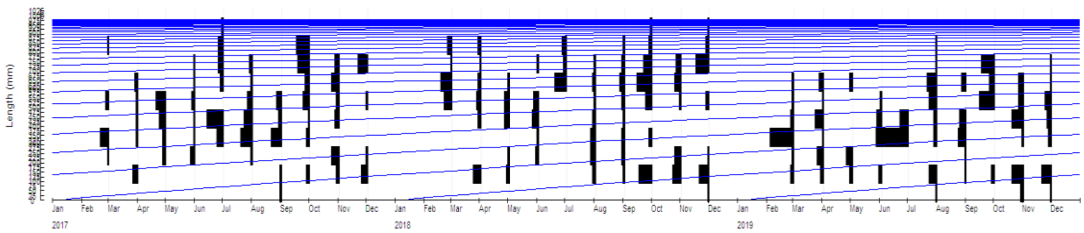


Fig. 57 Growth curve of *C. mrigala* over three years (2017-19) from river Ganga

***Labeo calbasu* (Ham, 1822)**The average total length (min: 40 mm; max: 660 mm) and weight (min: 1.392 g; max: 5000 g;) of *L. calbasu* was computed to be 237.83 mm (± 137.10). The present study indicated dominant range of size group from 101-160 mm in the studied river stretch (Fig 58). Previous published works on *L. calbasu* revealed different size lengths. Gupta and Jhingran 1973 observed maximum size of 725 mm from river Ganga at Prayagraj. Talwar & Jhingran 1991 described maximum length of *L. calbasu* to be 900 mm. Patiyal et al., 2013 have reported maximum length of 755 mm for *L. calbasu* from Allahabad (Prayagraj) stretch of river Ganga. The growth parameters like asymptotic length (L_∞) and Growth coefficient (K) of *L. calbasu* were estimated to be 630 mm (TL) and 0.54 year^{-1} respectively during the present study. The growth performance index (ϕ) for the species was found to be 5.20 during the present investigation. The annual mortality rates M, F and Z of *L. calbasu* from river Ganga was estimated to be 0.50, 1.25 and 1.75 respectively. The exploitation level (E) was computed to be 0.71 year^{-1}. Length weight relationship (W= 0.015 L $^{3.07}$, R^2 = 0.913) calculated for the species indicated somewhat isometric growth pattern from the river. Continuous recruitment pattern was observed all over the year with two major peaks in July (28%) and August (17.54%) (Fig. 59). The Y'/R and B'/R curve for different exploitation rates was calculated in the case of *L. calbasu* (Fig. 60). The value of max E were found to be 0.807 year^{-1} while the values obtained for E10 and E50 were 0.72 and 0.402 respectively.

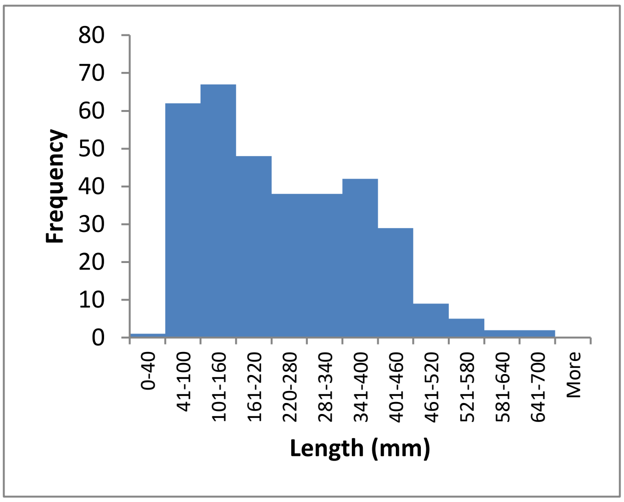


Fig. 58 Length frequency histogram of *L. calbasu* obtained from river Ganga

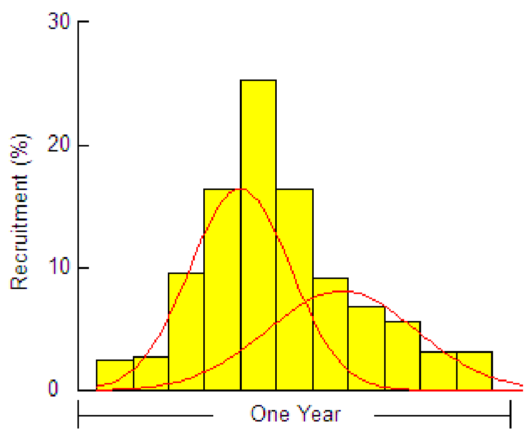


Fig. 59 Annual recruitment pattern of *L. calbasu* in river Ganga

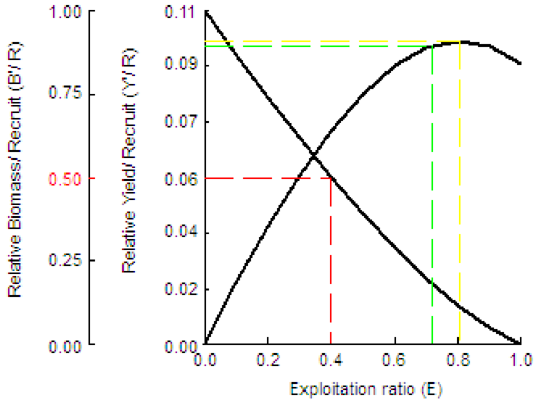


Fig. 60 Relative biomass recruitment of *L. calbasu* in river Ganga

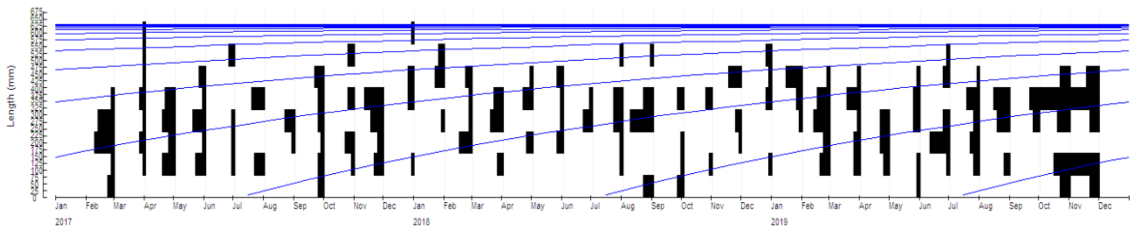


Fig. 61 Growth curve of *Labeo calbasu* over three years (2017-19) from river Ganga

- The present study indicated that *L. rohita* showed positive allometric growth pattern throughout the period. As per Gulland (1971), the level of exploitation (*E*) was found to be much below from the exploited level (E_{opt} = 0.5) though the continuous recruitment pattern was observed with two major peaks in May (28.98%) and October (18.25%) in the study period.
- *L. catla* indicated isometric growth pattern during the study period. Continuous recruitment pattern was observed for *L. catla* from river Ganga with two major peaks in July (20.08%) and August (20.72%). The exploitation rate for the species was observed to be at optimum level from the river.
- *C. mrigala* indicated positive allometric growth pattern during the present study. Continuous recruitment pattern was observed with two major peaks in July (12.30%) and August (19.60%). The exploitation rate suggests that *C.mrigala* was exploited slightly higher than the biological optimum level.
- *L. calbasu* indicated somewhat isometric growth pattern during the study. Continuous recruitment pattern was observed all over the year with two major peaks in July and

August. A much higher exploitation rate of E= 0.71year $^{-1}$ was confronted in case of *L. calbasu* indicating overexploitation of the present stock.

Ganga River is natural abode of Indian Major Carps (*L. rohita, L. catla, C. mrigala*) and *L. calbasu* as well as other native fish species. It is very much evident from the present study that the natural population of Indian Major Carp from the mighty river Ganga is at stake. As the riverine ecosystem is open access to all thus exploitation of natural stock is very difficult to conserve. The continuous overexploitation of the aforementioned species might create a diminishing stock in upcoming years if not assessed and managed sustainably. Indiscriminate fishing of adult brood stock from the river during peak spawning season needs strict monitoring and control measures. If not done, the recruitment process of the major carps may affect the overall population. So river ranching is necessary for the recruitment and build up the stock of the river.

IMCs Landing at Prayagraj (2016-2019)

The total Indian Major Carp (IMC) landing from Prayagraj stretch of the Ganga River System during July 2016 to October 2019 has been estimated as mentioned in the Fig. 62 & 63. During 2016, the total IMCs landing in the Ganga River was estimated to be 22.47tonnes. The contribution of *C. mrigala* in total landing is higher (8.48 tonnes) in comparison to other IMC's estimated landings (*Labeo catla* 7.41 tonnes), (*L. rohita* 5.68 tonnes) and (*L. calbasu* 0.9 tonnes) , on the other hand, the total IMCs landing was 21.26 tonnes during 2017. The *C. mrigala* landing is higher (9.8) ton followed by *Labeo catla* (5.54), *L. rohita* (4.05), and *L. calbasu* (1.87) ton. In 2018 total landing (13.45) ton among which the *C. mrigala* contribution is higher (6.01) ton in comparison to other IMC'S, *Labeo catla* (3.85), *L. rohita* (2.34) and *L. calbasu* (1.25) ton were observed. During 2019the total IMC'S landing (18.12) ton in which *Labeo catla* landing is higher (7.08) ton followed by *C. mrigala* (6.62), *L. rohita* (2.72), and the *L. calbasu* (1.7) ton were recorded. The average landing of IMC'S during (July 2016-October 2019) 18.83 ton were recorded among which the contribution of the *C. mrigala* contribution is higher (7.73) ton in comparison to other IMC'S, *Labeo catla* (5.97), *L. rohita* (3.69) and *L. calbasu* (1.43) ton were observed. Mean percentage contribution of IMCs at Prayagraj station during 2016-2019 is shown in Fig. 64. And the year-wise IMCs landing in tonnesduring 2016-2019 at Prayagraj station is mentioned in Table 18.

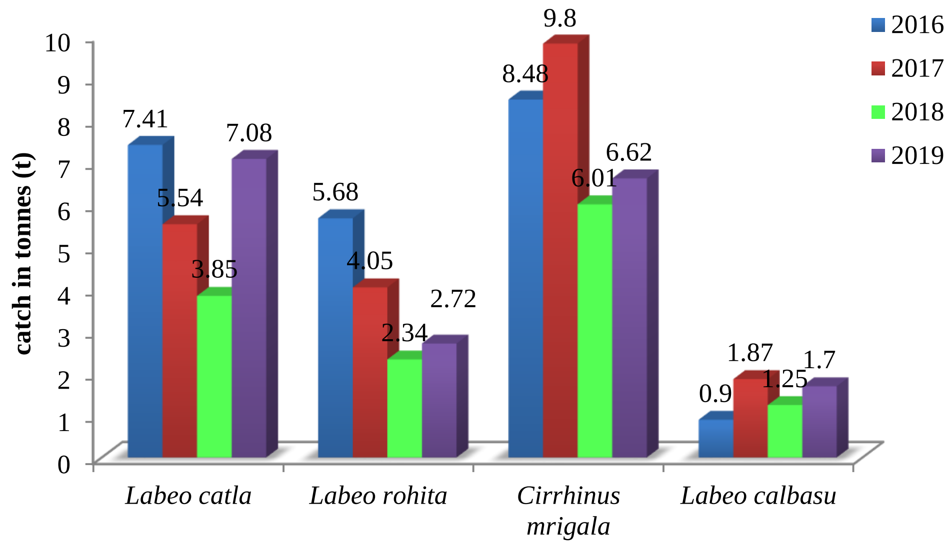


Fig. 62 Year wise (2016-2019) IMCs landings at Prayagraj

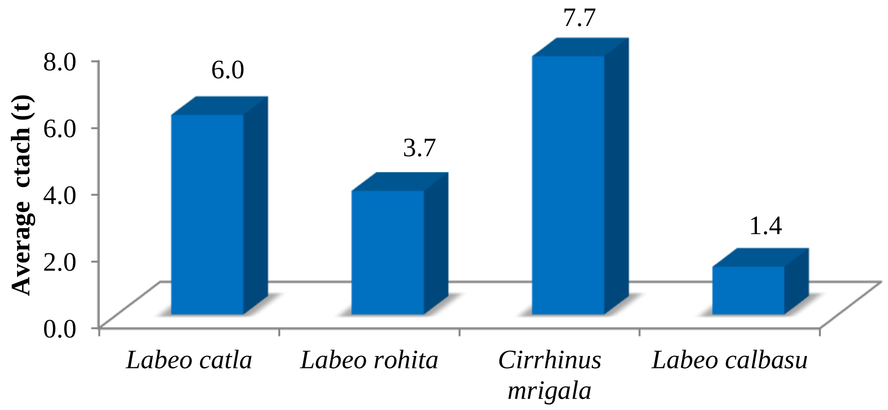


Fig.63 IMCs landings at Prayagraj during 2016-2019

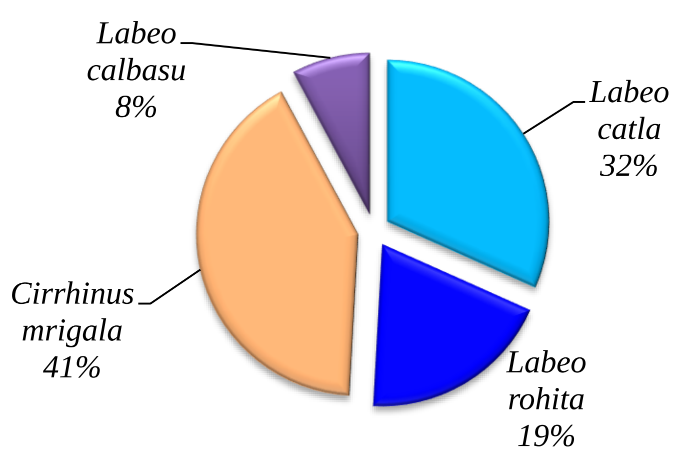


Fig. 64 Mean percentage contribution of IMCs at Prayagraj during 2016-2019

Table 18. Species-wise IMC landing at Prayagraj (2016-2019)

Species Name	2016		2017		2018		2019		(2016-2019)	
	t	%	t	%	t	%	t	%	t	%
Labeo catla	7.41	32.98	5.54	26.05	3.85	28.63	7.08	39.06	5.97	31.68
Labeo rohita	5.68	25.28	4.05	19.05	2.34	17.40	2.72	15.02	3.69	19.19
Labeo calbasu	0.9	04.01	1.87	08.80	1.25	09.29	1.7	09.38	1.1875	07.87
Cirrhinus mrigala	8.48	37.74	9.8	46.10	6.01	44.68	6.62	36.54	7.7275	41.26

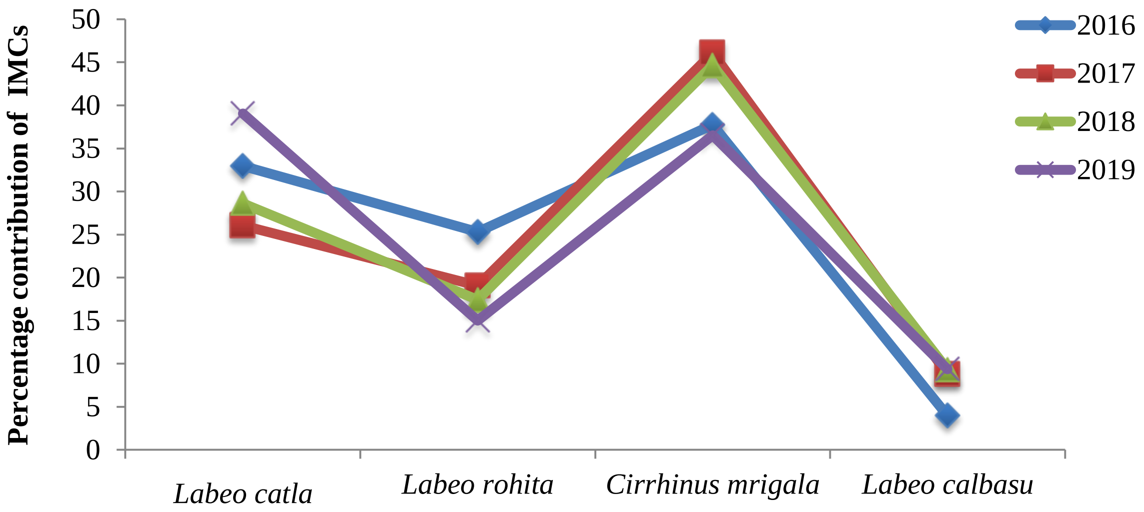


Fig. 65 Yearly percentage contribution of IMCs at Prayagraj during 2016-2019

Length and weight of the IMC'S of the river Ganga at Prayagraj

During the study period length and weight of *Labeo catla*, *Labeo rohita*, *Cirrhinus mrigala*, and *Labeo calbasu* were recorded during the 2016-2019 at Prayagraj landing centers. The length and weight **(**mean±SE) are given below in Table 19.

Table 19. Length and weight of the IMC'S of the river Ganga at Prayagraj

IMC'S	Parameters	No. of species	Min	Max	Mean ± SE
Labeo catla	Length (mm)	321	80	1010	685.56±38.26
	Weight (g)		56	24000	7848.79±458.07
Labeo rohita	Length (mm)	349	75	945	591.587±11.60
	Weight (g)		4	90200	4811.93±304.67
Cirrhinus mrigala	Length (mm)	905	65	1000	589.18±5.79
	Weight (g)		6	13500	3367.13±82.86
Labeo calbasu	Length (mm)		80	855	367.27±6.09
	Weight (g)	377	22	8200	1162.36±64.82

Mahseer landing at Tehri Lake

Landing data were collected from two landing centres of Tehri Lake namely Dobrachatti and Tiprifrom May 2018 to April 2019. Catch data revealed that catch comprisedof mainly two species i.e., *Tor putitora* and *Cyprinus carpio*. Landing data shows that average percentage composition of Golden mahseer is higher (69.40%) as compare to common carp (30.59%). Total catch from the landing centre depicted in Fig 66.

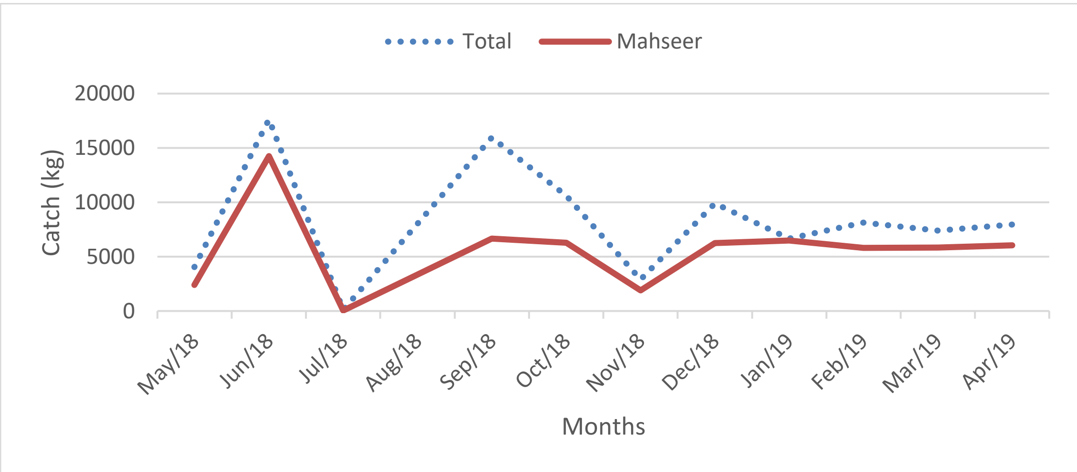


Fig. 66 Landing of Golden Mahseer at Tehri Lake

OBJECTIVE–IV

IDENTIFICATION OF MIGRATORY FISHES AND RANGE OF MIGRATION THROUGH TAGGING (NORMAL/SATELLITE) IN THE ENTIRE STRETCH OF RIVER GANGA

Migratory fish species of river Ganga were identified and enlisted during the present study (table 20) whereas, the range of migration trough tagging wasn't performed due some issues at Farakka Barrage. Identification of migration route of migratory fish species will be continued in NMCG Phase II titled ***"Fish Stock Enhancement Including Hilsa and Livelihood Improvement for Sustainable Fisheries and Conservation in River Ganga" under the "Namami Gange" Programme".*** However, Indian Major Carps were tagged and released in river Ganga for studying the migration behaviour and movements of the fish.

Table 20. Migratory Fishes of Ganga River

Species	Type of migration	Stretch of occurrence	Suitable Habitat	Threats	Actions required
Hilsa shad (*Tenualosa ilisha*) IUCN Red list: Least concerned	Anadromous (Sea to river)	Lower to Estuarine area (Farakka to Fraserganj)	• Breeding migration influenced by monsoon floods • Prefers depths from 1.8 to 18.3 m (Chondar, 1999) • Plankton requirement for feeding • Salinity range: 0.04-28.18 ppt • pH range: 8.16-8.18 • DO range: 6.02-7.23 mg/l • W. temp. range- 26.2-28.5°C	• Use of gill nets (< 90 mm) • Rampant use of mosquito net and bag net • Dams hindering migration • Natural threats such as delayed monsoon	• Reduce fishing pressure during breeding months • Reduce catches of juveniles • Protect spawning & nursery areas • Establishment of dialogues among Govt. authorities

Golden Mahaseer (*Tor putitora*) IUCN Red list: Near Threatened	Potamodromous (Within river)	Upper stretch (Tehri to Haridwar)	• Available at the height of 750-1300 m • Prefers slow current & deep pools (w. temp- 14-22˚C & D.O- 5.2-12.9 mg/l) • Rocky bottom chocked with algae	• Indiscriminate fishing of brooders and juveniles • Construction of Dams and Barrages hindering migration & habitat degradation • Boulder mining. Poaching etc.,	• Conservation planning by dam engineers, environmentalist etc. • Strict regulation on hunting and illegal poaching • Bridge between locals, govt. officials & scientist
Snow trout (*Schizothorax richardsonii*) IUCN Red list: Vulnerable	Potamodromous (Within river)	Upper stretch (Harsil to Tehri)	• Prefers snow fed hill streams with temperature 8-22˚C • Prefers clear water with flow 2.5-4.0 m/s & DO 8-10 mg/l	• Construction of Dams and Barrages hindering migration & habitat degradation • Mine fishing and illegal poaching	• Conservation planning by dam engineers, environmentalist etc. • Strict regulation on hunting and illegal poaching • Bridge between locals, govt. officials & scientist
Clown knifefish (*Chitala chitala*) IUCN Red list: Near Threatened	Potamodromous (Within river)	Upper to Lower stretch (Haridwar to Balagarh)	• They generally inhabit well oxygenated riverine water • It can withstand a wide range of water temperature (6–44℃) and can tolerate dH 5–19, pH 6–8.	• Rare availability due to due to over exploitation, habitat degradation, pollution, and related anthropogenic pressure ontheir natural habitats Rampant use of mosquito net and bag net	• Identification & protection of breeding ground in Ganga • Studies on riverine recruitments and reduced fishing pressure
Freshwater shark (*Wallago attu*) IUCN Red list: Vulnerable	Potamodromous (Within river)	Upper to Lower stretch (Haridwar to Balagarh)	• Prefers sluggish water and bottom part of river	• Loss of habitat and degradation of spawning ground	• Identification & protection of breeding ground in Ganga

			• Can tolerate wide range of temperature (range: 14.0-36.6 ° C) and low DO in Ganga	• Juvenile catching using mosquito nets	• Studies on riverine recruitments and reduced fishing pressure
PangusiaLabeo (*Labeo pangusia*) IUCN Red list: Near Threatened	Potamodromous (Within river)	Upper stretch (Haridwar to Bijnor)	• Prefers active water current (range: 0.66-0.68 m/s) and DO (range: 7.82-8.39 mg/l) • Feeds on algae and diatoms for sustenence	• Rampant fishing of brooders and juveniles as it is a excellent food fish • Construction of Dams and Barrages thus creating destruction of habitat	• Control of heavy fishing pressure in upstream of river
Pabdah catfish (*Ompok pabdah*) IUCN Red list: Near Threatened	Potamodromous (Within river)	Upper to Lower stretch (Bijnor to Farakka)	• Adults are found in quiet, shallow (0.5-1.5 m), often muddy water, in sandy streams	• Destruction of breeding and spawning grounds • Fishing of brooders and juveniles as it is a excellent food fish	• Control pollution load in breeding and spawning ground
Bombay Duck (*Harpadon nehereus*) IUCN Red list: Vulnerable	Oceanodromous (Within ocean)	Esturaine stretch (Diamond Harbour to Fraserganj)	• Moves in shoals at congregates near river mouth in monsoons • Prefers salinity range from 3.29 ppt - 28.18 ppt and pH range of 8.11-8.16 in river Ganga • Prefers turbidty range of 132.92-113 ntu	• Rampant use of bag net targeting juveniles of 50-98 mm • Delayed monsoon	• Reduce fishing pressure during June-July months • Reduce catches of juveniles

Paradise threadfin (*Polynemus paradiseus*) IUCN Red list: Least Concern	Amphidromous (Migrates both sea and freshwater)	Lower stretch (Godakhali to Fraserganj)	• Prefers salinity range from 0.23 ppt - 28.4 ppt and pH range of 8.15-8.35 in river Ganga • Lives over sandy bottoms, regularly entering freshwaters during breeding season. Feeds mainly on crustaceans (especially shrimps), small fishes and benthic organisms.	• Use of gill nets (< 30 mm) • Rampant use of surface bag net targeting juveniles of 10-50 mm • Natural threats such as delayed monsoon	• Reduce fishing pressure during April-July months • Reduce catches of juveniles
Giant freshwater prawn (*Macrobrachium rosenbergii*) IUCN Red list: Least Concern	Migrates from freshwater to estuarine waters during breeding season	Entire lower middle and upper stretches of Ganga River System	• Euryhaline species • Prefer salinity 12-16 ppt during larval development and pH of 7.0 to 8.5	• Rampant use of bag net, drag nets targeting juveniles. • Use of hook and line targeting giant freshwater prawn above 100 mm	• Control of indiscriminate fishing during May-October months during breeding migration • Reduce catches of juveniles in estuaries and sea mouth
Monsoon freshwater river prawn (*Macrobrachium malcolmsonii*) IUCN Red list: Least Concern	Migrates from freshwater to estuarine waters during breeding season	Entire lower middle and upper stretches of Ganga River System	• Euryhaline species • Prefer salinity 15-18 ppt during larval development. • pH of 6.0 to 8.0 and temperatur	• Rampant use of bag net, drag nets targeting juveniles. • Use of hook and line targeting giant freshwater prawn above 100 mm	• Control of indiscriminate fishing during May-October months during breeding migration • Reduce mass catches of

			e : 28˚ C	• Use of agricultural insecticides for mass catch.	juveniles in freshwater and estuaries using nets and chemicals
Indian longfin eel (*Anguilla bengalensis*) IUCN Red list: Near Threatened	catadromous Available in freshwater and brackishwater section	Recorded only from Bijnor (Uttar Pradesh) during the present study	• salinity ranged from 0.01 to 0.03 psu	• pollution, Habitat degradation, overfishing, fishing pressure from hook and line catching	• Fish passes should be designed into dam and weir constructions. • Population trends, threats, harvest levels management should be implemented
Gangetic mud eel (*Ophichthys cuchia*) IUCN Red list: Least concern	Available in freshwater and brackish water reaches of river Ganga	Found in lower middle and upper Hooghly estuary	• Prefers shallow water with mud holes to survive.	• Use of agricultural insecticides in few areas of lower and upper tidal river	• Control habitat loss of muddy bottom environments along river Ganga.

❖ *Scope of Tagging*

Fish tagging is a very old tool to study different scientific assessment and also stock management of fishes since more than hundred years. The purpose of the tagging is to study the migration and growth pattern of the species, population status in a particular area and fish catch . To re-establish the IMCs population in the river Ganga through ex-situ conservation, it is very essential to know thefish population status, migration pathway, breeding grounds, stock status, etc. Tagging of the fishes may be one of the best tools to study the migratory behavior of fishes.

❖ *Tagging procedure*

Tag may be fixed in different body parts of the fish like body-cavity, inter-dorsal muscle, inter-pelvic muscle, etc. The Floy T-bar anchor tags of standard size with printed serial numbers were inserted in dorsal muscle just below the dorsal fin. During tagging, the fish was held in a flat surface to clearly expose the area of tagging. The needle fitted with the tagging gun placed under the scale and inserted within half inch inside the muscle with a 45° angle and the gun was pressed to fix the tag in muscle.

❖ ***Activity***

The ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata tagged 100 numbers of Indian Major Carps and released in river Ganga for studying the migration behaviour and movements of the fish. Dr. Basanta Kumar Das, Director, ICAR-CIFRI and Principal Investigator, ICAR-CIFRI-NMCG Project highlighted the importance of tagging process and sensitized the local fisherman about the purpose in tagging. As a part of the ranching programme, the institute initiated the tagging of fishes for monitoring and developing proper sustainable management of exploited IMC fish stock in the Ganga River System. During the process of tagging, the adult fish weigh more than 500g body weight of Indian Major Carp (*Labeo rohita, Labeo catla* and *Cirrhnus mrigala*) popularly known as Rohu, Catla and Mrigal were tagged and released in the river Ganga. The tagged fishes were released into the river for identifying the fundamentals of migration range. The fishes used in tagging were those bred by ICAR-CIFRI, Barrackpore using native fish species of river Ganga.

	
Fig. 67a Tagging of fish	Fig. 67b Tagging gun
Fig. 67 a-b Tagging of IMC for migration study	

OBJECTIVE–V

ASSESSMENT OF REQUIREMENT OF KEY HABITAT VARIABLES IN RELATION TO FISH DISTRIBUTION AND VARIOUS BIOLOGICAL ACTIVITIES OF THE FISHES

WATER AND SEDIMENT QUALITY STATUS OF RIVER GANGA

The river receives high amount of water (142.6 million m^3) that mainly comes from tributaries originates at Gangotri glacier, along withthe monsoon rain,watercoming through surface run-off from catchment areas. During the past few decades, water and sediment quality of the mighty river Ganges have been degraded considerably with increased urbanisation and industrialisation along the banks of river Ganges. Increased anthropogenic activities with industrial and agricultural effluents, discharge from domestic wastes aggravated the situation when significant amount of river water was already being abstracted / diverted by construction of number of dams and barrages along the main channel as well as on almost all the tributaries especially during non-monsoon months. Change in aquatic ecosystem health has its impact on diversity and distribution of all the aquatic communities. Monitoring of aquatic health can help to identify the river stretch to be prioritised for management intervention. So, to take the appropriate action for the development of suitable conservation and restoration plan, sampling was performed to understand regular changes which was taking place in water and sediment quality of the river.

Water and sediment samples were collected during quarterly samplings round the year i.e., winter, pre-monsoon, monsoon and post-monsoon. The water quality parameters can be categorized under five broad heads as given below (Table 21).

Table 21. Different Physico-chemical parameters of River Ganga

Physical parameters	Chemical parameters	Nutrient parameters	Pollution indicating parameters	Productivity parameters
Water temperature	pH	Phosphorus	Biochemical Oxygen Demand	Chlorophyll a
Depth	Dissolved Oxygen	Nitrogen	Chloride	Total Chlorophyll
Flow	Alkalinity	Silicate	Specific conductivity	Gross Primary Productivity
Transparency	Calcium		Free CO_2	Net Primary Productivity

Turbidity	Magnesium			Community Respiration
	Total hardness			
	Total solid			
	Total dissolved solid			

Similarly, soil samples were analyzed for pH, organic carbon (%), available Nitrogen, available Phosphorus, soil free $CaCO_3$ and percentages of sand, silt and clay.

Methodology for Analysis

Water

Water sample collection

Water sampleswere collected early morning in triplicates for the laboratory analysis. For TS, TDS, TSS and hardness sterile water bottles were used and samples were immediately preserved at 4°C. For NO_2-N, NO_3-N and NH_4-N 2ml/litre of concentrated H_2SO_4 was used as preservative. For the chlorophyll analysis in-situ filtration was done with the help of Magnesium sulphate and residue were immediately transferred to ice box for laboratory analysis. For Available -P and Total-P the samples were taken in containers which were pre washed with phosphate free detergents and were immediately kept at 4°C for laboratory analysis.

In-situ Analysis

In situ analysis of water samples were done with the help advanced Multi parameter probes of YSI multiparameter probe and Aquaread probe (model AP-7000) In which parameters such as Temperature, Dissolved Oxygen, TDS, pH, Salinity, NH_3, NH_4, ORP, Turbidity, Dissolved Oxygen Saturation, Chlorophyll,Values were analysed.

In-situanalysis of chemical parameters

Parameters such as free CO_2,biochemicaloxygen demand, alkalinity, total hardness, calcium hardness, magnesium hardness, chlorinity were analysed.

Free CO_2

Free ***CO_2***was estimatedby titrimetric method with the help of Phenolphthalein indicator having end point pH 8.3. During analysis 50 ml of sample was taken and titrated with the help of N/44 NaOH solution using Phenolphthalein indicator. And was calculated by using the formula: -

Free CO_2 (ppm) = $\frac{\text{ml of N/44 NaOH required} \times 1000}{\text{ml of sample taken}}$

Biochemical Oxygen Demand

Biochemical oxygen demand was calculated using 300 ml B.O.D glass bottles. During the analysis the initial dissolved oxygen was measured by using Wrinkler method and then final D.O value was calculated after 5 Days of sample incubation at 20 ° C. Then the difference was calculated.

Calculation: BOD (mg/l) = Initial DO - Final DO after 5 days

Alkalinity (Hydroxide +Carbonate+ Bicarbonate)

Alkalinity was calculated by titrimetric method using Phenolphthalein and Bromocresol green-Methyl indicators. For Hydroxide and Carbonate alkalinity100 ml of sample was taken and PHTH indicator was used in case pink colour appeared the sample was titrated with the help of N/50 sulphuric acid till the colourless point is observed. For Bicarbonate alkalinity BCG mixed indicator was used, if sample turned Blue green using the indicator then the sample was titrated with the help of N/50 sulphuric acid till the red coloration end point is observed.

Calculation

Phenolphthalein alkalinity (ppm) = $\frac{\text{ml of 0.02N H2SO4 used in PHTH indicator} \times 1000}{\text{ml of sample}}$

Total alkalinity (ppm) = $\frac{\text{ml of 0.02N H2SO4 used in PHTH and BCG mixed indicator} \times 1000}{\text{ml of sample}}$

Total Hardness

Total Hardness was calculated by titrimetric method using Eriochrome Black-T indicator and sample was titrated with the help of ethylene diamine tetra acetic acid disodium salt(0.01M). For the analysis Ammonia buffer was used to bring the pH of the sample to 10 ± 0.1. During the analysis 50 ml of water sample was taken, 1 ml of Ammonium buffer was added to it. And sample was titrated until the end point is observed (Magenta to Blue).

Calculation

Total Hardness as $CaCO_3$ mg/ l= $\frac{\text{ml of EDTA titrant} \times 1000}{\text{ml sample taken for titration}}$

Calcium Hardness

Titrimetric method was used for calculation of Calcium Hardness using murexide (ammonium purpurate) indicator and sample was titrated with the help of 0.01 M EDTA solution. For the analysis 25 ml water sample was taken in which 1 ml in which pinch of murexide was added and titrated with the help of 0.01 EDTA until the end point is observed i.e. pink to magenta.

Calculation

$$Calcium\ (mg/l) = \frac{Titration\ reading\ \times 400.8}{sample\ volume\ (ml)}$$

Magnesium Hardness

Magnesium hardness was calculated using the data collected for Total Hardness and Calcium Hardness with the formula.

Magnesium (mg/l) = [Total hardness (mg/l) - Calcium (as mg/l CaCO3)] x 0.243

Chlorinity

Chloride was calculated by "**Argentometric method**" using Potassium chromate indicator and sample was titrated with the help of Silver nitrate solution (0.0141N). For the analysis 50 ml of sample was taken and in that 2-4 drops of Potassium chromate were added and titrated with the help of 0.0141 N Silver nitrate solution until end point is observed (yellow to brick red).

Calculation

$$\text{Chloride (mg/L)} = \frac{(\text{ml of titrant used for sample} - \text{ml of titrant for blank}) \times 0.0141 \times 35.46 \times 1000}{\text{ml of sample}}$$

Laboratory Analysis of water samples

Nutrient parameters

Nutrient parameters such as Nitrite Nitrogen, Nitrate Nitrogen, Total Nitrogen, Total-P

Nitrite Nitrogen (NO_2-N)

The analysis of Nitrite Nitrogen was done with the help of Azo dye and sulphanilamide solution. For the analysis sample was filtered with the help of Whatman filter paper of 45 µm pore size. Then on the 50ml of filtered sample 1 ml of sulphanilamide solution was added and was allowed to mix for 2-10 minutes. After 2-10 minutes of reaction, 1 ml of NNED *(*N-(l-naphthyl)- ethylene diamine dihydrochloride solution) was added. After addition of NNED sample was left for 10 minutes and, after 10 minutes absorbance reading was calculated at 543 nm. And the concentration of Nitrite Nitrogen was calculated with the help of standard calibration curve.

Nitrate Nitrogen (NO_3-N)

Nitrate Nitrogen was calculated by using "Phenol disulphonic acid method". In which phenol disulphonic acid, 10% Aluminium sulphate and 12 N NaOH were used. For the analysis 20 ml of water sample was evaporated in water bath, and on evaporated sample 2ml of phenol disulphonic acid was added drop by drop and rubbed with the help of glass rod. Sample was left for 5 minutes to react. After 5 minutes 2ml of aluminium sulphate solution was added. Then 12 N NaOH solution was added slowly and stirred until it gets alkaline. In case Yellow color appears, which signify presence of NO3-N, Aluminium hydroxide is removed by filtration and absorbance was measured at 410 nm in UV spectrophotometer. And concentration was calculated with the help of standard absorbance curve.

Total Nitrogen

Total nitrogen was calculated with the help of sodium hydroxide (NaOH), Devarda's Alloy and Nessler solution. For the analysis 200 ml of distilled water was taken in Kjeldahl flux and warmed. In the warmed sample 2 pellets of NaOH and little dust of Devarda's Alloy along with 50 ml of water sample was added to it. After addition of water sample the distillation assembly was added and 30 ml of was collected at receiver and was volume was made up to 50 ml with the help of distilled water. In the sample 10 drops of Nessler solution was added to it, and absorbance was observed at 410 nm in spectrophotometer. And concentration was calculated with the help of standard calibration curve.

Available phosphorous

For the analysis all the glassware's were pre-washed with phosphate free detergent. And following reagents were prepared.

1. Potassium antimony tartarate solution. (0.2743g PAT+ 100ml distilled water)
2. 4 % Ammonium molybdate
3. 5 N Sulphuric acid
4. Ascorbic acid solution. (0.528g Ascorbic acid+ 30ml water)
5. Colour developing reagent (50ml (5N) H_2SO_4 +5 ml PAT solution+ 15 ml 4% Ammonium molybdate solution + 30 ml freshly prepared ascorbic acid solution)

Prior to analysis 25 ml of water sample was filtered using Whatman 1 filter paper, in the sample 4 ml of colour developing agent was added and absorbance was observed at 880 nm using spectrophotometer.

Total-phosphorous

For the analysis of Total-P, 50 ml of water sample was reduced to 20-25 ml in sand bath, on reduced sample 2 ml of perchloric acid was added. After addition of acid sample was evaporated on hot plate up to of 5-10 ml of volume. In the solution little amount of distilled water was added and 1 N NaOH was added to neutralize the solution with the help of phenolphthalein indicator. The volume was made up to 50 ml with the help of distilled water. Then the sample was analysed by using Ascorbic acid method i.e. as that of Available phosphorous.

Available Silicate

For the analysis of Available silicate following reagents were prepared.: -

1. Oxalic acid solution (5g oxalic acid+ 50 ml distilled water).
2. 6N Hydro chloric acid.
3. 10 % Ammonium molybdate

   In 25ml of filtered water 1 ml of 6N Hcl solution and 1 ml of 10 % ammonium molybdate was mixed and left to react for 5 minutes. After 5 minutes 0.5 ml of oxalic acid solution was added. After 2 minutes absorbance of the sample was observed at 410 nm. And concentration was determined with the help of standard curve.

SEDIMENT

Sample collection: Sediment samples were collected with the help of Van veen grab. And was air dried.

1. Physical parameters

Soil Texture (Hydrometer method)

100 g of air-dried soil was taken in a 500 ml conical flask in which 0.5 N sodium oxalate and 200 ml distilled water was added to it and shacked for 1 hour in a mechanical shaker. The sample was transferred to 1000 ml of cylinder and volume was made up to 1000 ml with the help of distilled water. The hydrometer is dipped in the cylinder after 5 minutes and percentage of clay+ silt was determined similarly clay % was noted after 2 hours. Sand is obtained by deducting percentage of clay+ salt from 100. Likewise, percentage of silt is obtained from clay+ silt %.

2. Chemical Parameters

Soil pH

20g of sample was mixed in 50ml of distilled water and stirred for 30 minutes with glass rod. And reading was taken with the help of pH electrode.

Soil Conductivity

20g of sample was mixed in 50ml of distilled water and stirred for 30 minutes with glass rod. And reading was taken with the help of conductivity electrode.

Soil Organic carbon (Walkley-Black method)

For the analysis 1 g of soil sample was taken in 500 ml of conical flask in which 10 ml of 1 N $K_2Cr_2O_7$ solution was added. Then 20 ml of conc. H_2SO_4 was added to it and was kept inside cupboard. Then 200 ml of distilled water was added. And after that 10 ml of conc. H_3PO_4 and 1 ml diphenylamine indicator was added to it. Then the sample was titrated with the help of ferroin indicator using N/4 Mohr's solution until the end point is observed.

Calculation

$$\text{Organic carbon (\%)} = \frac{\text{Volume of dichromate (mL)} \times \text{Strengthof dichromate} \times (\text{Blank} - \text{sample reading}) \times 0.3}{\text{Blank reading (mL)} \times \text{Sample weight (g)}}$$

Available phosphorus (P)

In 1g of dried soil sample 200 ml of 0.002N H_2SO_4 (pH-3), was added and mixture was shaked for 30 minutes in a mechanical shaker and was left for 10 minutes and filtered with Whatman 42 filter paper. Then 50 ml of sample was collected and 4 ml of the colour developing reagent was added. After 10 minutes, absorbance was measured at 880 nm using UV spectrophotometer.

Calculation

Available-P mg/100g=quantity of P obtained from X-axis (mg/L) against a sample reading x volume of extracting reagent (L) x 100/ weight of sediment (g)

Soil available N

For analysis 10 g soil sample was taken in a 500 ml Kjeldahl flask in which 100 ml of 0.32% $KMnO_4$ solution, 100 ml of 2.5% NaOH, 2 ml of liquid paraffin and some glass beads was added. Then mixture was Distiledthe and collected the distillate in a conical flask containing 20 ml of 0.02N H_2SO_4 and added few drops of methyl red indicator. Collected about 75-80 ml of distillate. The excess of 0.02N H_2SO_4 was titrate with 0.02N NaOH to a colourless end point for methyl red indicator.

Calculation

Available nitrogen (mg/100 g soil) = [20 – (No. of ml of 0.02 N NaOH)] x 2.8

Free Calcium carbonate

5 g soil sample was taken in a 250 ml bottle. 100 ml 1N HCl was added and shaken for one hour. Allow to settle the suspension and pipette out 20 ml of the clear liquid in a conical

flask. Titration was done with 1N NaOH using Bromothymol blue indicator till it just turns blue (yellow to blue). A blank was carriedout in the same way without taking soil.

Calculation

% $CaCO_3$ = (Titre for blank - Titre for soil solution) x 5

Results

Water temperature (°C)

Average water temperature in the entire stretch of river Ganga varied from 7.22°C to 29.52°C (Fig. 68) During the entire sampling, the lowest water temperature (3.21°C) was observed at Harshil, While the highest temperature of 36.6°C was observed at Buxar-Baliya Stretch of river Ganga. During winter season, the average temperature across entire stretch was 21.04°C, while higher water temperature of 26°C was observed at Tribeni stretch of West Bengal which may be possibly due to thermal discharge from the BTPS thermal power plant which significantly influences the water temperature of the river. During the pre-monsoon season, the average water temperature was found at 27.45°C. The average temperature during the monsoon was found 28.9°C whereas in post monsoon it was found at 24.71 °C.

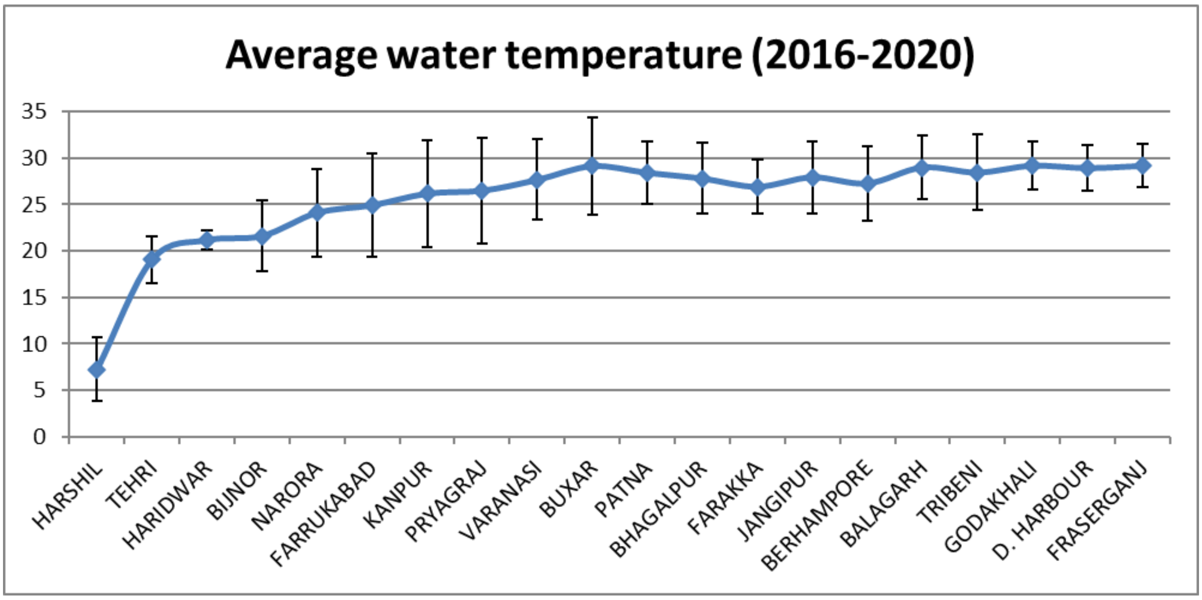


Fig. 68 Average water temperature (°C) in the entire stretch of river Ganga

Comparison with previous reported water temperature data from different stations revealed significantly higher water temperature at Haridwar. Reduced water level and flow in the changed regime of several obstructions in the river might be the reason for higher water temperature at Haridwar. Earlier Das et al. also reported shifting of availability of *Glossogobius giuris* towards higher altitude beyond Haridwar as an impact of higher water temperature regime in river Ganga. Varanasi-Buxar stretch of the river observed relatively higher average water temperature which might be due to higher ionic concentration (TDS) in this part of the river. Higher temperature regime at lower estuarine zone of Godakhali – Fraserganj may also be linked with significantly higher TDS caused by mixing of sea water. The changing pattern of water temperature of river Ganga is presented in Table 22.

Table 22. Changing Pattern of water temperature of river Ganga (Vass et al., 2008; CIFRI bulletin no. 154)

Sampling station	Period	Temperature (°C)	Sampling station	Period	Temperature (°C)
Haridwar	1984-85	11.25-19.75	Buxar	1960	18.0-31.0
	1995-96	12.5-26.0		1995-96	19.0-33.0
	2016-20	15.95-28.2		2016-20	13.13-31.3
Kanpur	1960	16.0-30.5	Patna	1960	18.5-31.0
	1995-96	16.0-30.0		1995-96	19.5-31.0
	2016-20	15.6-31.15		2016-20	16.2-32.3
Prayagraj	1960	17.5-31.5	Bhagalpur	1960	18.5-31.5
	1995-96	17.0-32.0		1995-96	18.5-31.0
	2016-20	13.13-31.3		2016-20	16.4-33.5
Varanasi	1960	18.5-31.5	Farakka	1960	18.5-31.5
	1995-96	20.0-31.5		1995-96	18.5-31.0
	2016-20	27.76		2016-20	13.1-31.8
			Diamond Harbour	1953-55	18.0-33.0
				1995-96	20.5-30.0
				2016-20	22.0-31.7

Water depth

Average depth in the entire river stretch was estimated at 6.34 m. (Fig. 69). During the study period, the lowest depth of 0.13 m was observed at Harshil, and the highest depth was observed at Diamond Harbour. The lowest average depth of 0.69 m was observed at Harshil in upper hilly stretch, whereas the highest average depth of 13.36 m was observed at Diamond Harbor, which is a tidal zone of the river. During the pre-monsoon season, the average depth of the river was 6.13 m. Slightly higher average depth (6.55 m) was recorded during monsoon. Average depth of the river during post monsoon season was 6.35 m, which was slightly reduced (6.19 m) during winter season. Among different years, the year 2018 observed higher water depth as compared to other years especially in upper stretch of the river.

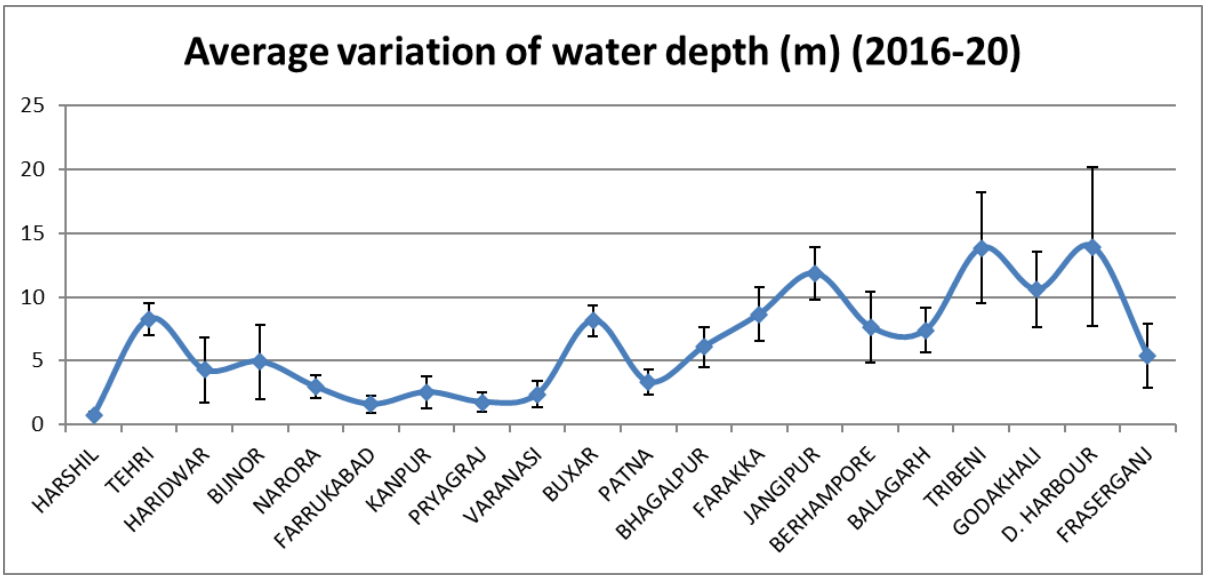


Fig. 69 Average water depth (m) in the entire river stretch

Flow (m/sec)

River flow in the entire stretch of river Ganga ranged from 0.1 m/sec to 1.8 m/sec with an average flow of 0.6 m/sec. (Fig. 70). In the upper stretch of the river, the highest average flow value of 1.09 m/sec was observed at Harshil, 0.63 m/secin the middle stretch at Narora, and in the lower stretch, highest average flow of 1.09 m/sec was observed at Tribeni. The lowest flow in the entire river was observed 0.12 m/sec at Tehri. The average flow observed during pre-monsoon, monsoon, post monsoon and winter season were0.47 m/sec,0.88 m/sec,0.44 m/sec and 0.6 m/sec respectively. From this study, it was observed that there is a reduction in flow pattern at most of the stations during last few years.

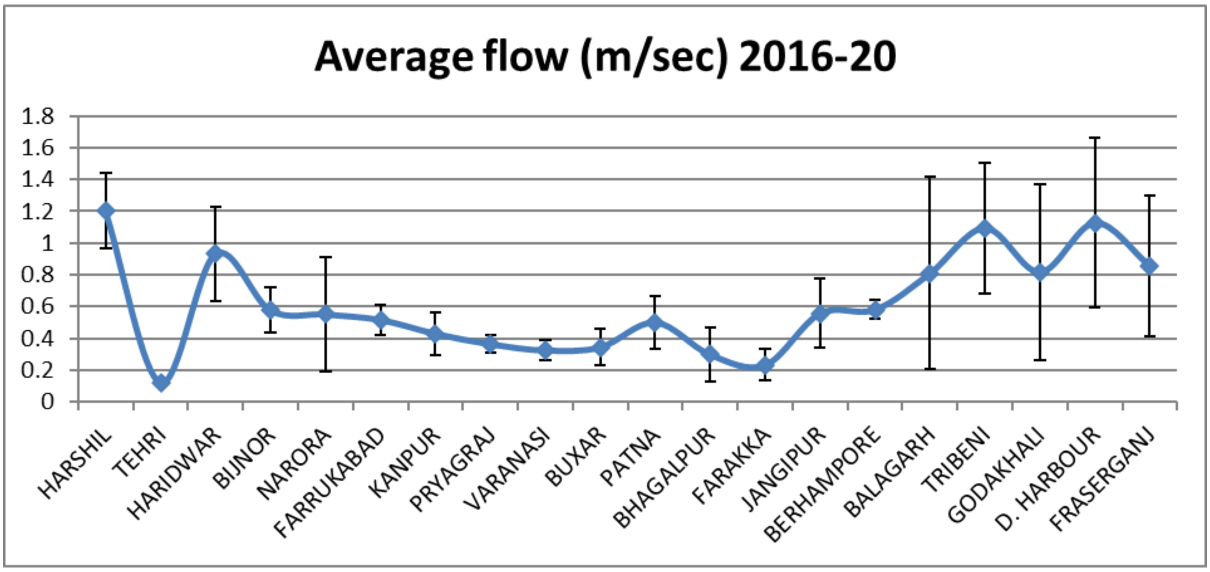


Fig. 70 Average flow (m/sec) in the entire stretch of river Ganga

Transparency (cm)

Average transparency in the entire river was estimated at 43.94 cm during the study period (2016-2020). The highest average transparency value of 88.20 cm was observed at Tehri in the upper stretch of the river. In the middle stretch, the highest transparency (52.50 cm) was recorded at Buxar and in the lower stretch the highest average transparency (73.75 cm)was observed at Farakka. The lowest transparency value (17 cm) in the entire stretch was observed at Diamond Harbour. Significantly lower transparency was recorded during monsoon months as compared to non-monsoon period. The average transparency value during monsoon was only 19.95 cm due to higher turbidity in increased riverine flow regime, whereasthe average transparency value recorded during pre-monsoon, post monsoon and winter seasonwere 49.06 cm, 45.51 cmand 46 cmrespectively. The average water transparency (cm) recorded in the entire Ganga River is shown in Fig. 71.

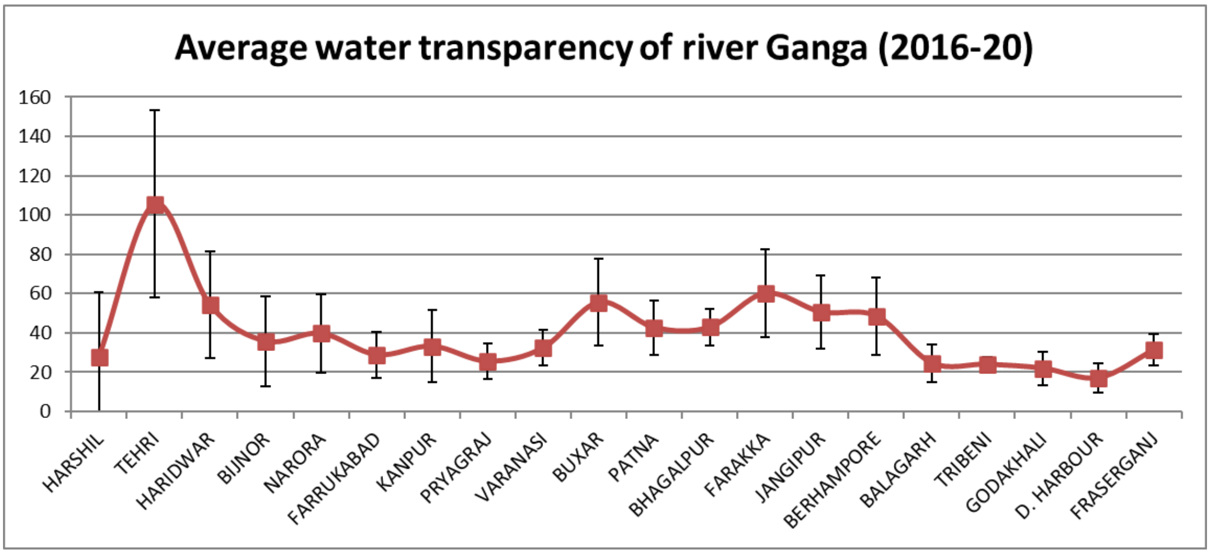


Fig. 71 Average water transparency (cm) in the entire Ganga River

Turbidity (NTU)

The turbidity in the middle and lower stretch ranges between 3.7 NTU and 523 NTU. Average turbidity in the entire river was 99.64 NTU. Highest average turbidity value of 208.06 NTU was recorded at D. Harbour. The average turbidity recorded during the pre-monsoon, monsoon, post-monsoon and winter were 99.24, 141.52, 107.27 and 63.09 NTU respectively. The estimated average turbidity in the middle and lower stretch of Ganga are depicted in Fig. 72.

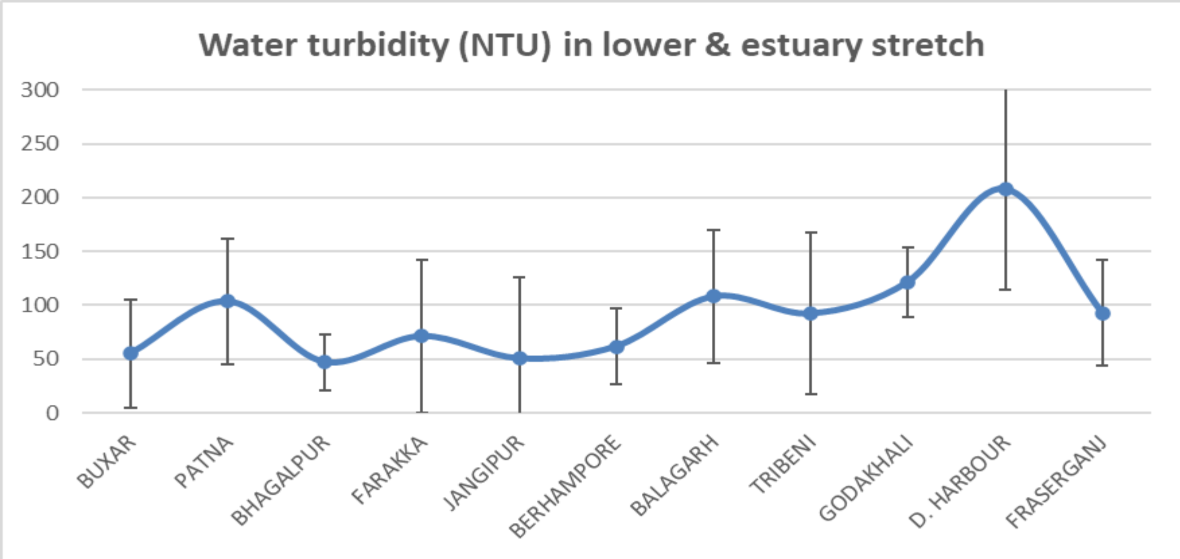


Fig. 72 Average Turbidity (NTU) in the middle and lower stretchof Ganga

Water pH

The observed average water pH in the entire river was 8.12, with the range between 7.2 and 9.51 (Fig. 73). During the entire 5 years the highest average water pH of (7.9) was recorded at Narora, and the lowest pH (7.29) was recorded at Farrukhabad. During the pre-monsoon season the average pH value was 8.18, the highest pH value of 9.11 was recorded at Prayagraj, while the lowest pH value was recorded 7.86 at Bhagalpur. During monsoon season the average pH value was 7.84 with the highest recorded pH value of 8.08 at Tehri, while the lowest value of 7.27 was recorded at Tribeni. The average water pH during post-monsoon season was 7.84. The highest pH value was 9.1 at Jangipur while the lowest pH value was at Harshil 7.44. During the winter season, the average pH value was 8.27, with the highest pH value of 8.75 at Varanasi, and the lowest pH value of 7.71 was recorded at Tehri and Farrukabad. The changing pattern of water pH of river Ganga is presented in Table 23.

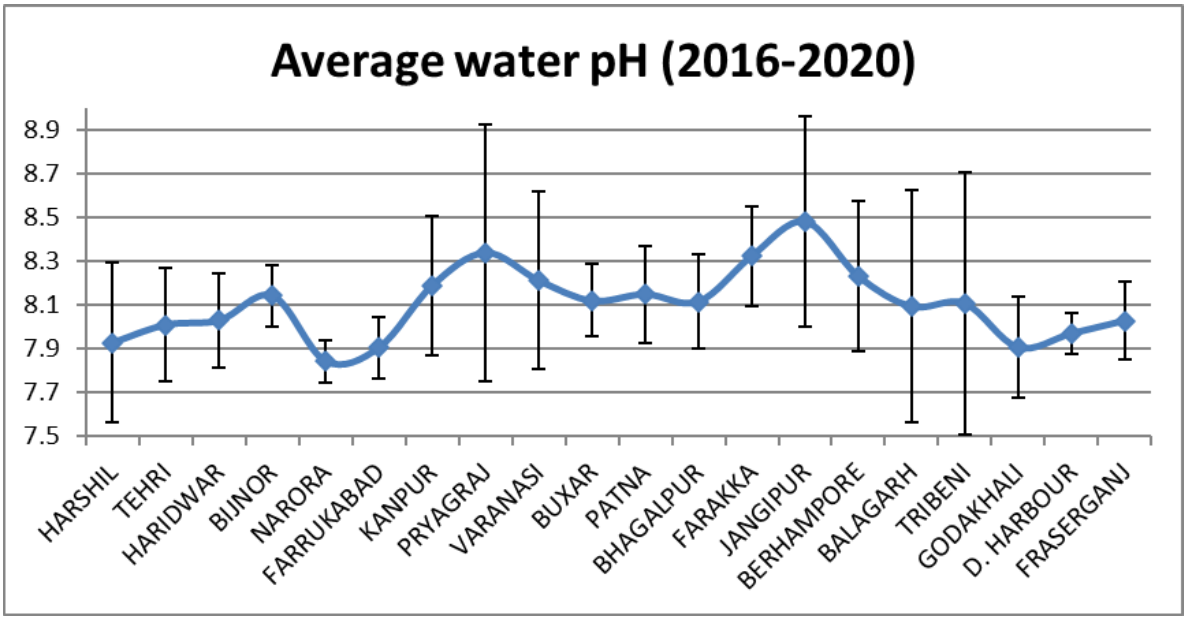


Fig. 73 Average water pH in the entire Ganga River

Table 23. Changing pH pattern of river Ganga over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	pH	Stretches	Period	pH
Kanpur	1960	7.9	Patna	1960	7.9
	1987-88	7.2		1987-88	8
	2001-06	8.2		2001-06	8.1
	2016-20	7.53		2016-20	7.54
Prayagraj	1960	8.1	Bhagalpur	1960	8.2
	1987-88	8		1987-88	8.1
	2001-06	8.2		2001-06	8.2
	2016-20	7.73		2016-20	7.51
Varanasi	1960	8	Farraka	1960	NA
	1987-88	7.4		1987-88	NA
	2001-06	8.1		2001-06	8.1
	2016-20	7.72		2016-20	7.66
			Diamond Harbour	1953-55	8.2
				2016-20	7.40

Dissolved Oxygen (ppm)

Dissolved oxygen in the entire stretch ranged between 3.0 ppm and 14.93 ppm (Fig. 74). Average dissolved oxygen in the entire river was 7.31 ppm. The highest average dissolved oxygen concentration of 9.04 ppm was observed at Harshil in the upper stretch of the river; 7.66 ppm in the middle stretch at Prayagraj, and in the lower stretch, highest dissolved oxygen (6.64 ppm) was observed at Farakka. The lowest dissolved oxygen concentration in the entire stretch was observed 5.54 ppm at Fraserganj. The average dissolved oxygen value observed during post-monsoon season was 7.17 ppm while during the winter season, average dissolved oxygen observed was 8.28 ppm. The changing pattern of dissolved oxygen of river Ganga is presented in Table 24.

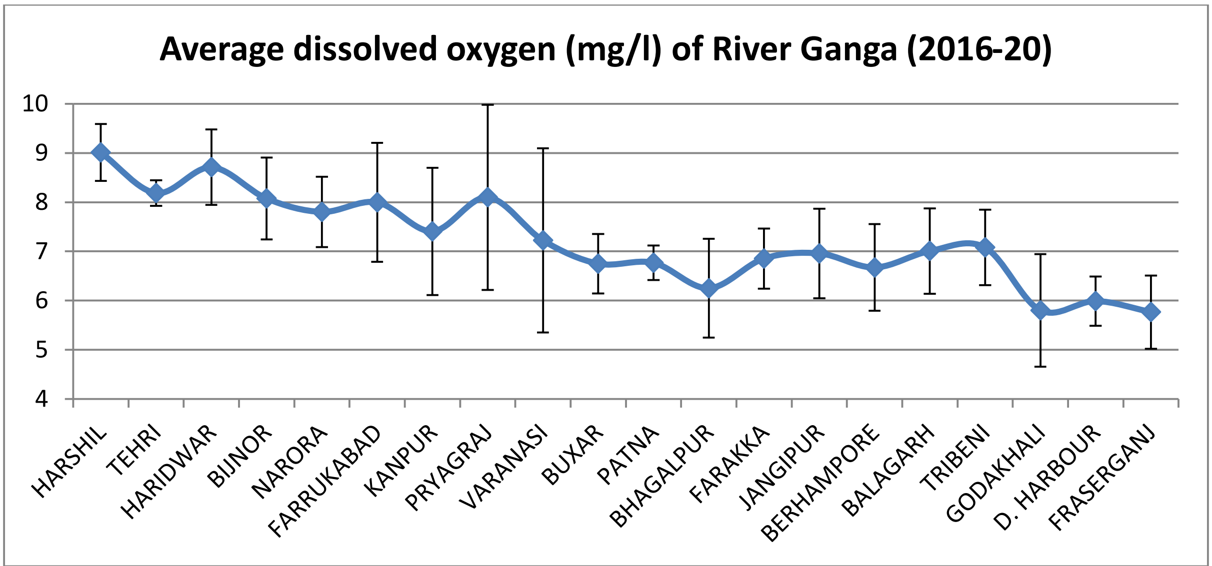


Fig. 74 Average Dissolved oxygen (ppm) in the entire stretch of Ganga

Table 24. Changing pattern of dissolved oxygen over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	D.O (ppm)	Stretches	Period	D.O (ppm)
Kanpur	1960	7.9	Patna	1960	7
	1987-88	7.2		1987-88	7.8
	2001-06	8.2		2001-06	7.8
	2016-20	6.92		2016-20	6.4
Prayagraj	1960	8.4	Bhagalpur	1960	6.9
	1987-88	8		1987-88	7.2
	2001-06	7.8		2001-06	7.6
	2016-20	7.66		2016-20	5.94
Varanasi	1960	7	Farraka	1960	NA
	1987-88	2.2		1987-88	NA
	2001-06	7.4		2001-06	7.4

	2016-20	7.18		2016-20	6.6
			D. Harbour	1953-55	4.8-7.3
				2016-20	5.62

Total Alkalinity (ppm)

The alkalinity in the entire stretch ranges from 2.4 ppm to 300 ppm (Fig. 75). Average alkalinity in the entire river was 116.76 ppm. Higher average alkalinity value of 163 ppm was recorded at Buxar-Baliya stretch of the river Ganga. The average alkalinity value during pre-monsoon, monsoon, season, post-monsoon and winter season were 109.83, 84.22, 119.07 and 136.62 ppm respectively. The changing pattern of total alkalinity of river Ganga is presented in Table 25.

Table 25. Changing pattern of total alkalinity over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	Total Alkalinity (ppm)	Stretches	Period	Total Alkalinity (ppm)
Kanpur	1960	148.5	Patna	1960	141.7
	1987-88	198.00		1987-88	139.6
	2001-06	200.00		2001-06	168
	2016-20	119.07		2016-20	117.85
Prayagraj	1960	142.00	Bhagalpur	1960	131.4
	1987-88	171.00		1987-88	142.2
	2001-06	198.00		2001-06	146
	2016-20	132.35		2016-20	157.85
Varanasi	1960	127.5	Farraka	1960	NA
	1987-88	178.6		1987-88	NA
	2001-06	192.00		2001-06	7.4
	2016-20	144.63		2016-20	112.89
			Diamond Harbour	1953-55	NA
				2016-20	131.22

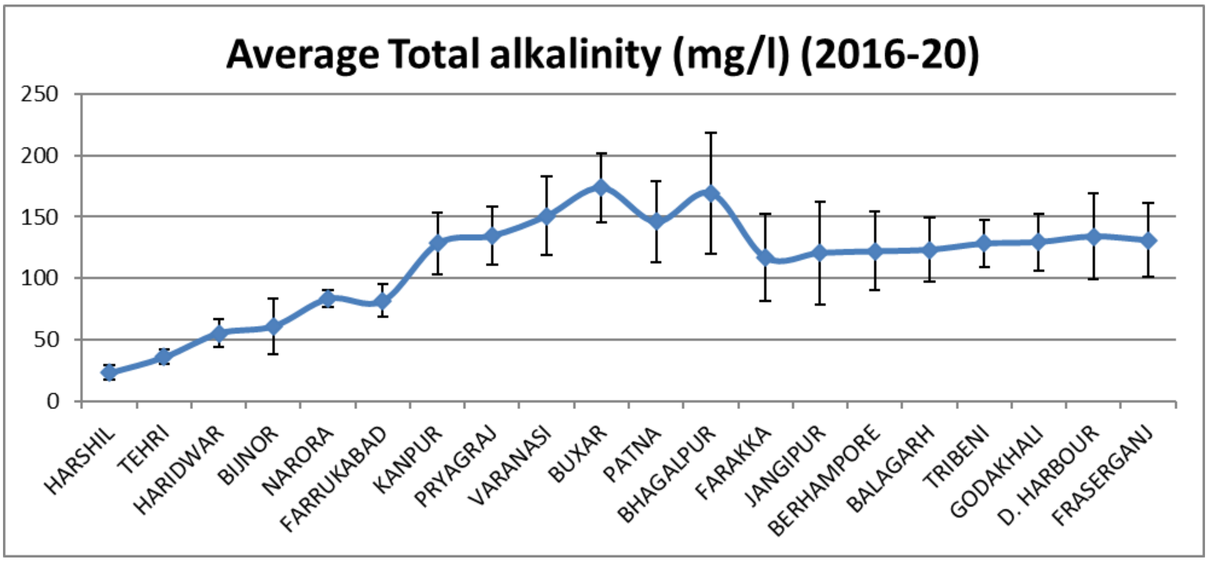


Fig. 75 Average Alkalinity (ppm) in the entire stretch of Ganga

Calcium hardness

The calcium hardness in the entire stretch ranges between 6.41 and 721 ppm (Fig. 76). Highest average calcium hardness value of 369.05 ppm was recorded at Fraserganj. During the pre-monsoon the average calcium hardness content in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 49.15 ppm, 44.47 ppm, 40.85 ppm and 50.70 ppm respectively.

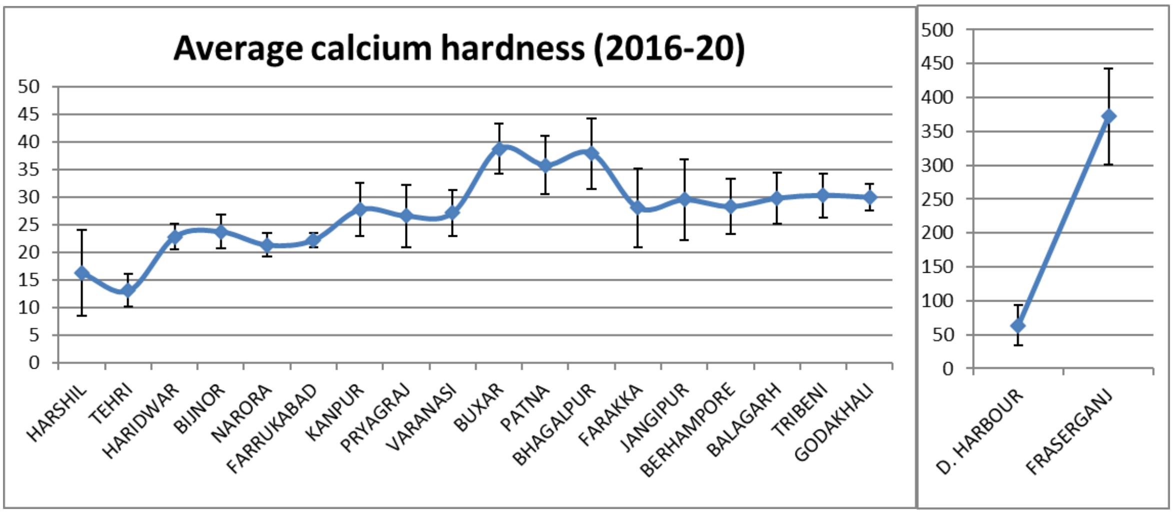


Fig. 76 Average Calcium hardness (ppm) in the entire stretch of Ganga

Magnesium hardness

Magnesium hardness in the entire stretch ranges from 2.43 ppm to 1943.6 ppm (Fig. 77). Magnesium hardness in the entire river was 78.93 ppm. Higher average magnesium hardness value of 947.61 ppm was recorded at Fraserganj of the river. The average magnesium hardness content in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 87.37 ppm, 92.70 ppm, 47.73 ppm and 50.70 ppm respectively.

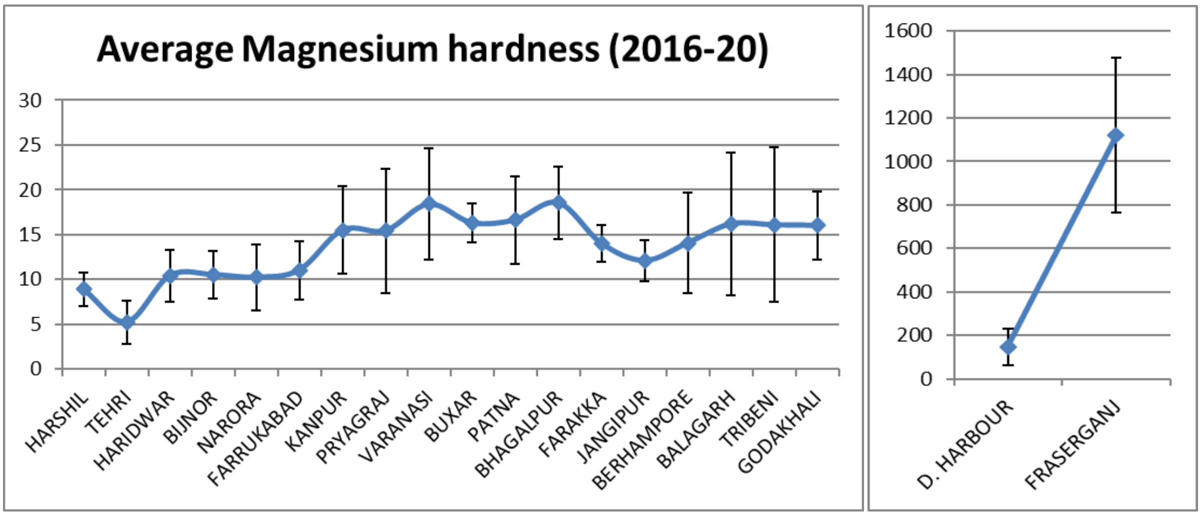


Fig. 77 Average Magnesium hardness (ppm) in the entire stretch of Ganga

Total hardness (ppm)

Total hardness in the entire stretch ranges from 16 ppm to 8900 ppm (Fig. 78). Average Total hardness in the entire river was 440.06 ppm. Highest average total hardness value of 1095.46 ppm was recorded at Fraserganj. The average totalhardnesscontent in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 488.36 ppm, 496.94 ppm, 288.2 ppm and 422.19 ppm respectively. Higher total hardness were observed in estuarine zone due to intrusion of sea water during high tide. The changing pattern of total hardness of river Ganga is presented in Table 26.

Table 26. Changing pattern of total hardness over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	Total hardness (PPM)	Stretches	Period	Total hardness (PPM)
Tehri	1995-96	NA	Patna	1960	120
	2016-20	NA		1987-88	118
Farrukhabad	1995-96	NA		2001-06	148
	2016-20			2016-20	
Kanpur	1960	128	Bhagalpur	1960	112
	1987-88	176		1987-88	120
	2001-06	182		2001-06	124
	2016-20			2016-20	
Prayagraj	1960	122	Farakka	1960	NA
	1987-88	152		1987-88	NA
	2001-06	164		2001-06	108

	2016-20			2016-20	
Varanasi	1960	110	Diamond Harbour	1953-55	
	1987-88	154		1995-96	
	2001-06	162		2016-20	
	2016-20				

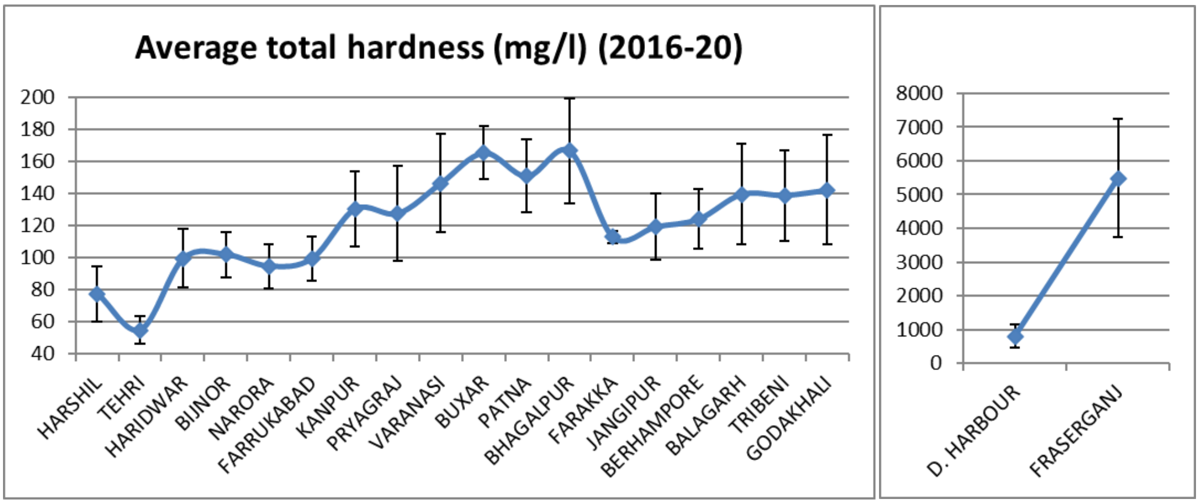


Fig. 78 Average total hardness (ppm) in the entire stretch of Ganga

Salinity (ppt)

The salinity in the entire stretch ranges from 0.01 ppt to 31.79 ppt (Fig. 79). Average salinity in the entire river was 1.99 ppt. Highest average salinity value of 28.73 ppt was recorded at Fraserganj. The average salinity in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 1.811 ppt, 1.55 ppt, 1.590 ppt and 1.70 ppt respectively.

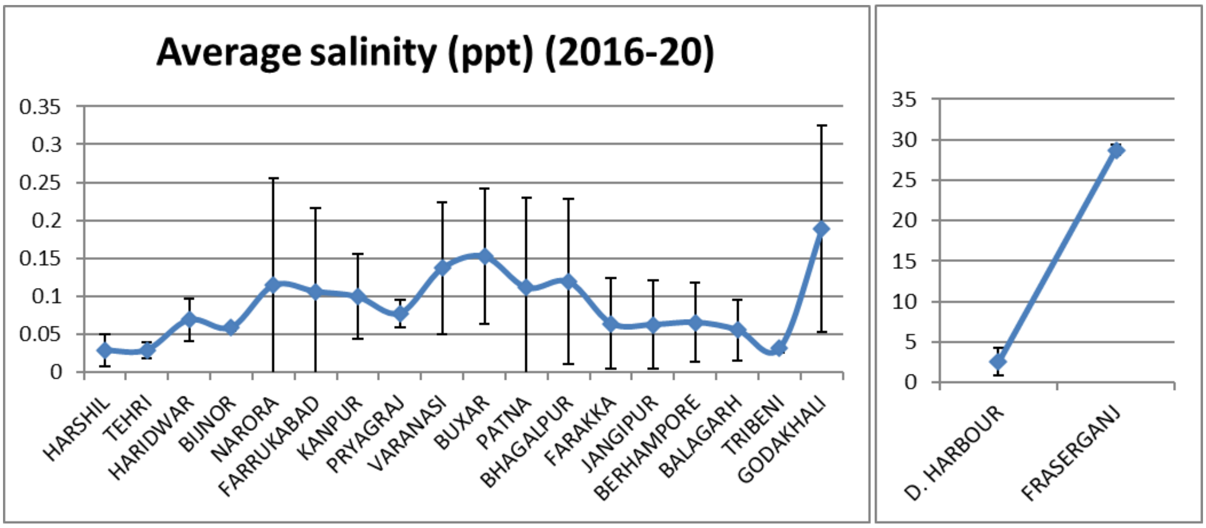


Fig. 79 Average salinity (ppt)in the entire stretch of Ganga

Total dissolved solid (g/l)

Total Dissolved Solid (TDS) in the entire stretch ranges from 0.04 g/l to 72.14 g/l. (Fig. 80). Average total dissolved solid in the entire river was 2.85 g/l. Highest average total dissolved solid value of 41.40 g/l was recorded at Fraserganj. The average TDS content in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 3.89 g/l, 3.23 g/l, 2.38 g/l and 2.87 g/l respectively. The Changing pattern of TDS in river Ganga is presented in Table 27.

Table 27. Changing pattern of TDS in river Ganga over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	TDS(g/l)	Stretches	Period	TDS(g/l)
Kanpur	1960	0.17	Patna	1960	0.148
	1987-88	0.278		1987-88	0.138
	2001-06	0.285		2001-06	0.155
	2016-20	0.2		2016-20	0.3
Prayagraj	1960	0.148	Bhagalpur	1960	0.134
	1987-88	0.206		1987-88	0.158
	2001-06	0.253		2001-06	0.164
	2016-20	0.2		2016-20	0.3
Varanasi	1960	0.13	Farakka	1960	NA
	1987-88	0.216		1987-88	NA
	2001-06	0.234		2001-06	0.121
	2016-20	0.3		2016-20	0.2

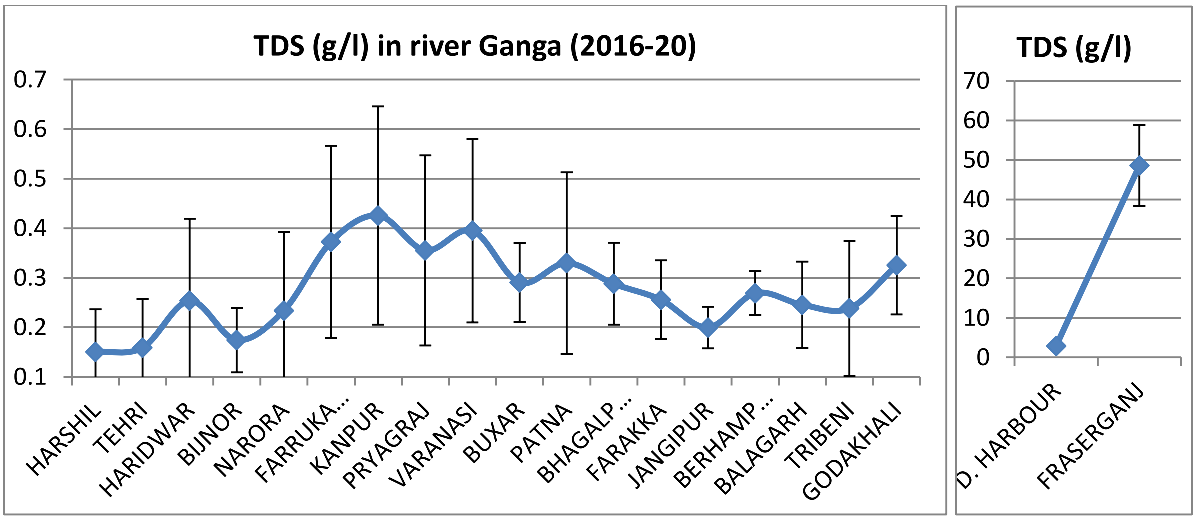


Fig. 80 Average Total Dissolved Solid (g/l)in the entire stretch of Ganga

Total solid (g/l)

The average total solid (TS) in the entire stretch ranges between 0.08 g/l and 78.38 g/l. (Fig. 81). Average TS in the entire river was 4.70 g/l. Highest average TS content of 50.62 g/l was recorded at Fraserganj. The average TS content in the river water during pre-monsoon,

monsoon, post-monsoon and winter season were 3.88 g/l, 3.24 g/l, 2.38 g/l and 2.87 g/l respectively.

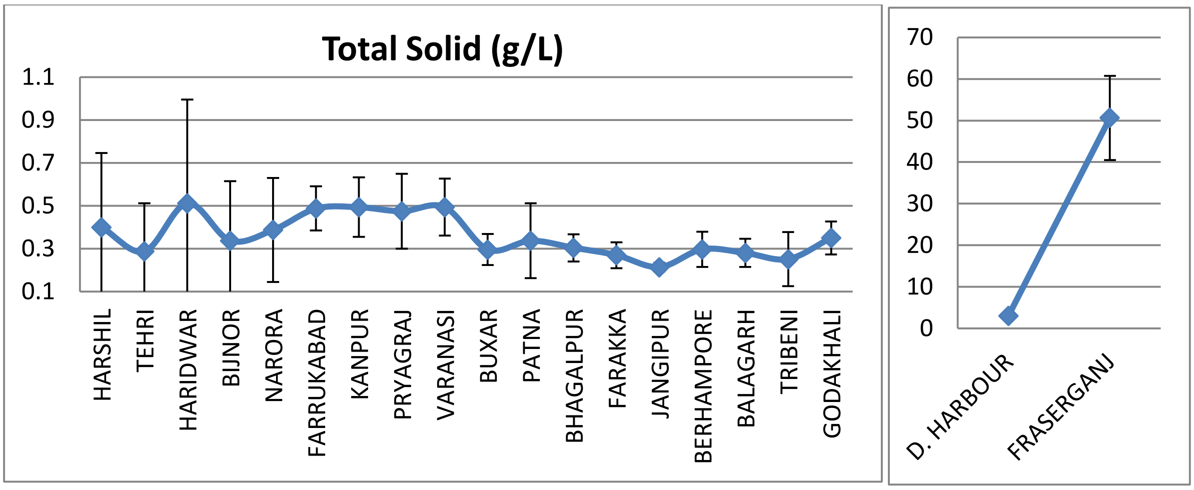


Fig. 81 Average Total Solid (g/l)in the entire stretch of Ganga

Total Phosphorus (ppm)

Total phosphorus concentration in the entire stretch ranges from 0.0007 and 9.16 ppm (Fig. 82). Average total phosphorusconcentrationin the entire river was 0.30 ppm. Highest average total phosphorus concentration of 0.65 ppm was recorded at Bhagalpur. The average total phosphorus concentration in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 0.29 ppm, 0.26 ppm, 0.52 ppm and 0.138 ppm respectively. The changing pattern of total phosphorus in river Ganga is presented in Table 28.

Table 28. Changing pattern of total phosphorus (ppm) in river Ganga over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	Total Phosphorus (ppm)	Stretches	Period	Total Phosphorus (ppm)
Kanpur	1960	0.14	Patna	1960	0.1
	1987-88	0.18		1987-88	0.18
	2001-06	0.14		2001-06	0.12
	2016-20	0.199		2016-20	0.21
Prayagraj	1960	0.15	Bhagalpur	1960	0.09
	1987-88	0.18		1987-88	0.12
	2001-06	0.12		2001-06	0.1
	2016-20	0.191		2016-20	0.64
Varanasi	1960	0.04	Farakka	1960	NA
	1987-88	0.17		1987-88	NA
	2001-06	0.1		2001-06	0.12
	2016-20	0.33		2016-20	0.35

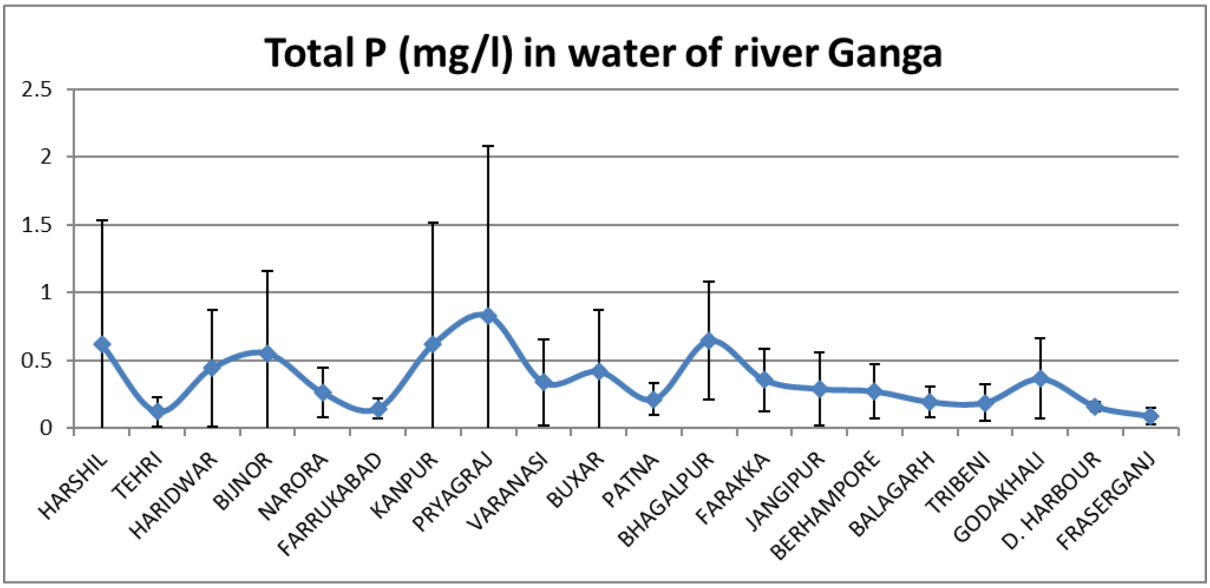


Fig. 82 Average Total Phosphorus (ppm) in the entire stretch of Ganga

Available Nitrogen (Nitrate)

Available nitrogen concentration in the entire stretch ranges between 0 and 6.65 ppm (Fig. 83). Average available nitrogen in the entire river was 0.23 ppm. Highest average available nitrogen value of 1.18 ppm was recorded at Varanasi. The average available nitrogen concentration in the river water during pre-monsoon, monsoon, post-monsoonand winter season were 0.32 ppm, 0.19 ppm, 0.17 ppm and 0.26 ppm respectively. The changing pattern of available nitrogen in river Ganga is presented in Table 29.

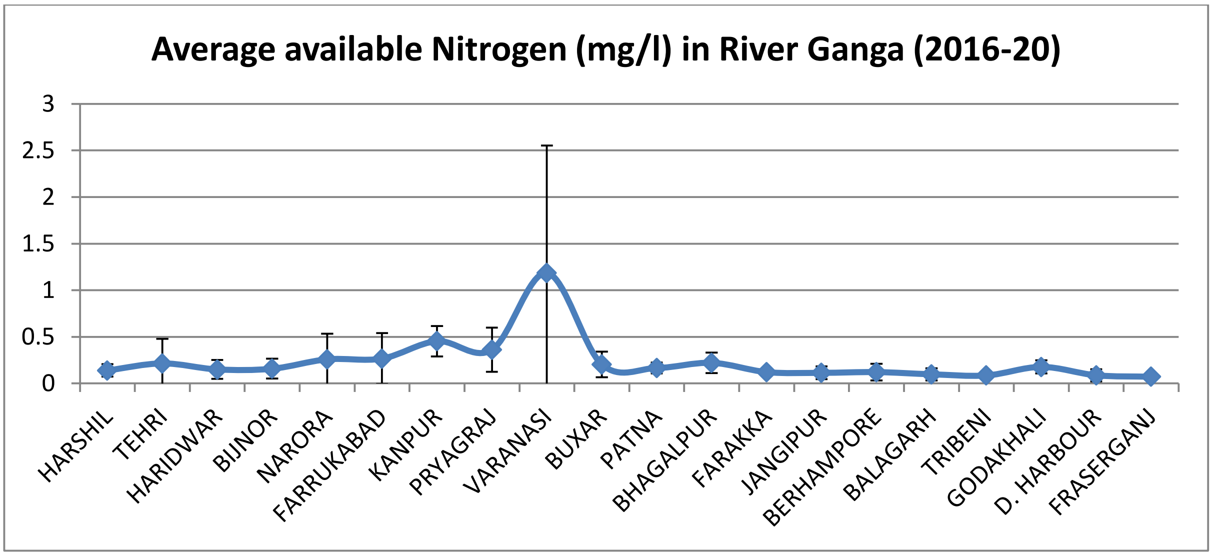


Fig. 83 Average Available Nitrogen (ppm)in the entire stretch of Ganga

Table 29. Changing pattern of available nitrogen over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	Available Nitrogen (ppm)	Stretches	Period	Available Nitrogen (ppm)
Haridwar	1995-96	0.01-0.24	Patna	1960	0.14
	2016-20	0.1-3.6		1987-88	0.22
				2001-06	0.16
				2016-20	0.165
Kanpur	1960	0.14	Bhagalpur	1960	0.14
	1987-88	0.28		1987-88	0.18
	2001-06	0.18		2001-06	0.16
	2016-20	0.45		2016-20	0.221
Prayagraj	1960	0.17	Farraka	1960	NA
	1987-88	0.19		1987-88	NA
	2001-06	0.18		2001-06	0.14
	2016-20	0.361		2016-20	0.121
Varanasi	1960	0.1	Diamond Harbour	1953-55	NA
	1987-88	0.22		1995-96	NA
	2001-06	0.11		2016-20	0.08
	2016-20	1.18			

Total nitrogen (ppm)

Total nitrogen concentration in the entire river stretch ranged between 0.1 and 4.38 ppm (Fig. 84). Average total nitrogen in the entire river was 0.75 ppm. Highest average total nitrogen concentration of 3.6 ppm was recorded at Godakhali. The average total nitrogen concentration in the river water during pre-monsoon, monsoon, post-monsoonand winter season were 0.83 ppm, 0.99 ppm, 0.72 ppm and 0.54 ppm respectively.

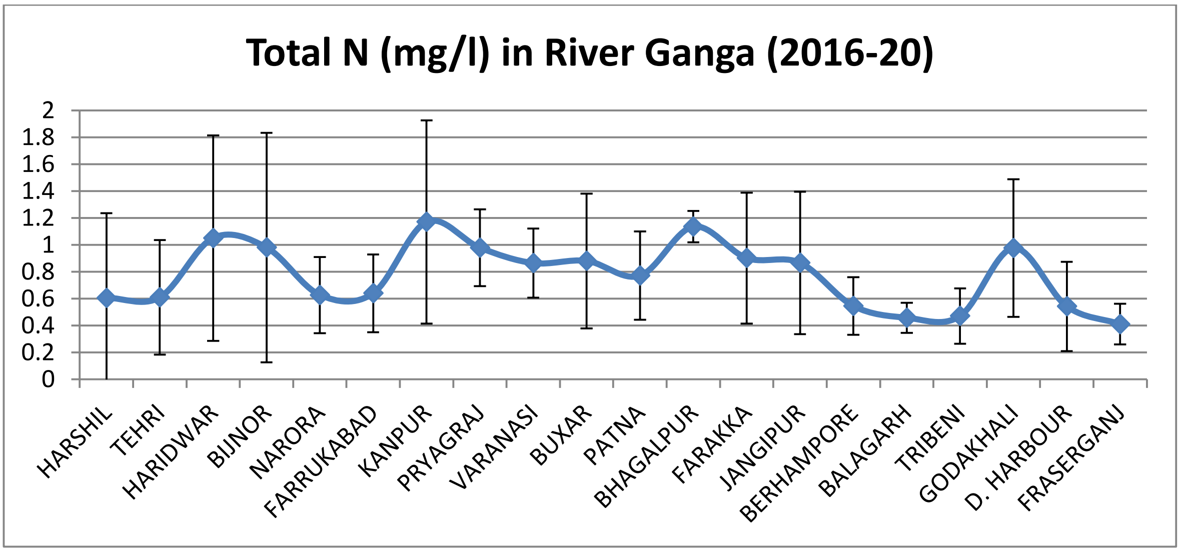


Fig. 84 Average total nitrogen (ppm) in the entire stretch of Ganga

Silicate (ppm)

Silicate in the entire stretch ranged between 0.05 ppm and 9.16 ppm (Fig. 85). Average silicate in the entire river was 4.99 ppm. Highest average total silicate value of 9.74 ppm was recorded at Farakka. The average total nitrogen concentration in the river water during pre-monsoon, monsoon, post-monsoonand winter season were 4.96 ppm, 6.46 ppm, 4.22 ppm and 5.16 ppm respectively.

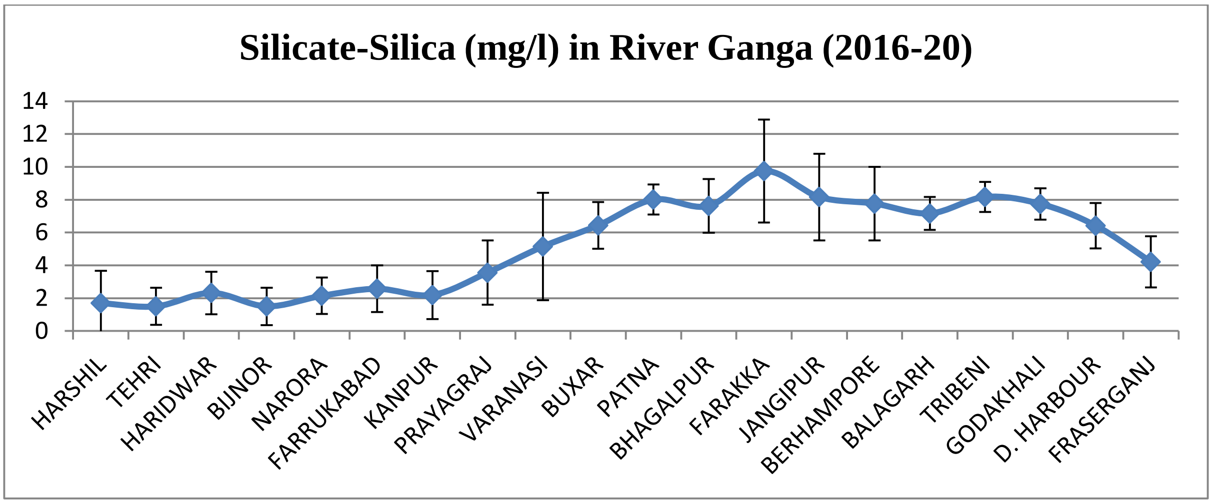


Fig. 85 Average Silicate (ppm)in the entire stretch of Ganga

Biochemical oxygen demand (ppm)

Biochemical oxygen demand (BOD) in the entire river stretch ranges between0.1 and9.8 ppm (Fig. 86). Average B.O.D in the entire river water was 1.47 ppm. Highest average B.O.D value of 3.6 ppm was recorded at Prayagraj. The average BOD concentration in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 1.73 ppm, 1.29 ppm, 1.19 ppm and 1.20 ppm respectively.

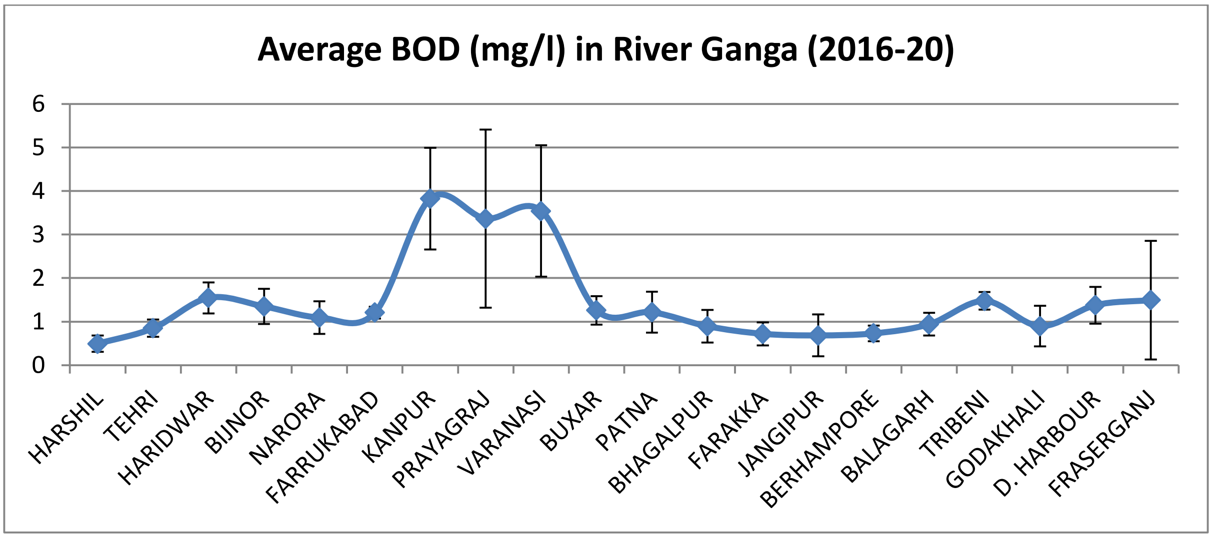


Fig. 86 Average B.O.D (ppm)in the entire stretch of Ganga

Free CO_2

AveragefreeCO_2in the entire river water was 2.59 ppm (Fig. 87) . Higher average free CO_2 value of 5.41 ppm was recorded at Haridwar stretch of the river Ganga. The average free CO_2 in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 2.42 ppm, 3.56 ppm, 2.34 ppm and 1.29 ppm respectively.Higherfree CO_2 value was observed during monsoon, whichmay be due to the absence of sunlight and higher turbidity value in the water preventing aquatic photosynthesis that utilizes free CO_2. The changing pattern of free CO_2 in river Ganga is presented in Table 30.

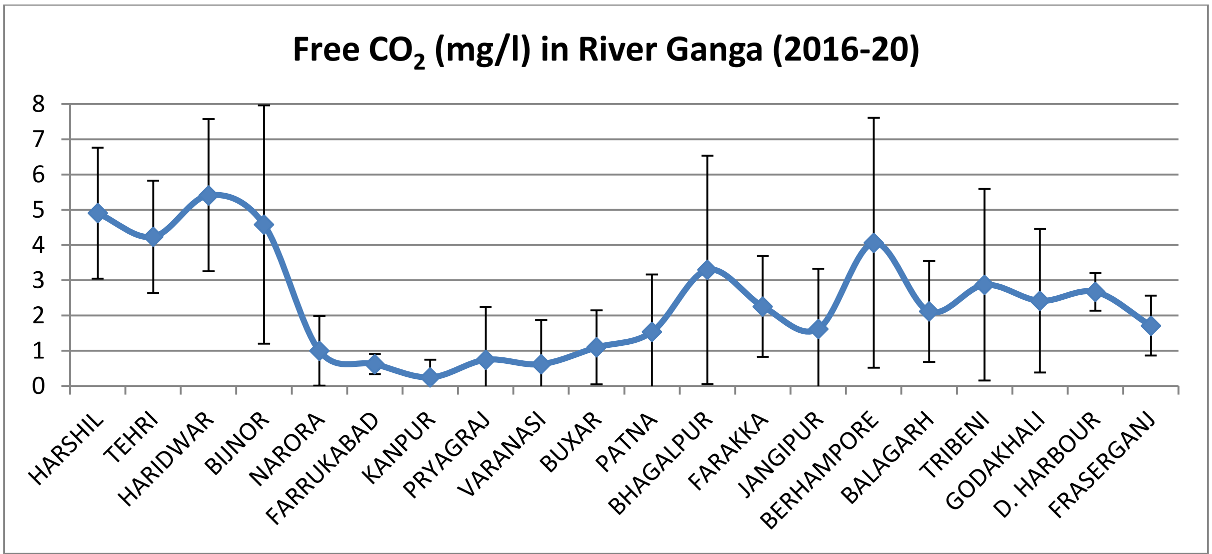


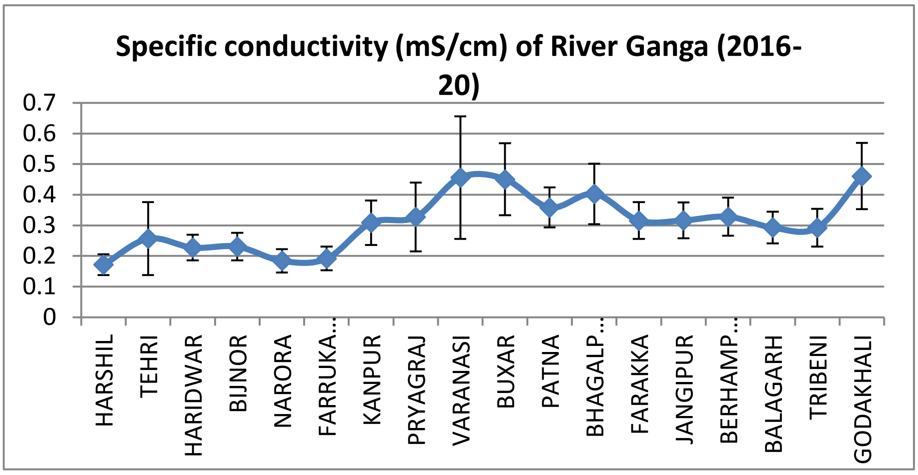
Fig. 87 Average free CO_2 in the entire stretch of Ganga

Table 30. Changing pattern of free CO_2 over the years (Vass et al., 2008; CIFRI bulletin no. 154)

Stretches	Period	Free CO_2 (ppm)	Stretches	Period	Free CO_2 (pm)
Kanpur	1960	2.2	Patna	1960	4
	1987-88	12.4		1987-88	2
	2001-06	3.2		2001-06	2.6
	2016-20	4.9		2016-20	1.54
Prayagraj	1960	1.5	Bhagalpur	1960	2.3
	1987-88	4.6		1987-88	2.5
	2001-06	1.8		2001-06	2.2
	2016-20	0.75		2016-20	3.3
Varanasi	1960	3.1	Farraka	1960	NA
	1987-88	8.8		1987-88	NA
	2001-06	2.4		2001-06	2.6
	2016-20	0.63		2016-20	2.26
			Diamond Harbour	1995-96	3.5-8
				2016-20	2.67

Specific Conductance (mS/cm)

Specific conductivity of waterin the entire stretch ranges between0.15 mS/cm and56.2 mS/cm (Fig. 88). Average specific conductivity in the entire river water was 5.16 mS/cm. Highest average specific conductivity value of 43.12 mS/cm was recorded at Fraserganj. The average free CO_2 in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 2.58 mS/cm, 2.75 mS/cm,0.72 mS/cmand2.71 mS/cm respectively.



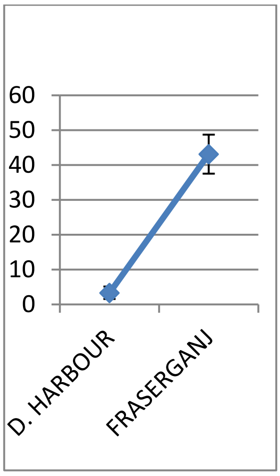


Fig. 88 Average Specific Conductivity (mS/cm) in the entire stretch of Ganga

Total Chlorophyll

Chlorophyll content of river water was determined in lower and estuarine stretch of the river. Lower chlorophyll value was indicative of a good aquatic health without eutrophication caused by anthropogenic nutrient loading. Average total chlorophyll in the middle and lower stretch ranges between 0.29 and 42.05 mg/m^3. Highest average chlorophyll content in river waterof 16.47 mg/m^3 was recorded at Tribeni (Fig. 89). The average GPP in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 2.97 mg/m^{3,} 2.78 mg/m^3, 3.28 mg/m^{3}and 5.12 mg/m^3 respectively.

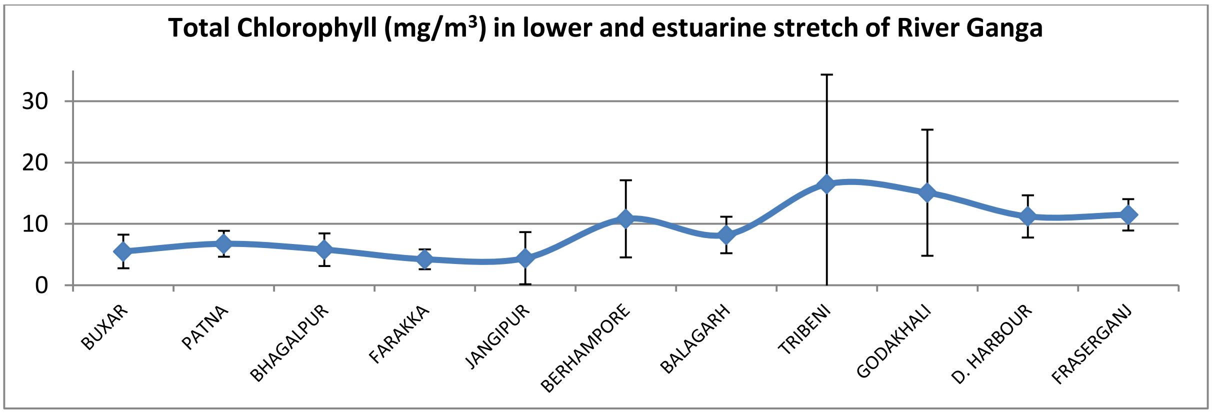


Fig. 89 Average total chlorophyll in the middle and lower stretch of Ganga

Gross Primary Production (mgC/m³/h)

Gross Primary Productivity (GPP) in the entire stretch ranges between 23.44 and 552.05 mgC/m³/h (Fig. 90). Average GPP in the entire river water was 103.63 mgC/m³/h. Highest average GPP value of 303.4 mg C/m³/h was recorded at Varanasi. The average GPP in the river water during pre-monsoon, monsoon, post-monsoon and winter season were 141.08 mgC/m³/h, 74.60 mgC/m³/h, 86.36 mgC/m³/h and 123.09 mgC/m³/h respectively.

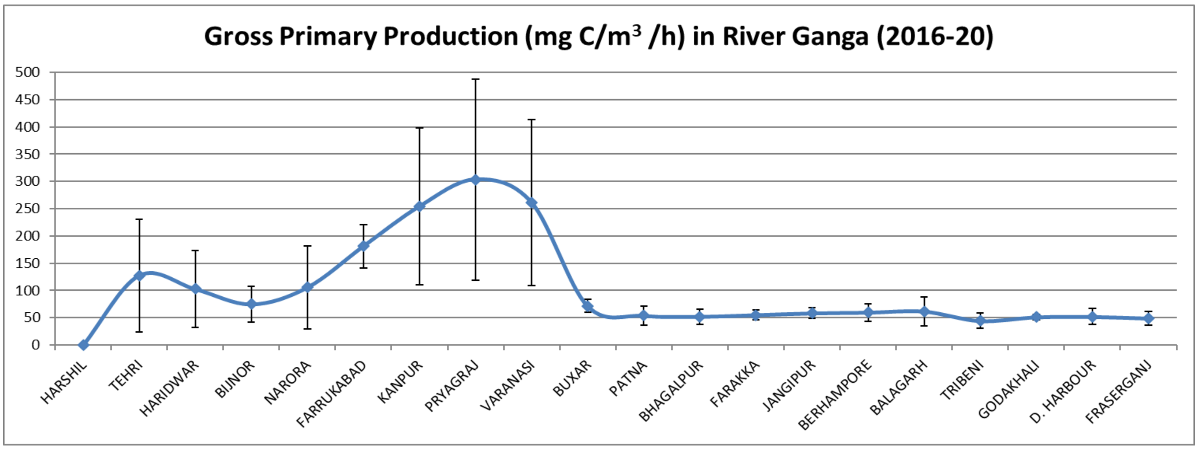


Fig. 90 Gross primary Productivity in the entire stretch of Ganga

Community Respiration

Community Respirationin the entire stretch ranges from 0.29 to 331.25 mgC/m³/h (Fig. 91). Average Community Respirationin the entire river was 38.84 mgC/m³/h. Highest average Community Respiration value of 164.24 mg C/m³/h was recorded at Prayagraj. During the pre-Monsoon the average Community Respirationvalue was 53.52mgC/m³/h. During monsoon the average Community Respirationvalue was 29.52mgC/m³/h. The average Community Respiration during post-Monsoon was 36.42mgC/m³/h. The average Community Respirationvalue during winter was 46.23mgC/m³/h.

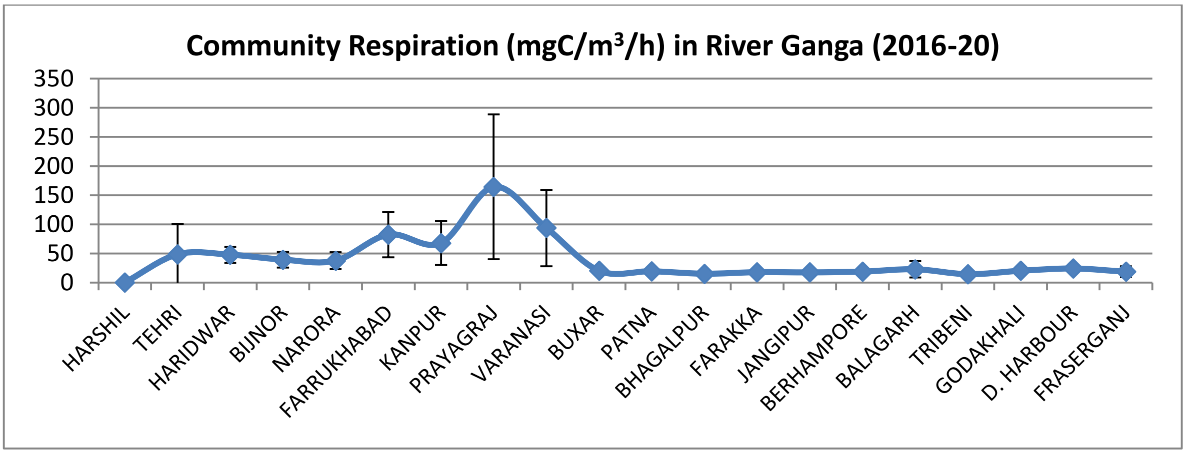


Fig. 91 Community Respirationin the entire stretch of Ganga

SEDIMENT CHARACTERISTICS OF RIVER GANGA

Sediment pH

The sediment pH in the entire stretch of river Ganga rangedbetween7.3 and 8.46 (Fig. 92). The highest average soil pH value of 8.46 was recorded at Farrukhabad. During the pre-monsoon, the average pH value was 8.03. During monsoon, the average pH value was 8.25. The average pH value during post-monsoon was 8.19, whereas, during winter, average pH value was 7.96.Soil of hilly stretch (Harsil to Tehri) of river Ganga was observed slightly acidic in nature; however, the rest of the stretch from Haridwar to Fraserganj was observed to be alkaline in nature and congenial for aquatic life especially fishes. Changing pattern of soil pH of River Ganga over the years presented at Table 31.

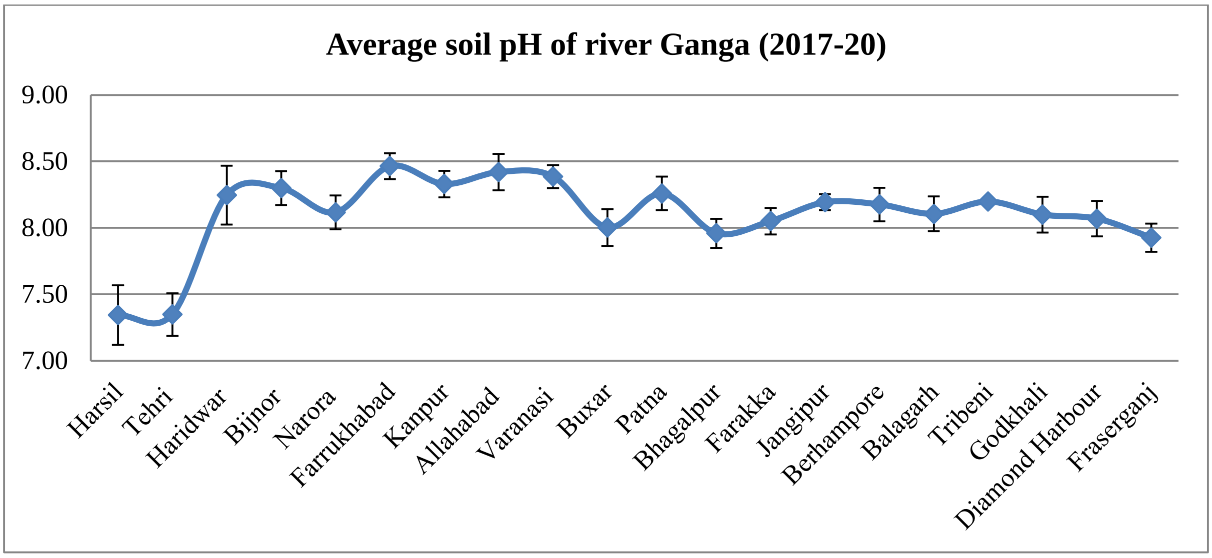


Fig. 92 Average sediment pH of River Ganga

Table 31. Changing pattern of soil pH of River Ganga over the years

Stretches	Soil pH	Reference
Haridwar	6.8 - 8.5	Sinha et al 1998
	8.25	Present study (2017-2020)
Kanpur	7.1-8.4	Sinha et al 1998
	6.7-7.3	Khwaja et al 1999
	8.33	Present study 2017-2020
Allahabad	7.24	Pandey et al 2017
	8.42	Present study 2017-2020
Varanasi	8.38	Pandey et 2014
	8.39	Present study 2017-2020
Diamond harbour	8.60	Mitra et al 2019
	8.07	Present study 2017-2020
Fraserganj	8.2 - 8.8	Sinha et al 1998
	7.93	2017-2020

Specific conductivity (µS/cm)

Specific conductivity of the sediment in the entire stretch of river Ganga ranged between 0.14 and 5.59 µS/cm (Fig. 93). Highest average sediment specific conductivity value of 5.59 µS/cm was recorded at Fraserganj. During the pre-monsoon, the average specific conductivity value was 0.70 µS/cm. During monsoon, the average specific conductivity value was 0.75 µS/cm. The average specific conductivity value during post-monsoon was 0.48 µS/cm, whereas, during winter average specific conductivity value was 0.54 µS/cm. Higher values of specific conductivity was observed in estuarine zone due to intrusion of sea water during high tide.

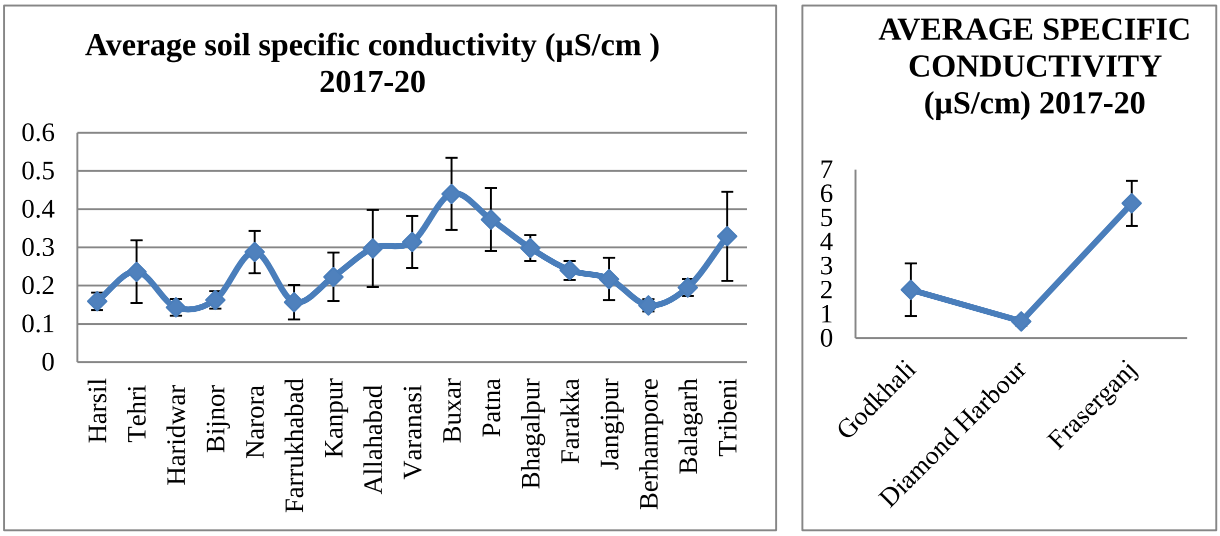


Fig. 93 Average sediment specific conductivity of River Ganga

Table 32. Changing pattern of specific conductivity (µS/cm) over the years

Stretches	EC	Reference
Haridwar	0.11 - 1.64	Sinha et al 1998
	0.18	Present study (2017-2020)
Kanpur	0.08 - 0.92	Sinha et al 1998
	0.22	Present study (2017-2020)
Allahabad	0.4	Present study (2017-2020)
	0.29	Pandey et al 2017
Varanasi	0.07	Pandey et 2014
	0.15	Present study (2017-2020)
Fraserganj	1.23 - 8.00	Sinha et al 1998
	5.59	Present study (2017-2020)

Soil organic carbon (%)

The organic carbon of sediment of entire stretch ranges from 0.07 to 0.69 % (Fig. 94). Highest average organic carbon (0.69%) was found at Fraserganjstretchof river Ganga. During the pre-monsoon the average organic carbon value was 0.39%, inmonsoon was 0.13%, in post-monsoon was 0.35%, whereas, inwinter 0.35%. Organic carbon accumulation in sediment was noted in few locations like Fraserganj due to higher primary productivity. However, as sediment organic carbon is less that 1%, it may be concluded that sediment ofriverGanga is congenial for survival of aquatic organism.

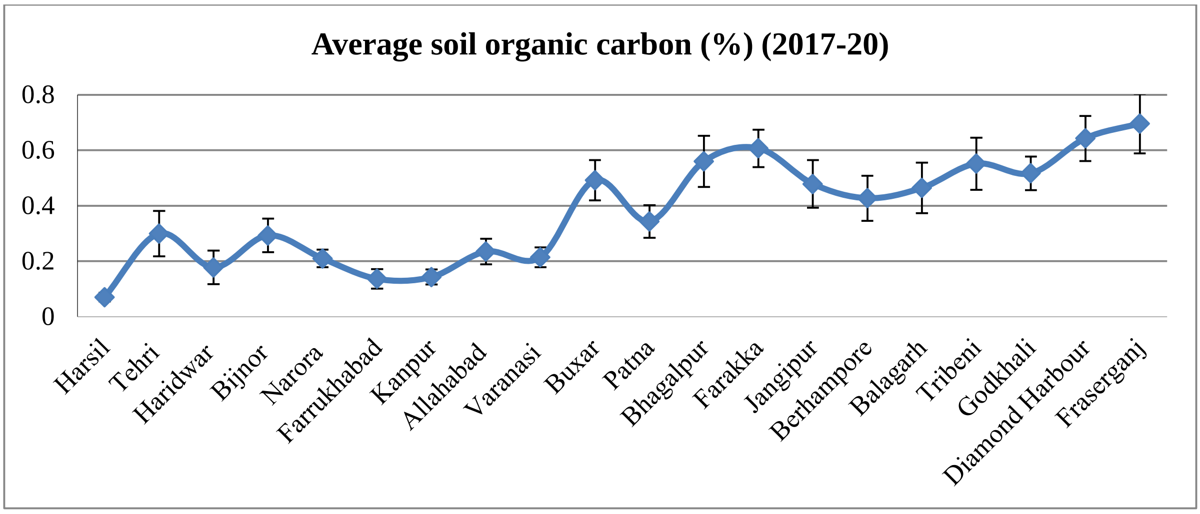


Fig. 94 Average sediment organic carbon of River Ganga

Table 33. Changing pattern of soil organic carbon (%) over the years

Stretches	organic carbon (%)	Reference
Haridwar	0.01 - 0.49	Sinha et al 1998
	0.18	2017-2020
Kanpur	0.02 - 0.35	Sinha et al 1998
	0.14	2017-2020
Allahabad	0.36	Pandey et al 2017
	0.23	2017-2020
Diamond harbour	0.7	Mitra et al 2019
	0.64	2017-2020
Fraserganj	0.46 - 0.80	Sinha et al 1998
	0.69	2017-2020

Available nitrogen (mg/100g)

The sediment available nitrogen in the entire stretch ranges between 4.9 and 12.56 mg/100g (Fig. 95). Highest average available nitrogen value of 12.56 mg/100g was recorded at Tribeni. During the Pre-monsoon the average available Nitrogen value was 9.67 mg/100g, 8.79 mg/100g was in monsoon,8.62 mg/100g was in Post monsoonwhereas, 11.02 mg/100g. was inwinter.Average available Nitrogen value was Low available nitrogen may be attributed to predominantly sandy character of river Ganga.

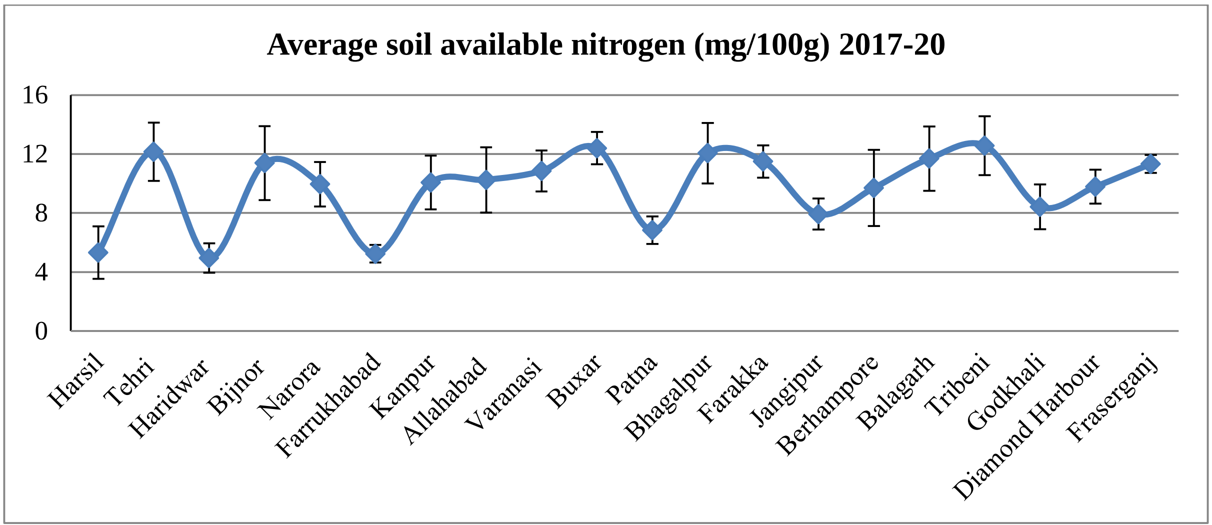


Fig. 95 Average sediment available nitrogen of River Ganga

Available phosphorus (mg/100g)

The available phosphorus of sediment in the entire stretch ranges from 2.68 to 6.83 mg/100g (Fig. 96). Highest average available phosphorus value of 6.83 mg/100g was recorded at Tehri. During the pre-monsoon, the average Available phosphorus value was 3.30 mg/100g, 3.47 mg/100g was recorded in monsoon,3.61 mg/100g was during post monsoon whereas, 5 mg/100g. was during winter. Low available phosphorous concentration in sediment of river Ganga may be attributed by predominantly sandy character of river Ganga.

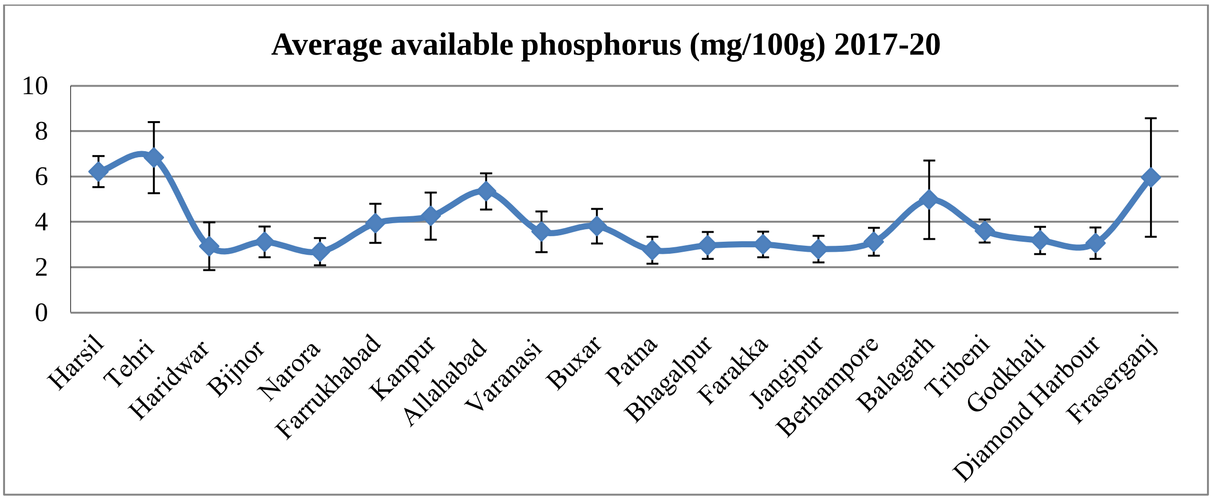


Fig.96 Average sediment available phosphorus of River Ganga

Free $CaCO_3$ (%)

The free $CaCO_3$ of sediment in the entire stretch ranged from to 4.68 to 10.15% (Fig. 97). Highest average Free $CaCO_3$ value of 10.15%was recorded at Bhagalpur. During, Pre-monsoon the average Free $CaCO_3$ value was 8.96%while, in monsoon the average Free $CaCO_3$ value was 8.62% and 7.80%wasin Post monsoon. During winter average Free $CaCO_3$ value was 6.92%.

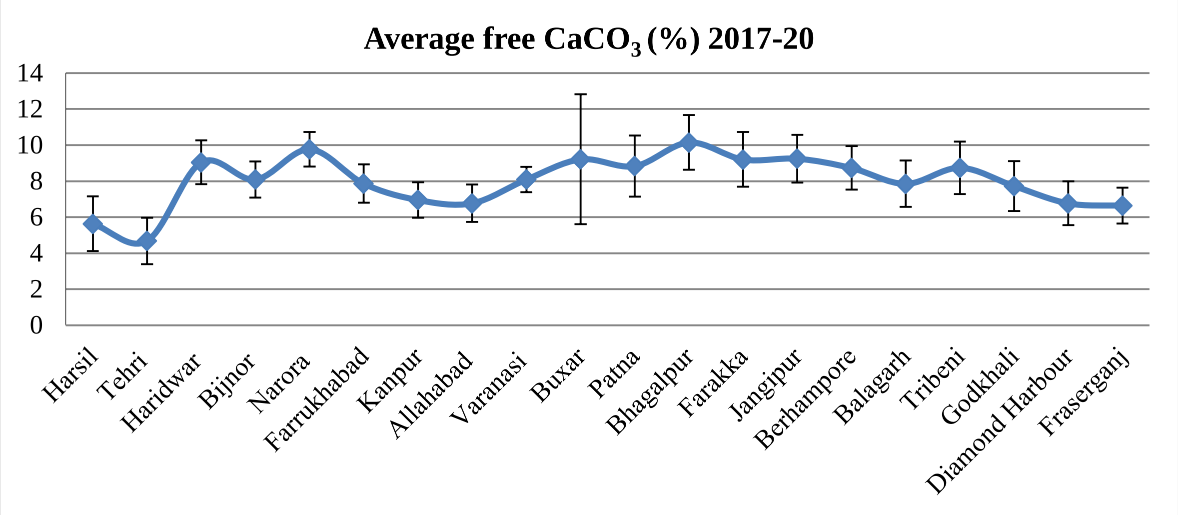


Fig. 97 Average sediment Free calcium Carbonate of River Ganga

Sand (%)

The percentage of Sand in sediment in the entire stretch ranges from 55 to 91% (Fig. 98). Highest average sand value of 91% was recorded at Haridwar. During, Pre-monsoon the average Sand value was 81%, in monsoon was 75% while, the value was recorded 71% in Post monsoon and 78% in winter. Sandification of river bed (>90% sand) is a matter of concern especially upper and middle stretch of river up to Allahabad.

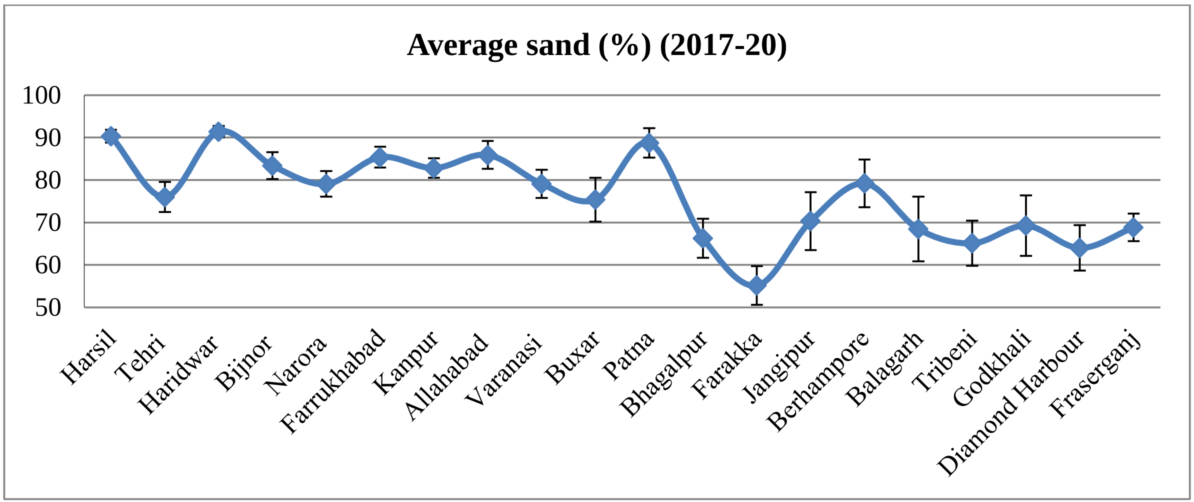


Fig. 98 Average sand content (%)of River Ganga

Table 34. Changing pattern of sand (%) over the years

Stretches	Sand (%)	Reference
Haridwar	97.3 - 99.8	Sinha et al 1998
	91	2017-2020
Kanpur	79.0 - 99.5 82	Sinha et al 1998 2017-2020
Varanasi	71	Pandey et 2014
	79	2017-2020
Diamond harbour	28	Mitra et al 2019
	64	2017-2020
Fraserganj	30.0 - 55.0	Sinha et al 1998
	68	2017-2020

Silt (%)

The percentage of silt in sediment in the entire stretch ranges from 1 to 27%. Highest average silt value of 27% was recorded at Farakka. In pre-monsoon, monsoon, post monsoon and winter the average silt in sediment was found 10%, 13%,13% and 13% respectively.

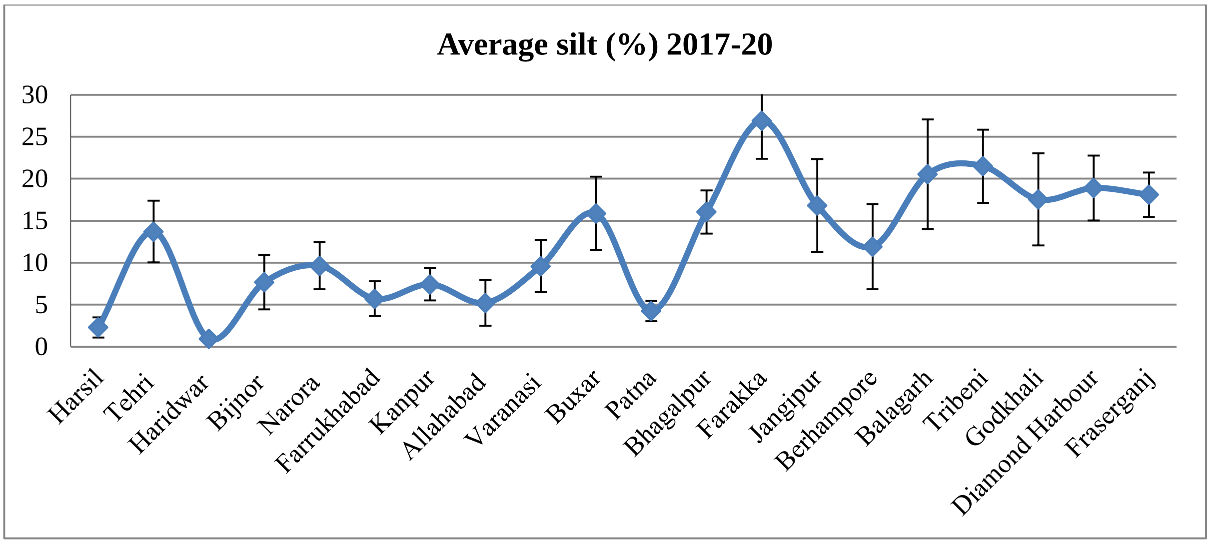


Fig. 99 Average silt content of River Ganga

Table 35. Changing pattern of silt (%) over the years

Stretches	Silt	Reference
Haridwar	0.2 - 1.1	Sinha et al 1998
	0.9	2017-2020
Kanpur	0.4 - 14.0	Sinha et al 1998
	7.43	2017-2020
Varanasi	25	Pandey et 2014
	10	2017-2020
Diamond Harbour	51	Mitra et al 2019
	19	2017-2020
Fraserganj	25.0 - 54.0	Sinha et al 1998
	18	2017-2020

Clay (%)

The percentage of clay of sediment in the entire stretch ranges from 6 to 18% (Fig. 100). Highest average clay value of 18% was recorded at Farakka. During the Pre-monsoon the average clay value was 9% and in monsoon, post monsson as well as winter the value was recorded as 12% 12% and 9% respectively.

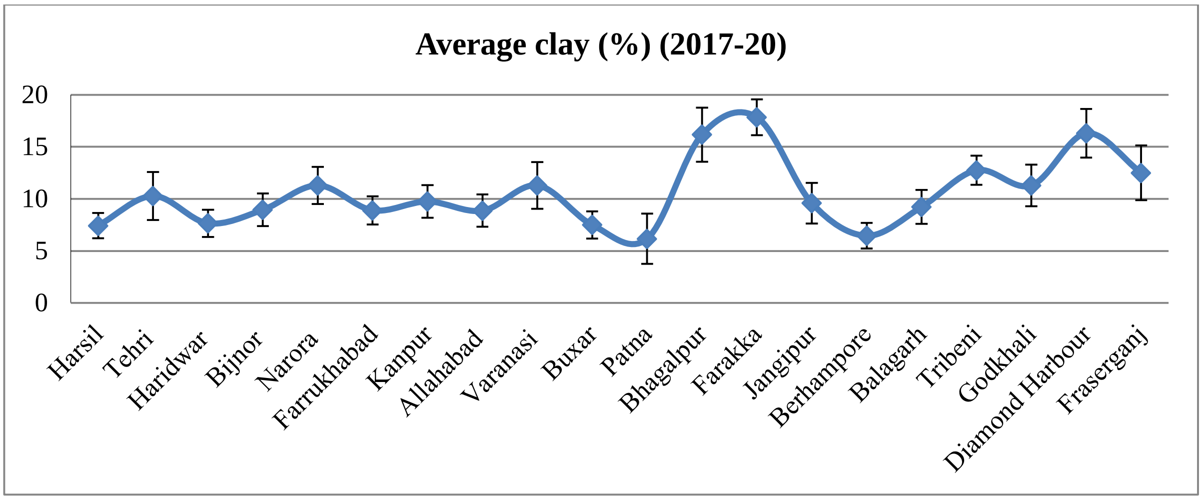


Fig.100 Average clay content(%) of River Ganga

Table 36. Changing pattern of clay (%) over the years

Stretches	Clay (%)	Reference
Kanpur	0.0 - 12.0	Sinha et al 1998
	8	2017-2020
Varanasi	3	Pandey et 2014
	11	2017-2020
Diamond Harbour	31	Mitra et al 2019
	16	2017-2020
Fraserganj	11.0 - 35.0	Sinha et al 1998
	13	2017-2020

Significant finding in changes of important water and sediment quality parameters during the study period of 2016-20

A comparison was made between dissolved oxygen level of 2017 and 2019 revealed that there is significant increase of average dissolved oxygen level in almost all the stations in 2019 with respect to those in 2017. In upper & middle stretch, significant improvement was observed at Haridwar (13.1%), Narora (17.5%), Kanpur (17.4%), Allahabad (32.71%) and Varanasi (7.6%). In lower stretch, improvement was observed at Buxar (6.9 %), Patna (21.8%) & Bhagalpur (27.5%). In estuarine stretch also, improvement was observed at Balagarh (46 %), Triveni (44.9 %), and Godakhali (26.4 %). However, supersaturated condition of oxygen level was obtained at Buxar, Patna, Balagarh and Tribeni (middle to lower stretch) during pre-monsoon mainly due to *Microcystis* sp. (Blue green algae)bloom formation and at Balagarh and Tribeni in winter due to bloom by the diatom, *Aulacoseira granulata.*

Conductivity values in freshwater often indicates the pollution status in a river. Studies in the year 2019 in the entire stretch of river Ganga observed decreasing of conductivity values at almost all the sampling stations with respect to those in 2017. In upper and middle stretch, significant reduction in specific conductivity of the river waterwas observed at Harshil (38.16%), Tehri (31.39%), Narora (36.3%), Farrukabad (32.03%), Kanpur (32.4%), Allahabad (31.45%) and Varanasi (18.33%). In lower stretch, significant reduction in specific conductivitywas observed at Buxar (2.7%) and Farraka (14.3%) showing the improvementin the health status of the river. Slightly higher values (>0.5 mS/cm) of conductivity and total hardness (~200 ppm) at Kanpur, Allahabad and Varanasi during pre-monsoon needs management intervention.Soilorganiccarbon accumulation in sediment was noted in few locations like Bijnaur(above barrage; 1.14%) due to partialstagnationofwater in the region and estuarine zone (like Fraserganj)records 1.08% due to higher primary productivity. On the other hand, slightly acidic sediment pH was noticed in hilly stretch of river Ganga during some occasions (Range 6.55 to 9.01; Average 8.02). Sandification of river bed (>90% sand) is a matter of concern especially upper and middle stretch of river up to Allahabad (Range 30 to 100 %; Average 76.48%).

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HEAVY METAL STATUS ALONG MIDDLE AND LOWER STRETCH OF RIVER GANGA

Metals in Water

The average concentration of metal in the river water is represented in Fig. 101 & 102. The average concentration of *Cadmium* in river water was found below detectable limit in all the stations except Fraserganj. All the metal concentrations in river water were found with in safe limit (US EPA , 2002; WHO, 1993).

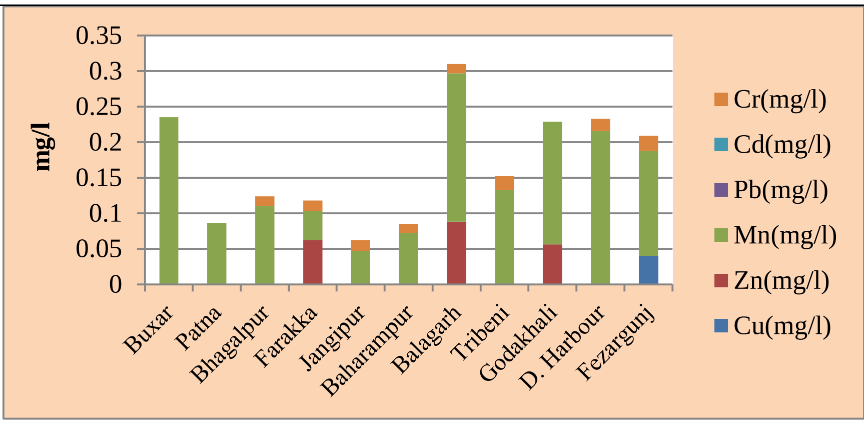


Fig. 101 Heavy metal in water of river Ganga (2018-19)

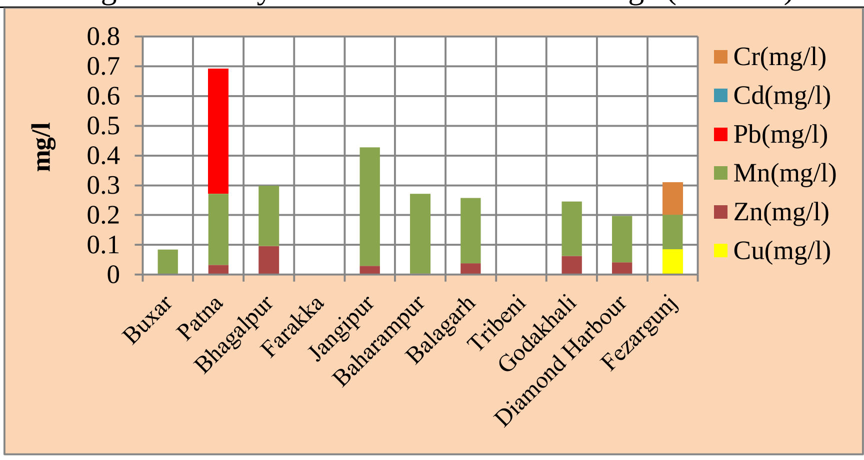


Fig. 102 Heavy metal in water of river Ganga (2019-20)

Metals in sediment

The average concentration of Cuwas found highest (34.95 mg/kg) at Bhagalpur (Bihar), which indicates the sediment in this stretch is moderately polluted (according tothe safe limit of heavy metal in sediment given by International Joint Commission (1982), US EPA (2002).The average concentration of Crrecorded highest (54.104 mg/kg) at Fraserganj (West Bengal). As per International Joint Commission (1982), US EPA (2002) safe limit of heavy metal in sediment the Chromium concentration at Fraserganj showing the moderately polluted area. During 2019-20, *Cu* was found highest in sediment at Godakhali (148.28

mg/kg) and average value was found 53.242 mg/kg. The *Zn* was found highest at Adi Ganga Khal (133.027 mg/kg) and average value was found 82.460 mg/kg. The *Mn* was found highest at Diamond Harbour (363.883 mg/kg) and average value was found 249.101 mg/kg. The *Pb* and *Cd* were below detection level at all sampling sites. The *Cr* was found highest at Buxar (150.552 mg/kg) and average value was found 87.942 mg/kg.

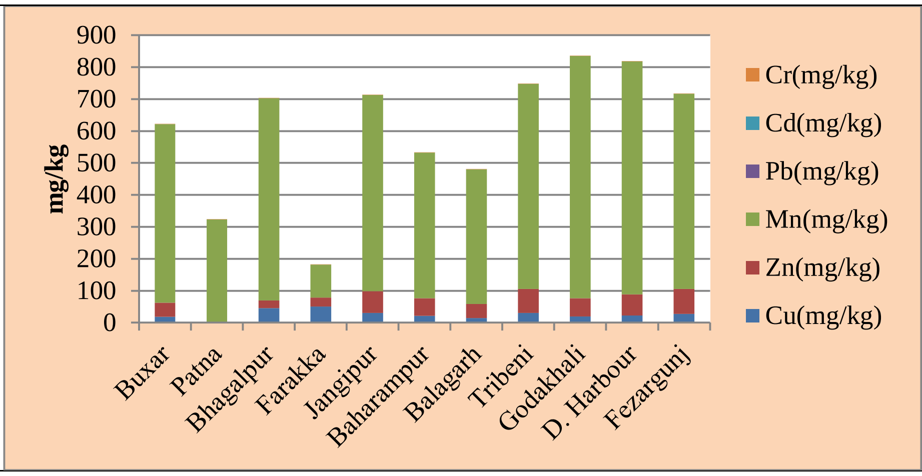


Fig. 103 Heavy metal in sediment of River Ganga (2018-19)

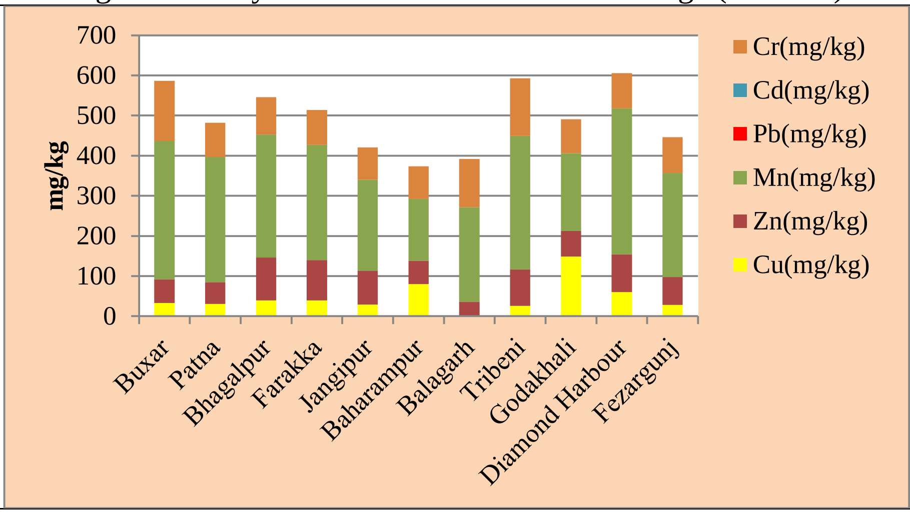


Fig. 104 Heavy metal in Sediment of River Ganga (2019-20)

Heavy metal in periphytic algae

In case of *Copper* the highest concentration (20.174 µg/g) found at Buxar, lowest concentration (12.349 µg/g) found at Diamond Harbour and not found at Jangipur. In case of *Zinc* the highest concentration (215.11µg/g) found at Jangipur and lowest concentration (31.753 µg/g) found at Baharampur. In case of *Manganese* the highest concentration (191.164µg/g) found at Jangipur and lowest concentration (78.07µg/g) found at Diamond Harbour. In case of *Lead* the highest concentration (26.451 µg/g) found at Buxar, lowest concentration (21.734 µg/g) found at Jangipur. In case of *Cadmium* all the nine sites are free from this metal. In case of *Chromium* the highest concentration (79.035 µg/g) found at Buxar and lowest concentration (17.601 µg/g) found at Jangipur.

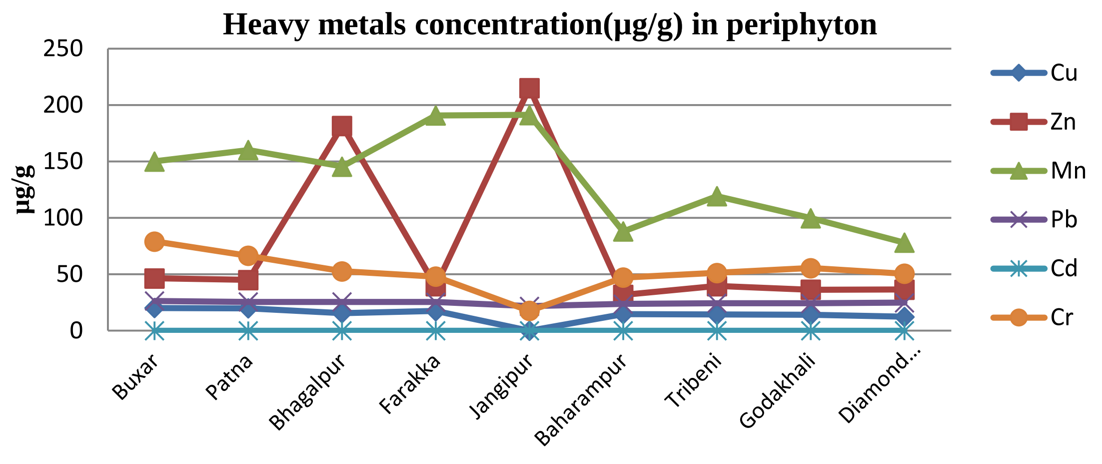


Fig. 105 Heavy metal concentration in periphytic algae at Ganga river stretch

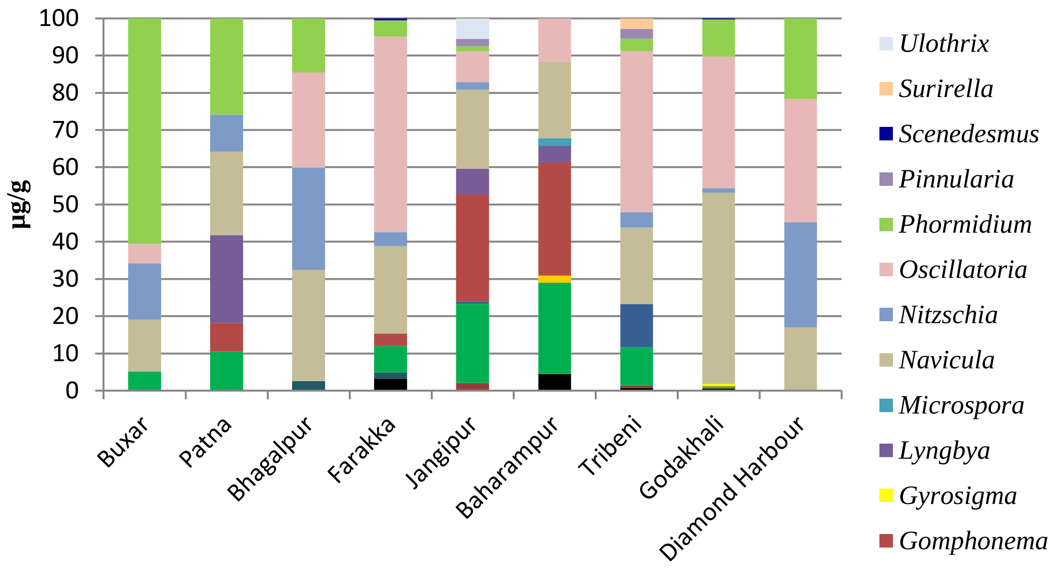


Fig. 106 Heavy metal concentration in different species of periphytic algae at Ganga river stretch

At Buxar region five types of periphyton genus are identified and according to their percentage of availability, *Phormidium* (60.61) > *Nitzschia* (15.15) > *Navicula* (13.85) > *Cymbella* (5.19) = *Oscillatoria* (5.19) were observed. At Patna region seven types of periphyton genus are identified and according to their percentage of availability, *Phormidium* (25.88) > *Lyngbya* (23.53) > *Navicula* (22.35) > *Cymbella* (10.59) > *Nitzschia* (10) > *Gomphonema* (7.65) > *Scenedesmus* (0.59) were observed. At Bhagalpur region five types of periphyton genus are identified and according to their percentage of availability, *Navicula*

(29.91) > *Nitzschia* (27.35) > *Oscillatoria* (25.64) > *Phormidium* (14.53) > *Cyclotella* (2.56) were observed. At Farakka region eight types of periphyton genus are identified and according to their percentage of availability, *Oscillatoria* (52.43) > *Navicula* (23.49) > *Cymbella* (7.10) > *Phormidium* (4.37) > *Nitzschia* (3.82) > *Aulacoseira* (3.28) = *Gomphonema* (3.28) > *Cyclotella* (1.64) were ovserved. At Jangipur region, eleven types of periphyton genus are identified and according to their percentage of availability,*Gomphonema* (28.77) > *Cymbella* (21.23) = *Navicula* (21.23) > *Oscillatoria* (8.22) > *Lyngbya* (6.85) > *Ulothrix* (5.48) > *Caloneis* (2.05) = *Nitzschia* (2.05) = *Pinnularia* (2.05) > *Phormidium* (1.37) > *Fragilaria* (0.68) were observed. At Baharampur region, eight types of periphyton genus are identified and according to their percentage of availability, *Gomphonema* (30.32) > *Cymbella* (24.51) > *Navicula* (20.64) > *Oscillatoria* (11.61) > *Aulacoseira* (4.52) = *Lyngbya* (4.52) > *Euglena* (1.94) = *Microspora* (1.94) were observed. At Tribeni region, ten types of periphyton genus are identified and according to their percentage of availability, *Oscillatoria* (43.15) > *Navicula* (20.55) > *Fragilaria* (11.64) > *Cymbella* (10.27) > *Nitzschia* (4.11) > *Phormidium* (3.42) > *Pinnularia* (2.74) = *Surirella* (2.74) > *Aulacoseira* (0.68) = *Caloneis* (0.68) were observed. At Godakhali region, eight types of periphyton genus are identified and according to their percentage of availability, *Navicula* (51.36) > *Oscillatoria* (35.35) > *Phormidium* (9.97) > *Nitzschia* (1.21) > *Aulacoseira* (0.60) = *Chroococcus* (0.60) = *Gyrosigma* (0.60) > *Scenedesmus* (0.30) were observed. At Diamond Harbour region four types of periphyton genus are identified and according to their percentage of availability, *Oscillatoria* (33.02) > *Nitzschia* (28.30) > *Phormidium* (21.70) > *Navicula* (16.98) were observed.

Heavy metal in Fish

Concentration (µg/g) of metals in fish flesh

Copper was found 0.18 µg/g in the flesh of *R.rita* fish and the flesh of others 13 fishes found below detection limit. *Zinc* was found in the flesh of *M. cavassius* (55.42 µg/g), *P. conchonius* (39.321 µg/g), *X. cancila* (38.094 µg/g), *O. rubicundus* (22.53 µg/g), *R. rita* (2.178 µg/g) and the flesh of others 9 fishes found below detection limit. *Manganese* was found below detection limits among all the 14 fishes. *Lead* found 5.439 µg/g in the flesh of *R. rita* fish and flesh of others 13 fishes found below detection limits. *Cadmium* is below detection limits among all the 14 fishes. *Chromium* was found in the flesh of *R. rita* (0.676 µg/g), *S. Phasa* (0.013 µg/g) and the flesh of others 12 fishes found below detection limit.

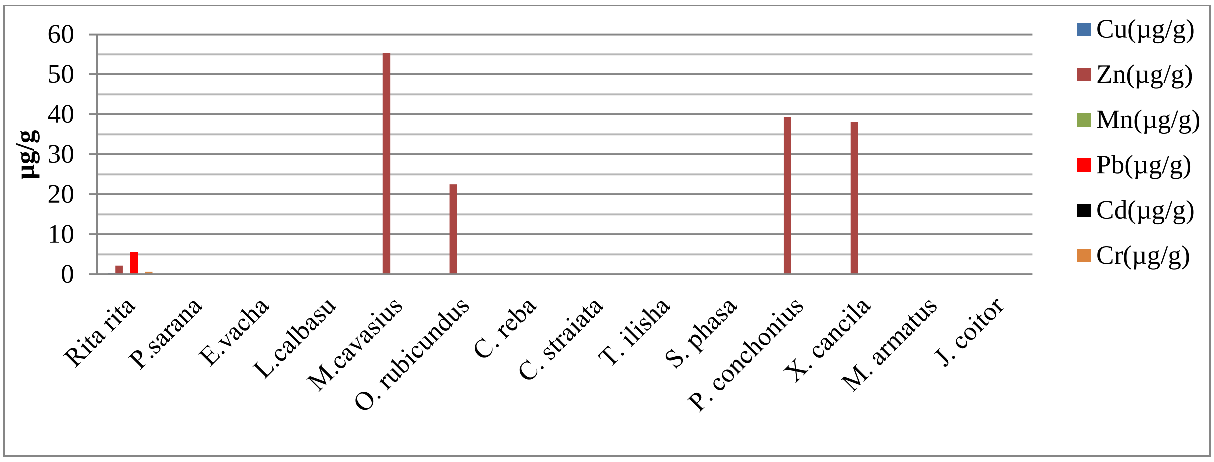


Fig. 107 Heavy metal Concentrations (µg/g) in fish flesh (2018-19)

Heavy metal Concentrations in fish (2019-20)

During 2019-20, different body parts of five fishes have been analysed. In fishes, during this period *Cu* was found highest in the flesh of *W. attu* (100.776 µg/g) and average value was found 14.396 µg/g. The *Zn* was found highest in the gill of *L. gonius* (304.61 µg/g) and average value was found 68.878 mg/kg. The *Mn* was found highest in the gill of *L. gonius* (178.57 µg/g) and average value was found 43.395 µg/g. The *Pb*, *Cd* and *Cr* were below detection level in body parts of all fishes.

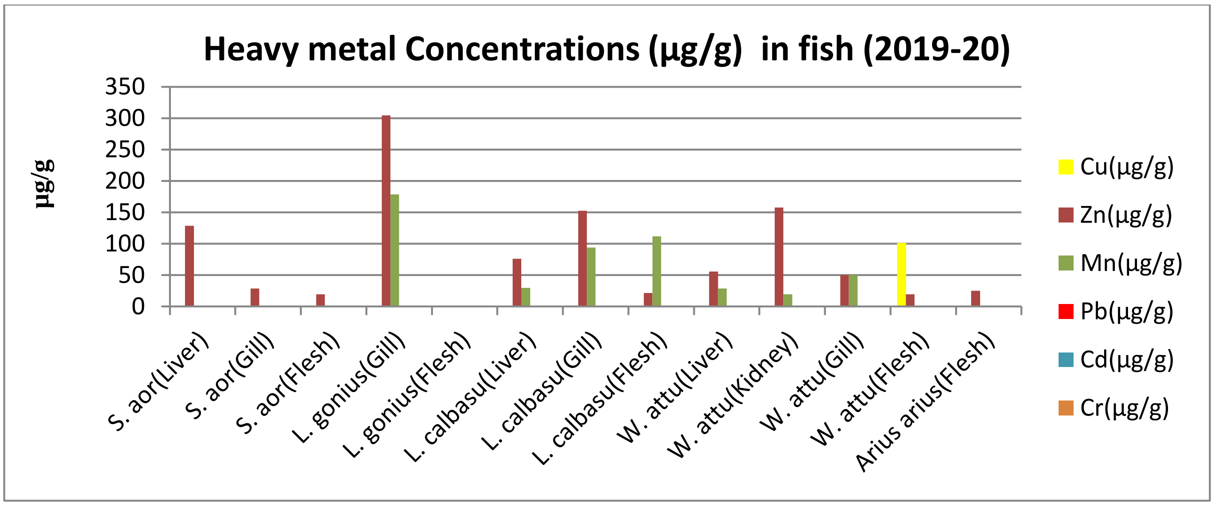


Fig. 108 Heavy metals status in body parts of fishes

Table 37. Safe limits for heavy metal residue in water, soil and fish as per International standards

Source	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Reference**
				Water (μg/l)				
Fresh water	0.25	11/74	9	-	52	2.5	120	US EPA (2002)
Saline water	8.8	50	3.1	-	8.2	8.1	81	
Drinking water	0.003	0.05	2	0.5	-	0.01	3	WHO (1993)

				Soil (μg/g)				
Not polluted	-	< 25	< 25	-	< 20	< 40	< 90	International Joint Commission (1982), US EPA (2002)
Moderate pollution	-	25 – 75	25 – 50	-	20 – 50	40 – 60	90 – 200	
Heavy pollution	> 6	> 75	> 50	-	> 50	> 60	> 200	

				Aquatic organism (μg/g)				
Fish	3	12	-	-	70	1.5	-	US FDA (2001)
Crustacean	4	13	-	-	80	1.7	-	

Safe limits for heavy metal residue in fish (μg/g) as per various country specific standards

Source	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Reference**
				Fish flesh in μg/g				
Freshwater fish	2 (Hong Kong)	1 (Hong Kong)	10 (India) Dry Wt basis	-	-	5 (India) Dry wt. basis	50 (India) Dry Wt basis)	Nauen, 1983
Marine fish	2 (Hong Kong)	1 (Hong Kong)	10 (India) Dry wt basis	-	-	5 (India) Dry wt basis	50 (India) Dry wt basis	
Shellfish	2 (Hong Kong)	1 (Hong Kong)	30 (Australia)	-	-	6 (Hong Kong)	40 (Australia)	

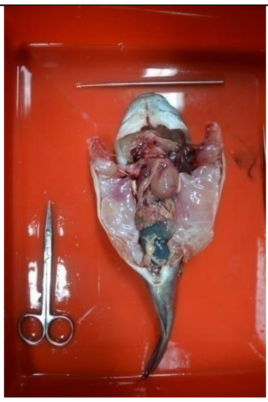
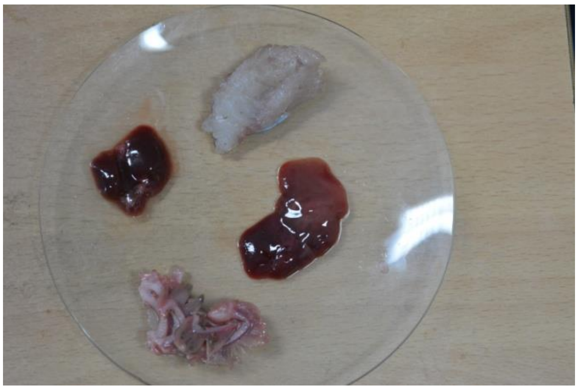
	
109a	109b
	
109c	109d

Fig. 109 (a-d) Heavy metal analysis and collection procedures of samples

PLANKTONIC STATUS IN RIVER GANGA

Plankton are diverse collection of aquatic organisms which drifts with the help of water current and are well-known biological indicator. Phytoplankton occupies the base position in the ecological food pyramid because of its autotrophic mode of nutrition. Phytoplankton's are considered as the wealth of a healthy aquatic ecosystem, as they are an integral part of the aquatic food chain (Tas and Gonulal, 2007; Saravana kumar et al., 2008). Among all the photosynthetic organisms, phytoplankton contributes 40% photosynthetic product (Schmidt, 2000). Plankton and other aquatic organisms are well-known for their role in monitoring the health status of any water bodies (Boyd, 1982). Due to their short life-cycle, they are vibrantly influenced by the environmental factor. Phytoplankton can be used to determine the trophic status of the water body (Meena et al., 2019). Biomass and community structure of phytoplankton are found lower in the river as compared to lentic waters. The density and dimensional distribution of zooplankton narrate the biotic and abiotic factors of the water body (Marneffe et al., 1998).

Methodology

Quarterly Sampling was done during 2016-2020 between 8.00 to 9.00 hours in the selected stretch of River Ganga**.** A conical shaped plankton net, fitted with a stainless-steel ring of very fine mesh size (20µm) was used for plankton filtration. A total of 100 litres of river water was filtered with the help of plankton net having mesh size (20 µm). Further, the amount of concentrated river water with planktons was collected in dry air tight HDPE plastic containers. Collected samples were then fixed and preserved by adding 4% Neutral Buffer formalin (NBF) solution and kept for quantitative analysis. Prior to analysis the collected concentrated samples were diluted (15mlwater+5ml sample) and observed under microscope. Samples were examined by employing Trinocular microscope (40x and 60x magnification; Scope.A1 AXIO Zeiss) and identification were done using various key notes (Desikachary, 1959; Prescott, 1962; Datta-Munshi, 2018; Bellinger and Sigee, 2015 and Cox, 1996). AlgaeBase was followed to validate the updated names. Quantitative analysis was carried out by using drop count method and was expressed as unit litre^{-1}.

Fig. 110a

Fig. 110b

Fig. 110c

Fig. 110d

Fig. 110 (a-d) Collection of sample and preservation of plankton

Phytoplanktonic species record from river Ganga

The survey recorded a total of 95 genera of phytoplankton, belonging to 13 classes and 7 phyla. The recorded phyla are Bacillariophyta, Chlorophyta, Cyanophyta, Dinophyta, Xanthophyta, Zygnematophyta, and Euglenophyta. Bacillariophyceae (26 genera), Coscinodiscophyceae (4 genera), Mediophyceae (6 genera), Dinophyceae (2 genus), Ulvophyceae (2 genera), Chlorophyceae (20 genera), Trebouxiophyceae (6 genera), Zygnematophyceae (8 genera), Xanthophyceae (4 genera), Synurophyceae (1 genus), Euglenophyceae (4 genera), Cyanophyceae (12 genera) were recorded. The diversity and density of phytoplankton was observed higher in all the stretches than that of zooplankton.

❖ In the upper stretch, Bacillariophyceae (19 genera), Coscinodiscophyceae (2 genera), Mediophyceae (2 genera), Ulvophyceae (2 genera), Chlorophyceae (13 genera), Trebouxiophyceae (5 genera), Zygnematophyceae (5 genera), Xanthophyceae (3 genera),Synurophyceae (1 genus), Euglenophyceae (3 genera), Cyanophyceae (9 genera) were recorded.

- ❖ In the middle stretch, Bacillariophyceae (23 genera), Coscinodiscophyceae (3 genera), Mediophyceae (2 genera), Dinophyceae (1 genus), Ulvophyceae (1 genus),Chlorophyceae (20 genera), Trebouxiophyceae (6 genera), Zygnematophyceae (8 genera), Xanthophyceae (3 genera), Euglenophyceae (4 genera), Cyanophyceae (12 genera) were recorded.
- ❖ In the lower stretch, Bacillariophyceae (17 genera), Coscinodiscophyceae (4 genera), Mediophyceae (5 genera), Dinophyceae (1 genus), Noctilucophyceae (1 genus), Ulvophyceae (2 genera), Chlorophyceae (13 genera), Trebouxiophyceae (5 genera), Zygnematophyceae (5 genera), Synurophyceae (1 genus), Euglenophyceae (3 genera), Cyanophyceae (9 genera) were recorded.

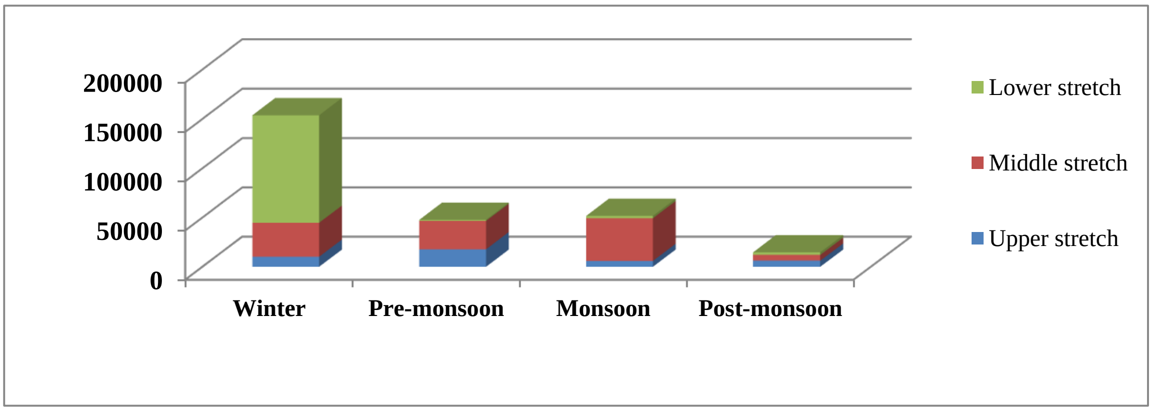


Fig. 111 Seasonal variation in Phytoplankton density at different stretches of river Ganga (2016-2020)

- ❖ In Upper stretch, the highest density of phyto-planktonic community was found during pre-monsoon (17797 unit/l) and lowest during monsoon (5960 unit/l) (Fig. 112).
- ❖ In Middle stretch, highest density of phyto-planktonic community was found during monsoon (43347 unit/l) and lowest during post-monsoon (5840 unit/l) (Fig. 112).
- ❖ In Lower stretch, the highest density of pyhto-planktonic community was found during winter (109036 unit/l) and lowest during pre-monsoon (1091 unit/l) (Fig. 112).

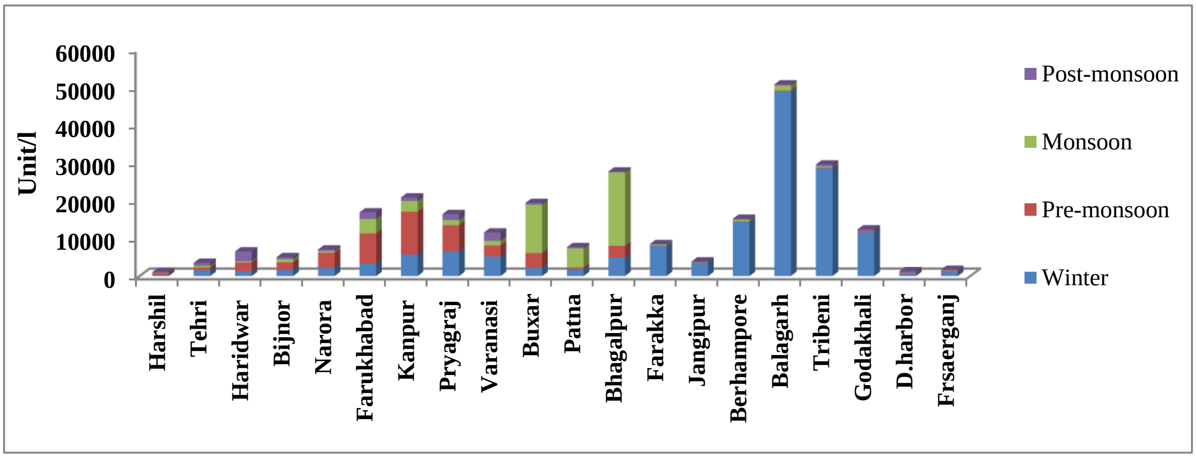


Fig. 112 Seasonal variation in Phyto plankton density at different station of river Ganga (2016-2020)

Highest density of phyto-planktonic community was recorded at Kanpur (11385 unit/l) and lowest at Farakka (82 unit/l) during pre-monsoon. During monsoon highest dominance was recorded at Bhagalpur (19552 unit/l) and lowest at Godakhali(40 unit/l). During post-monsoon highest density was recorded at Haridwar (2622 unit/l) and lowest at Harshil (130 unit/l), while recorded highest at Balagarh (49070 unit/l) and lowest at Harshil (210 unit/l) during winter season.

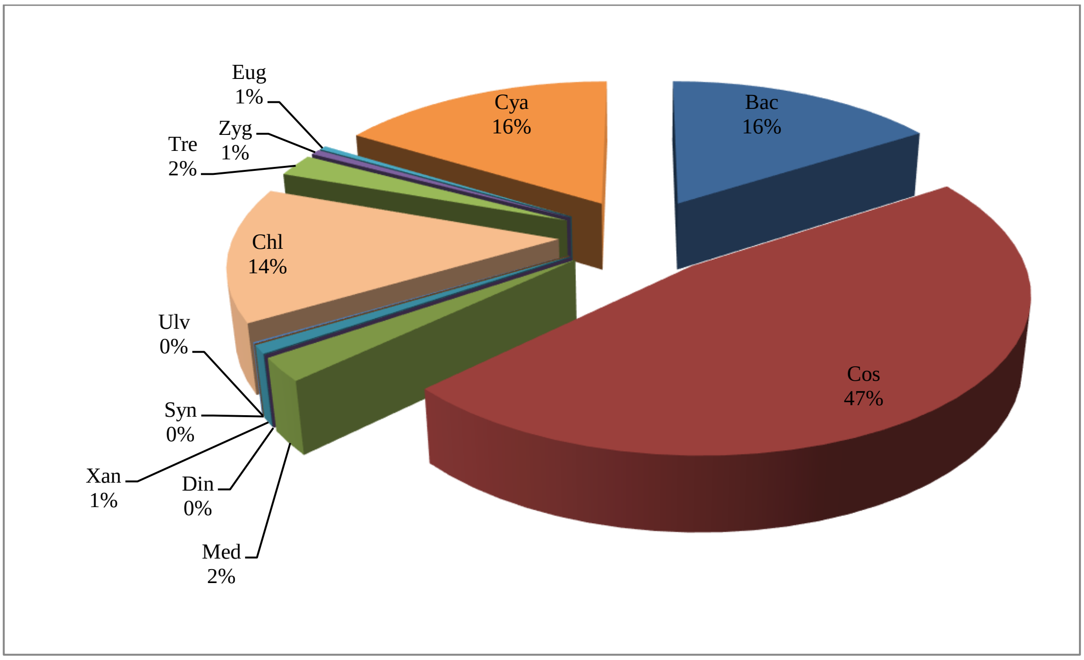


Fig. 113 Percentage density of different algal group of river Ganga

Percentage density of different algal groups in two years was shown in the Fig. 113. The highest abundance was contributed by Coscinodiscophyceae (47%), followed by Bacillariophyceae (16%), Cyanophyceae (16%), and Chlorophyceaee (14%).

Phylum wise description of the recorded Phytoplankton

1. Bacillariophyta

Diatoms are of two types based on cell shape and frustule morphology one is centric and another is pinnate. In the river, Ganga diatoms were found dominated during post-monsoon and winter over other groups (Lakshminarayana, 1965). The bloom of *Aulacoseira* sp.was noticed in river. They are regarded to be dominant species in inland freshwater (Ambawaniet al., 2003) due to the eutrophic condition of the water body. Some dominant genera are *Aulacoseira* sp., *Cyclotella* sp., *Asterionella* sp., *Navicula* sp., *Fragilaria* sp., *Synedra* sp. etc.

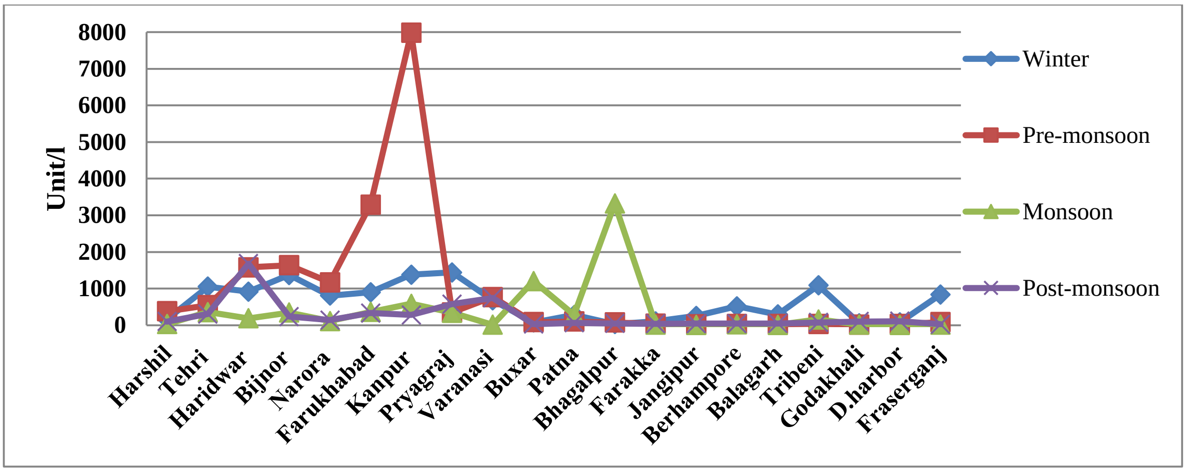


Fig. 114 Seasonal variation in Bacillariophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

The group Bacillariophyceae was recorded to be dominant in post-monsoon (18232 unit/l) followed by winter (1228 unit/l) (Fig.114). Among all the sampling stations Kanpur (7985 unit/l) has shown vivid dominancy of Bacillariophyceae during pre-monsoon time and lowest density was observed at Godakhali (15 unit/l). During monsoon,thehighest dominance was recorded at Bhagalpur (3321 unit/l) and lowest at Diamond Harbour (2 unit/l). During post-monsoon, highest density was recorded at Haridwar (1680 unit/l) and lowest density was recorded at Fraserganj (25 unit/l) and during winter highest density was recorded at Kanpur (1380 unit/l) and lowest recorded at Bhagalpur (28 unit/l).

Coscinodiscophyceae

The class Coscinodiscophyceae was recorded to be dominant in winter (105105 unit/l). Farrukhabad (825 unit/l) has shown vivid dominancy of Bacillariophyceae during pre-monsoon time and lowest density at Farakka (10 unit/l). During monsoon,thehighest dominance was recorded at Buxar (2467 unit/l) and lowest at Harshil (20 unit/l). During post-monsoon highest at Farrukhabad (530 unit/l) and lowest at Bhagalpur (19 unit/l) and during winter highest at Balagarh (45230 unit/l) and lowest at Tehri (70 unit/l).

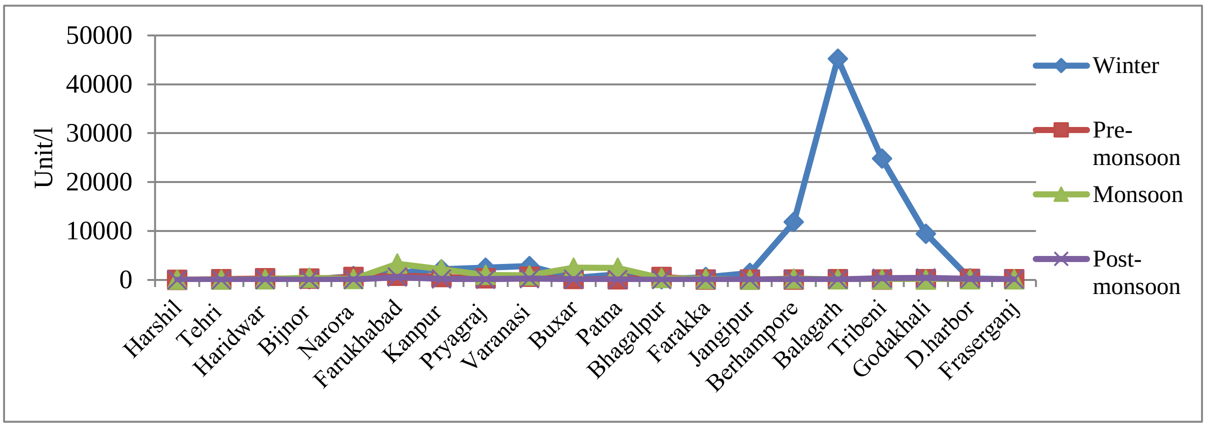


Fig. 115 Seasonal variation in Coscinodiscophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

Mediophyceae

The class Mediophyceae belongs to phylum Bacillariophyta and highest density was observed during winter (4100 unit/l) followed by post-monsoon (1206 unit/l). High density of this class was recorded at Buxar (540 unit/l) and lowest at Godakhali (2 unit/l) during pre-monsoon. During monsoon, thehighest dominance was recorded at Buxar (83 unit/l) and lowest at Farakka (2 unit/l). During post-monsoon highest at Haridwar (650 unit/l) and lowest at Jangipur and Berhampore during winter highest at Balagarh (1001unit/l) and lowest at Bijnor (10 unit/l).

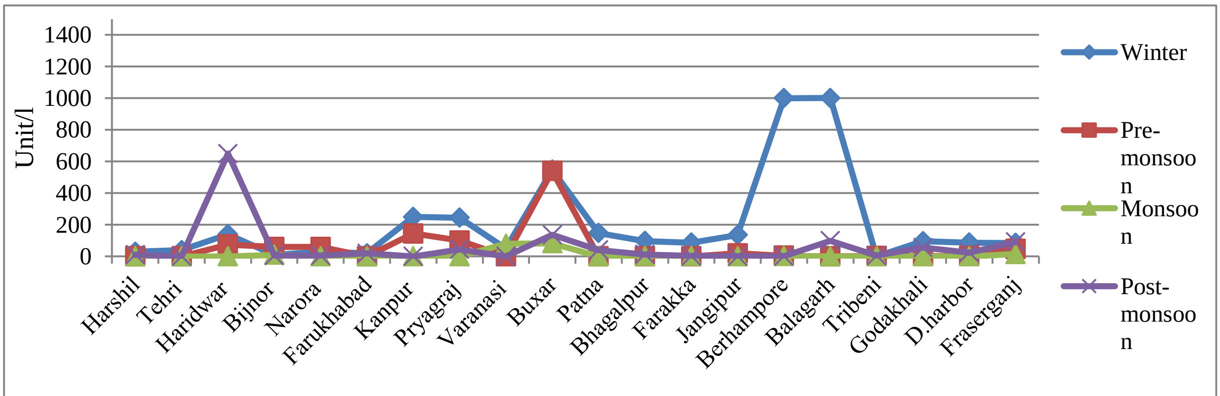


Fig.116 Seasonal variation in Mediophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

2. Xanthophyta

The genera of this group are unicellular, colonial, or filamentous. A total 5 genera belong 2 classes and 5 families were recorded during study period. *Ophiocytium* sp., *Centritractus* sp., *Tribonema* sp., *Mallomonas* sp., etc. were commonly found in this group.

Xanthophyceae

The class Xanthophyceae belongs to phylum Xanthophyta. Its highest density was observed during winter (1181 unit/l) followed by pre-monsoon (735 unit/l). Among all the sampling stations highest density of this class was recorded at Kanpur (475 unit/l) and lowest at Prayagraj (20 unit/l) during pre-monsoon. During monsoon the class was found only at Narora (25 units/l). During post-monsoon highest density was recorded at Varanasi (138unit/l) and lowest at Patna. During winter highest density was recorded at Varanasi (730 unit/l) and lowest at Fraserganj (1 unit/l).

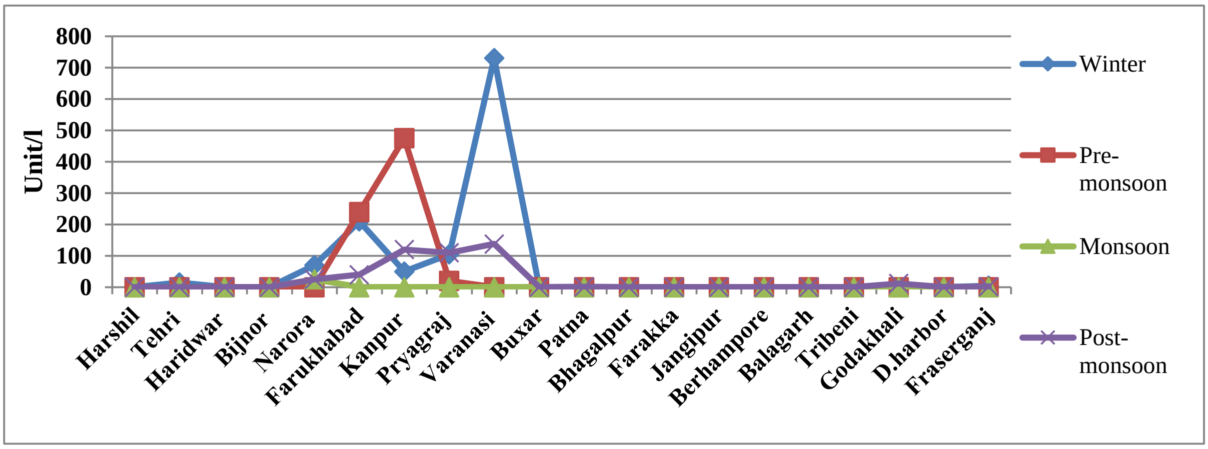


Fig. 117 Seasonal variation in Xanthophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

3. Chlorophyta

These groups are mostly found in green colour because of the presence of a photosynthetic pigment namely chlorophyll a and b. Total 28 genera belongs 3 classes and 14 families were recorded during study period. *Scenedesmus* sp., *Volvox* sp., *Eudorina* sp., *Pediastrum* sp., *Crucigenia* sp., *Chlorella* sp. were commonly found in this group.

Ulvophyceae

The class Ulvophyceae belongs to phylum Chlorophyta. Its highest density was observed during winter (278 unit/l). High density of this class was recorded at Bhagalpur and lowest was observed at Tribeni during pre-monsoon. During post-monsoon, the highest density was recorded at Haridwar and during winter highest at Prayagraj (150unit/l).

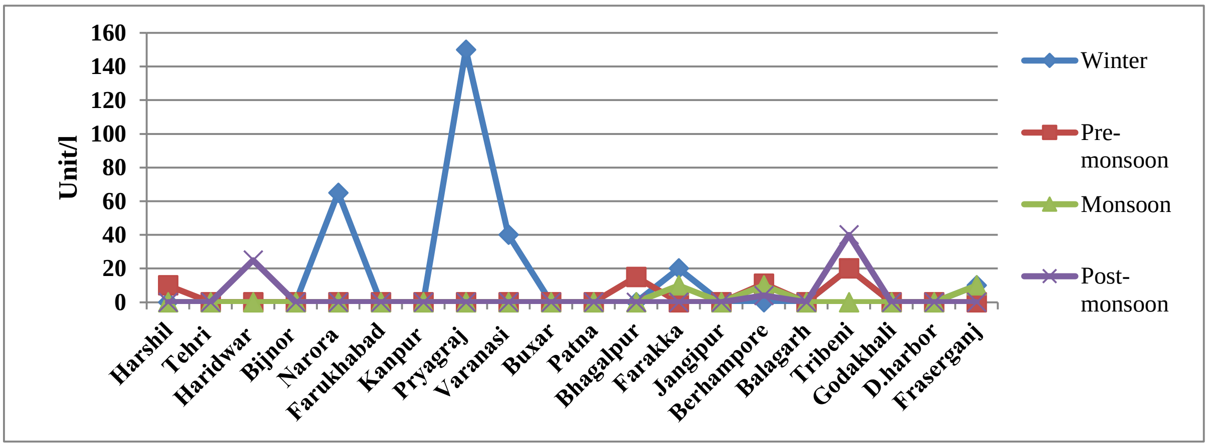


Fig. 118 Seasonal variation in Ulvophyceaeofphy to-plankton at different stretches of river Ganga (2016-2020)

Chlorophyceae

The class Chlorophyceae belongs to phylum Chlorophyta and highest density was observed during winter (22550 unit/l) followed by pre-monsoon (11865 unit/l). High density of this class was recorded at Prayagraj (475 unit/l) and lowest at D. Harbour (10 unit/l) during pre-monsoon. During monsoon, highest dominance was recorded at Buxar (343 unit/l) and lowest at Farakka (20 unit/l). During post-monsoon, highest at Farrukhabad (450 unit/l) and lowest at Balagarh (20 unit/l) during winter highest at Farakka (6206 unit/l) and lowest at Harshil (10 unit/l).

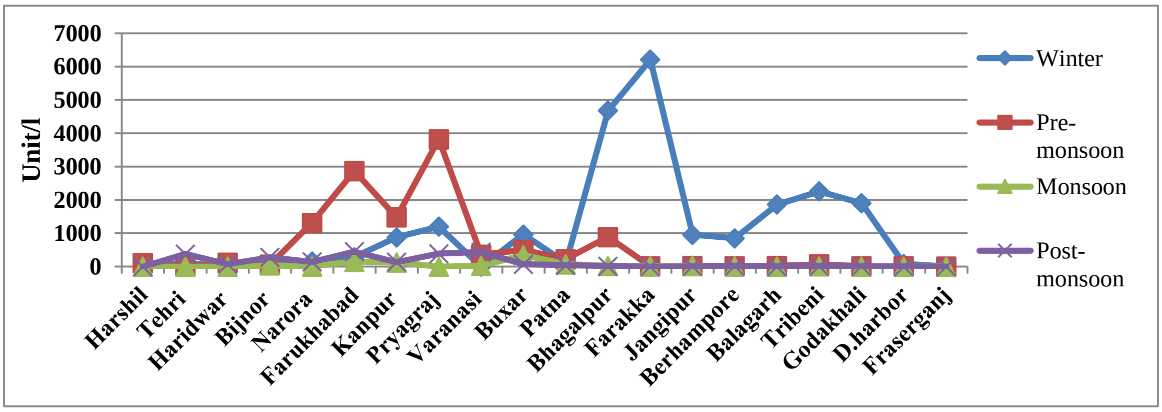


Fig. 119 Seasonal variation in Chlorophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

Trebouxiophyceae

The class Trebouxiophyceae belongs to phylum Chlorophyta and its highest density was observed during winter (3165 unit/l) followed by pre-monsoon (2059 unit/l). High density of this class was recorded at Narora (635 unit/l) and lowest at Balagarh, Tribeni, Godakhali during pre-monsoon. During monsoon, highest dominance was recorded at Varanasi (240 unit/l) and lowest at Farakka (10 unit/l). During post-monsoon, highest dominance was recorded at Farrukhabad (220 unit/l) and lowest at Farakka, Berhampore, Balagarh. During winter, highest density was found at Kanpur (930 unit/l) and lowest at D. Harbour (10 unit/l).

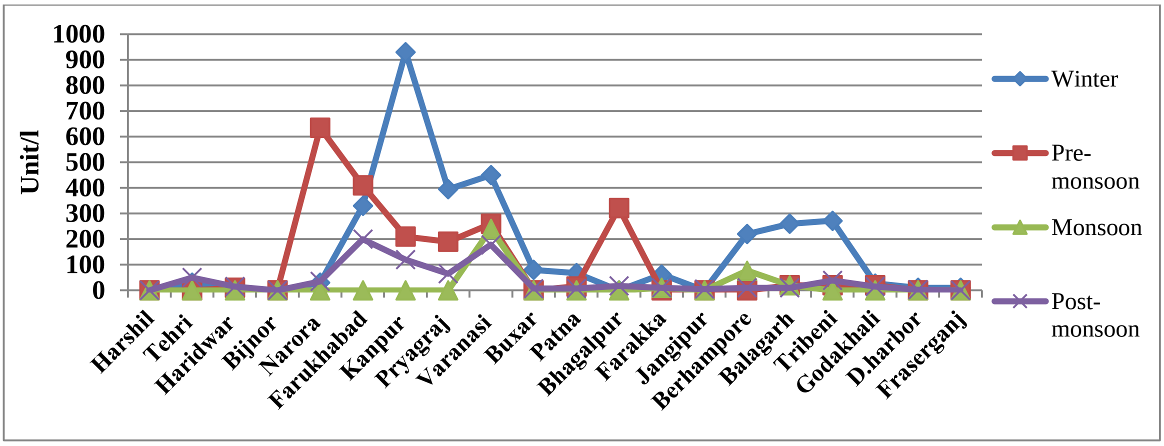


Fig. 120 Seasonal variation in Trebouxiophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

4. Zygnematophyta

The members of Zygnematophyta are one of the most diverse green algae, with a variation in thallus types (filaments, unicellular, colonies).The conjugating green algae are important ecological indicator species and for the ecological services they provide. A total of eight genera belonging toone class and three families were recorded during study period. *Closterium* sp., *Staurastrum* sp., *Cosmarium* sp., *Spirogyra* sp., *Mougeotia* sp., *Zygnema* sp. etc. were commonly found in this group.

Zygnematophyceae

The class Zygnematophyceae belongs to phylum Zygnematophyta and highest density was observed during pre-monsoon (705unit/l) followed by winter (575 unit/l) (Fig. 121). Highest density of this class was recorded at Narora (260 unit/l) and lowest was observed at Godakhali during pre-monsoon. During monsoon, highest dominance was recorded at Godakhali (11 unit/l) and lowest at Patna (10 unit/l). During post-monsoon, highest dominance was recorded at Prayagraj (65 unit/l) and lowest at Tribeni (15 unit/l). During winter, highest density was found at Bijnor (130 unit/l) and lowest at Farakka (10 unit/l).

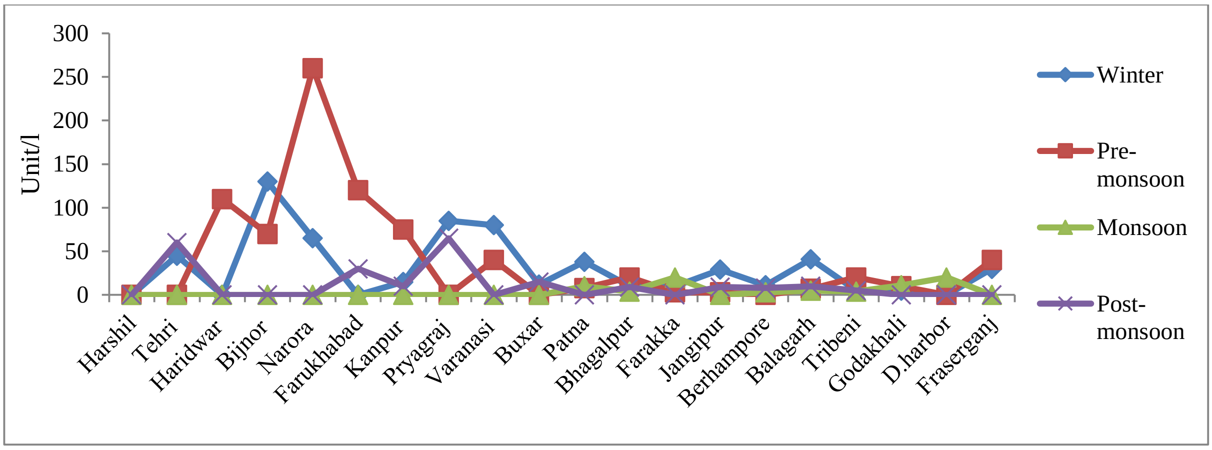


Fig. 121 Seasonal variation in Zygnematophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

5. Euglenophyta

Genera of the group are mostly unicellular with colonial morphology. Cells have flagella, which are emergent from the flask-shaped depression on the anterior side. An eye-spot is present. A total of fourgenera belonging to one class and 2 families were recorded during study period. *Euglena* sp., *Phacus* sp., *Trachelomonas* sp., *Lepocinclis*sp., etc. were commonly found in this group.

Euglenophyceae

The class Euglenophyceae belongs to phylum Euglenophyta and its highest density was observed during pre-monsoon (5650unit/l) followed by winter (420 unit/l)) (Fig. 122). High density of this class was recorded at Prayagraj (440 unit/l) and lowest at Bijnor (5 unit/l) during pre-monsoon. During monsoon, the Class had very less density and was recorded in all the stretches. During post-monsoon highest dominance was recorded at Haridwar (45 unit/l) and lowest was observed at Berhampore. During winter, highest density was found at Prayagraj (225 unit/l) and lowest at Godakhali (30 unit/l).

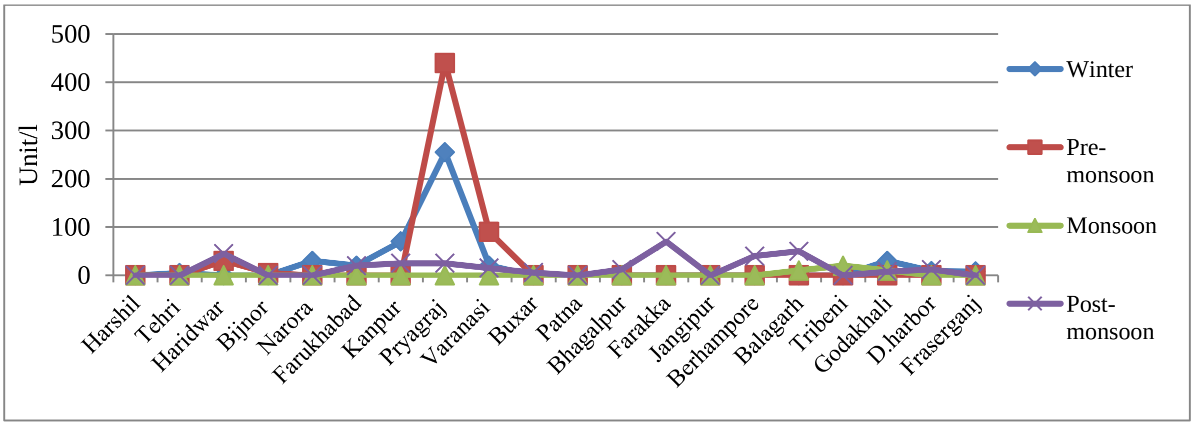


Fig. 122 Seasonal variation in Euglenophyceae of phyto-plankton at different stretches of river Ganga (2016-2020)

6. Cyanophyta

In monsoon, the group was found to be dominant at Buxar and Bhagalpur due to bloom of genus *Microcystis* sp. The possible reasons behind the bloom was high nutrient enrichment due to sewage, industry and agricultural farm runoff, which has made a loss of aquatic plants and promotes the growth of phytoplankton. *Chroococcus* sp., *Microcystis* sp., *Merismopedia* sp., *Aphanizomenon* sp., *Nodularia* sp., *Oscillatoria* sp., *Phormidium* sp.,etc. were commonly found in this group.

Cyanophyceae

The class Cyanophyceae belongs to phylum Cyanophyta and highest density was observed during monsoon (28656 unit/l) followed by pre-monsoon (7650 unit/l) (Fig. 123). High density of this class was recorded at Buxar (2667 unit/l) and lowest at Godakhali (10 unit/l) during pre-monsoon. During monsoon highest dominance was recorded at Bhagalpur (15852 unit/l) and lowest at Fraserganj (4 unit/l). During post-monsoon highest dominance was recordedat Varanasi (450 unit/l) and lowest at Narora (5 unit/l). During winter highest density was found atFarakka (1007 unit/l) and lowest at Fraserganj (3 unit/l). A bloom of Cyanophyceae was noticed during the month of June followed by July in Buxar, Patna, and Bhagalpur. This might be due to high conductivity attributed by agricultural activity that enhances the growth of *Mycrocystis* sp., which is one of the toxic genera of the group Cyanophyceae.

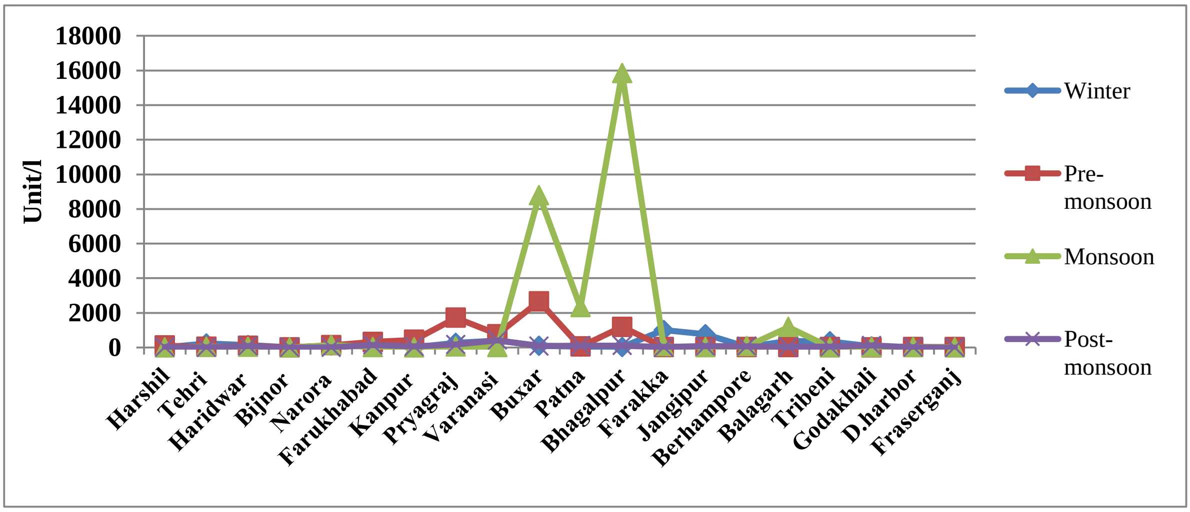


Fig. 123 Seasonal variation in Cyanophyceae of phytoplankton at different stretches of river Ganga (2016-2020)

Brackish water species phyto-planktono in river Ganga

Brackishwater plankton species such as *Noctiluca* sp., *Chaetocerus* sp., *Dictylum*sp., *Odontella* sp, *Entomoneis* sp., *Thallasionema* sp., *Rhizosolenia* sp., *Skeletonema* sp., etc. were recorded from Godakhali and Fraserganj due to saline condition.

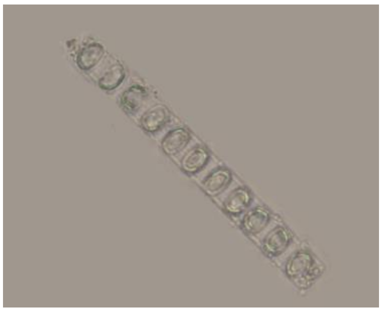


Fig. 124a *Skeletonema* sp

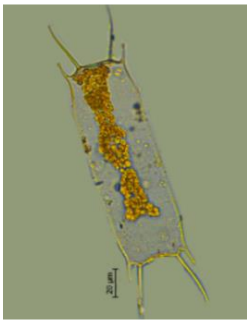


Fig. 124b *Odontella* sp

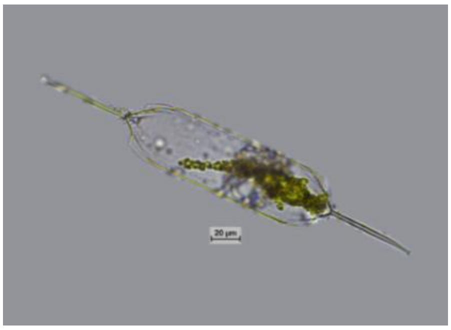


Fig. 124c *Dictylum* sp.

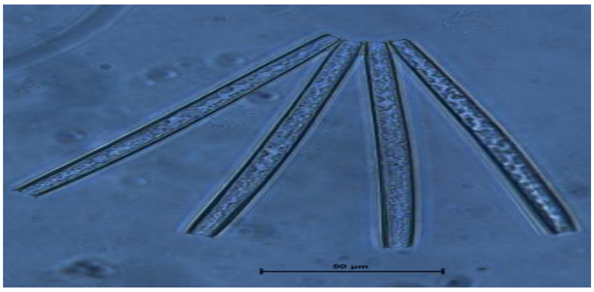


Fig. 124d *Thallasionema* sp.

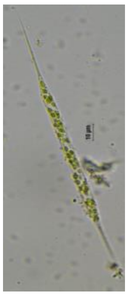


Fig. 124e *Rhizosolenia* sp.

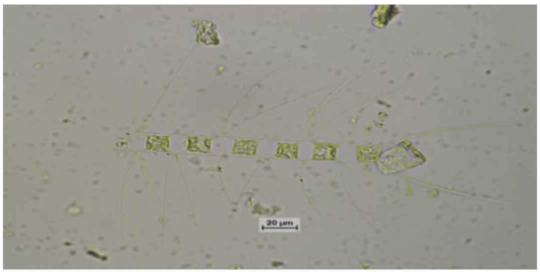


Fig. 124f *Chaetoceros* sp.

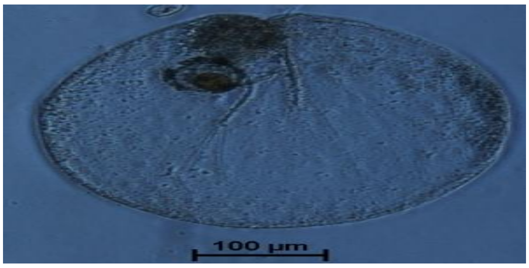


Fig. 124g *Noctiluca sp.*

Fig. 124 (a-g) Brackish water species of Phyto-plankton in River Ganga

Table 38. Pollution indicator species of Phytoplankton in River Ganga and their influencing parameters

Water Parameter					
Genera	Total-N	Nitrate-N	Phosphate-tp	Silicate	Level of significance
*Asterionella*sp	↑				0.01
Navicula sp.		↑		↑	0.01
Nitzschia sp.		↑			0.01
*Eunotia*sp			↑	↑	0.01
Tabellaria sp.	↑				0.01
Surirella sp.				↑	0.01
Tryblionella sp.		↑			0.05
*Eudorina*sp.			↑		0.01
Pandorina sp.			↑		0.01
*Oocystis*sp			↑		0.05
Euglena sp.		↑			0.01
*Lepocinclis*sp.		↑			0.01
*Phacus*sp.		↑			0.01
Trachelomonas sp.		↑			0.05
*Chroococcus*sp.		↑			0.01
*Nodularia*sp.		↑			0.05
*Phormidium*sp.		↑			0.01
*Aphanizomenon*sp	↑				0.05
*Nostoc*sp.	↑				0.05
*Coelosphaerium*sp		↑		↑	0.01 & 0.05
Microcystis sp.				↑	0.01
*Gomphosphaeria*sp.		↑			0.01
Genera	Total-N	Nitrate-N	Phosphate-tp	Silicate	
Diatoma sp.				↓	0.05
*Stauroneis*sp.				↓	0.05
Synedra sp.				↓	0.01
Cymbella sp.				↓	0.01
*Gomphonema*sp				↓	0.01
Hormidium sp.				↓	0.05

* ↑ : Positively influenced

↓ : Negatively influenced

High nutrient enrichment due to sewage, industry and agricultural farm runoff promotes growth of several phytoplankton. Sometime high nutrient made the water eutrophic and thus favoring the bloom of several phytoplankton. Some genera of phytoplankton had shown significant positive correlation with the nutrient parameters (total-N, Nitrate-N, total phosphate). Six genera of phytoplankton had shown significant negative correlation with silicate.

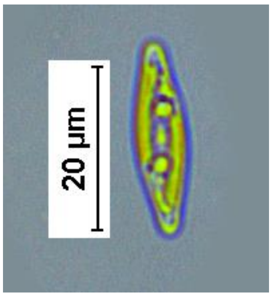


Fig. 125a *Navicula* sp.

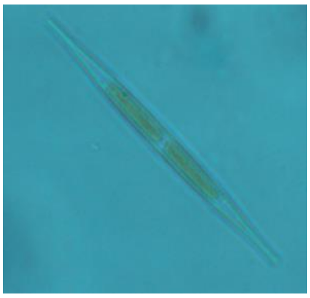


Fig. 125b *Nitzschia* sp.


Fig. 125c *Surirela* sp.


Fig. 125d *Tryblionella* sp.

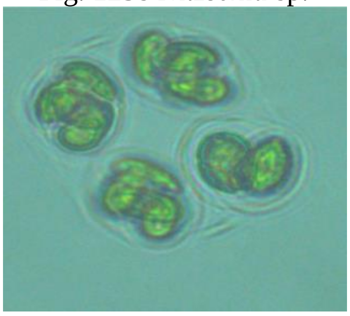


Fig. 125e *Oocystis sp.*

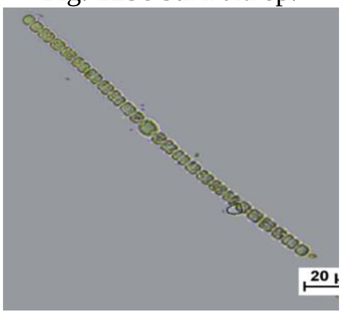


Fig. 125f *Nostoc* sp.

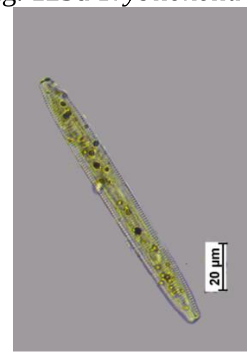


Fig. 125g *Synedra sp.*

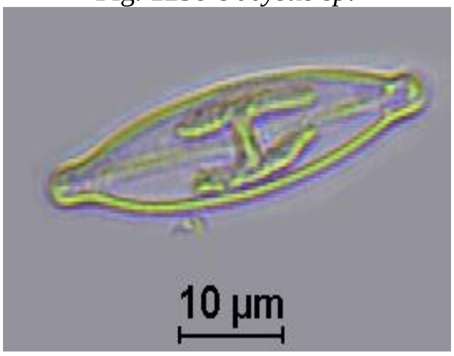


Fig. 125h *Stauroneis* sp.

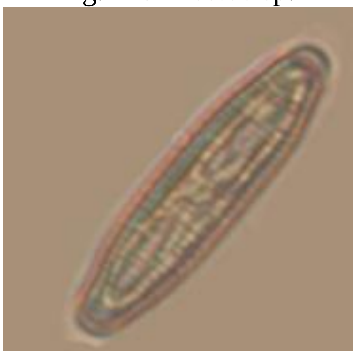


Fig. 125i *Diatoma* sp.

Fig. 125 (a-i) Pollution indicator plankton species of River Ganga

Zooplanktonic species of river Ganga

A total of 36 genera belonging to 11 classes and 4 phyla of zooplankton, which belongs to Rotifera, Arthropoda, Ciliophora, and Amoebozoa were recorded from the river. A few groups like fish eggs, larvae, nematodes, etc. could not be identified upto species level.

- ❖ In the upper stretch, among zooplankton Rotifera (7 genera), Arthropoda (2 genera), Ciliophora (10 genera), Amoebozoa (2 genera) were recorded (Fig. 126).

❖ In the middle stretch among zooplankton Rotifera (13 genera), Arthropoda (8 genera), Ciliophora (4 genera), Amoebozoa (3 genera) were recorded.

❖ In thelower stretch among zooplankton, Rotifera (6 genera), Arthropoda (7 genera), Ciliophora (3 genera), Amoebozoa (2 genera) were recorded.

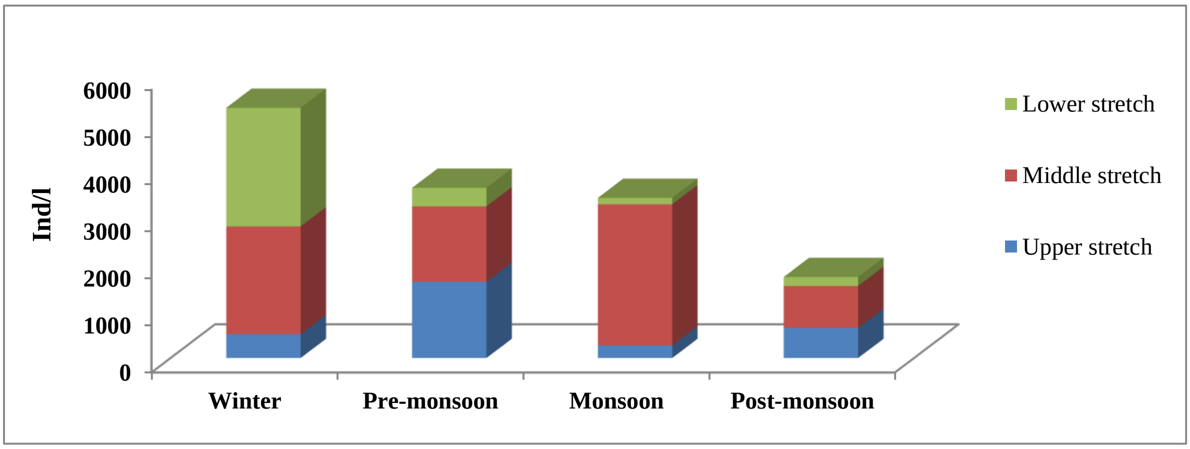


Fig. 126 Seasonal variation in Zoo plankton density at different stretches of river Ganga (2016-2020)

❖ In the upper stretch, highest density of zooplanktonic community was found during pre-monsoon (1620 ind/l) and lowest during monsoon season (270 ind/l) (Fig. 127).

❖ In the middle stretch, highest density of zooplanktonic community was found during winter (2288 ind/l) and lowest during post-monsoon season (890 ind/l).

❖ In the lower stretch, highest density of zooplanktonic community was found during winter (109036 ind/l) and lowest during pre-monsoon season (1091 ind/l).

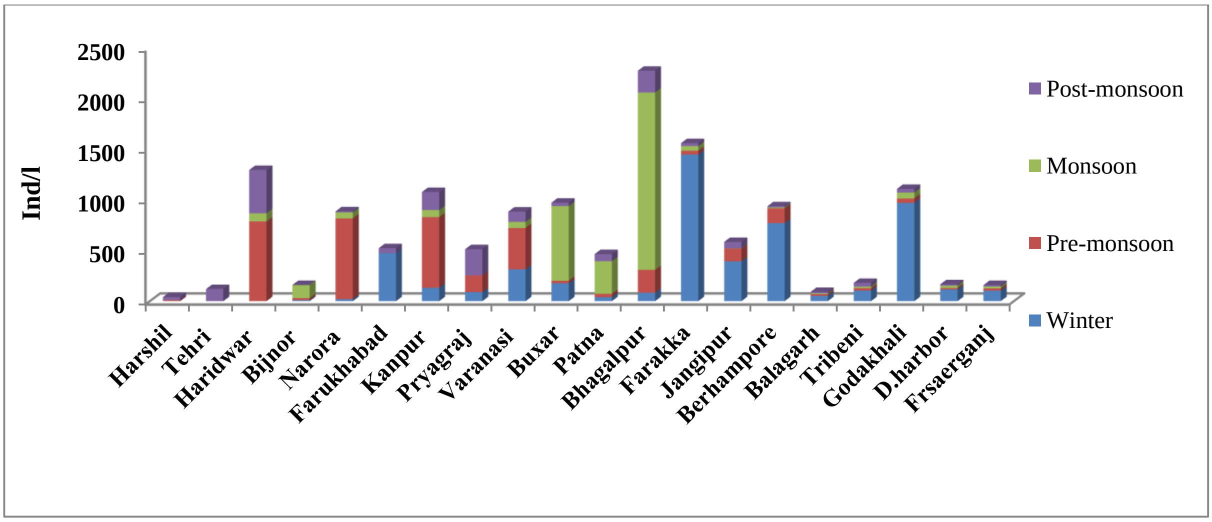


Fig. 127 Zoo- plankton density at different stretches of river Ganga (2016-2020)

During pre-monsoon season, highest density of zooplanktonic community was recorded at Narora (800ind/l) and lowest at Bijnor (10 ind/l). During monsoon season, highest dominance was recorded at Bhagalpur (1754 ind/l) and lowest at Jangipur (2 ind/l). During post-monsoon, highest density was recorded at Haridwar (430 ind/l) and lowest was recorded at Narora (10 ind/l) during winter highest at Farakka (1451 ind/l) and lowest at Bijnor (10 ind/l).

Phylum wise description of the recorded zooplankton

1. Rotifera

Phylum Rotifera is one of the major group of zooplankton. During pre-monsoon season, highest abundance was recorded at Kanpur (650 ind/l) and lowest was observed at Farakka. During monsoon season, highest dominance was recorded at Buxar (580 ind/l) and lowest at Godakhali (1 ind/l). During post-monsoon season, highest dominance was recorded at Prayagraj (235 ind/l) and lowest at Balagarh, Fraserganj. Highest density was found at Farakka (1121 ind/l) and lowest at Bijnor (10 ind/l) during winter season.

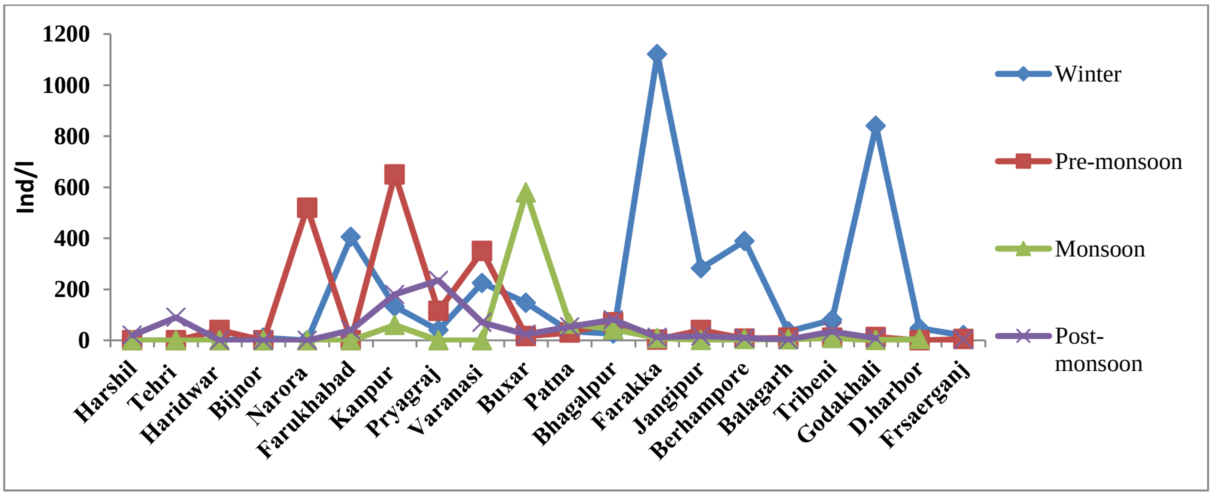


Fig. 128 Seasonal variation in Rotifera of zoo-plankton at different stretches of river Ganga (2016-2020)

2. Arthropoda

The group include crustaceans, such as Copepoda and Cladocera.

Copepoda

The class Copepoda belongs to phylum Arthropoda and highest density was observed during monsoon (1522 ind/l) followed by winter (701 ind/l) (Fig. 129). During pre-monsoon highest abundance was recorded at Narora (130 ind/l) and lowest was observed at Patna. During monsoon highest dominance was recorded at Bhagalpur (871 ind/l) and lowest at Berhampore (4 ind/l). During post-monsoon highest dominance was recorded at Jangipur (47 ind/l) and lowest at Tribeni. During winter highest density was found at Farakka (326 ind/l) and lowest at Patna (4 ind/l).

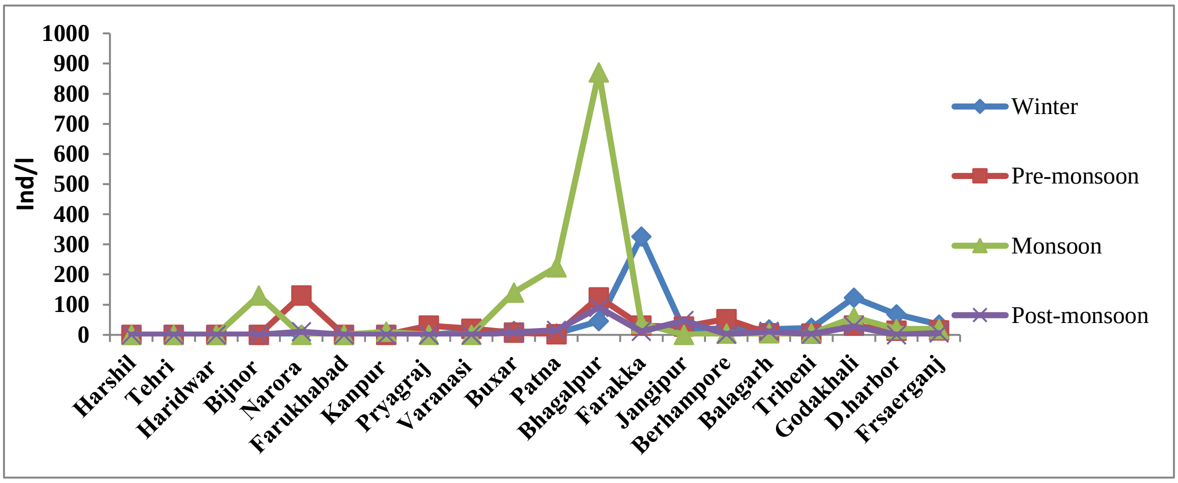


Fig.129 Seasonal variation in Copepoda of zoo-plankton at different stretches of river Ganga (2016-2020)

Cladocera

The class Cladocera belongs to phylum Arthropoda and highest density was observed during monsoon (955 ind/l) followed by pre-monsoon (304 ind/l) (Fig. 130). During Pre-monsoon highest abundance was recorded at Narora (650 ind/l) and lowest was observed at Buxar, Patna, Balagarh. During monsoon, highest dominance was recorded at Bhagalpur (840 ind/l) and lowest at Tribeni (1 ind/l). During post-monsoon, highest dominance was recorded at Bhagalpur (42 ind/l) and lowest at Buxar, Patna. During winter highest density was found at Jangipur (47 ind/l) and lowest at Tribeni (2 ind/l).

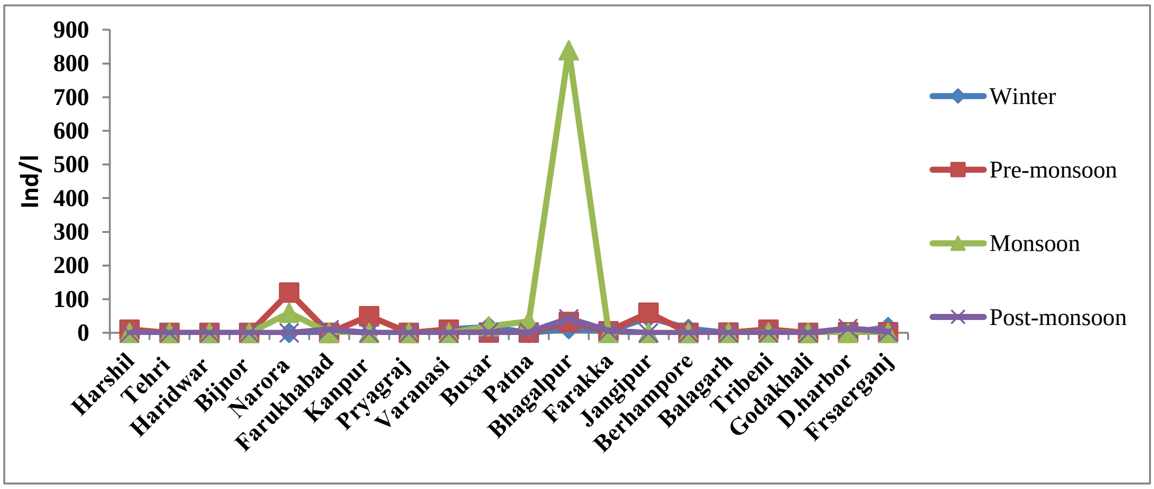


Fig. 130 Seasonal variation in Cladocera of zoo-plankton at different stretches of river Ganga (2016-2020)

3. Ciliophora

Highest density was observed during pre-monsoon (838 ind/l) followed by winter (653 ind/l) (Fig. 131). During pre-monsoon highest abundance was recorded at Haridwar (680 ind/l) and lowest was observed at Bijnor, Prayagraj (20 ind/l). During monsoon highest dominance was recorded at Haridwar (80 unit/l). During post-monsoon highest dominance was recorded at Haridwar (430 ind/l) and lowest at Fraserganj. During winter highest density was found at Berhampore (350 ind/l) and lowest at Godakhali (10 ind/l).

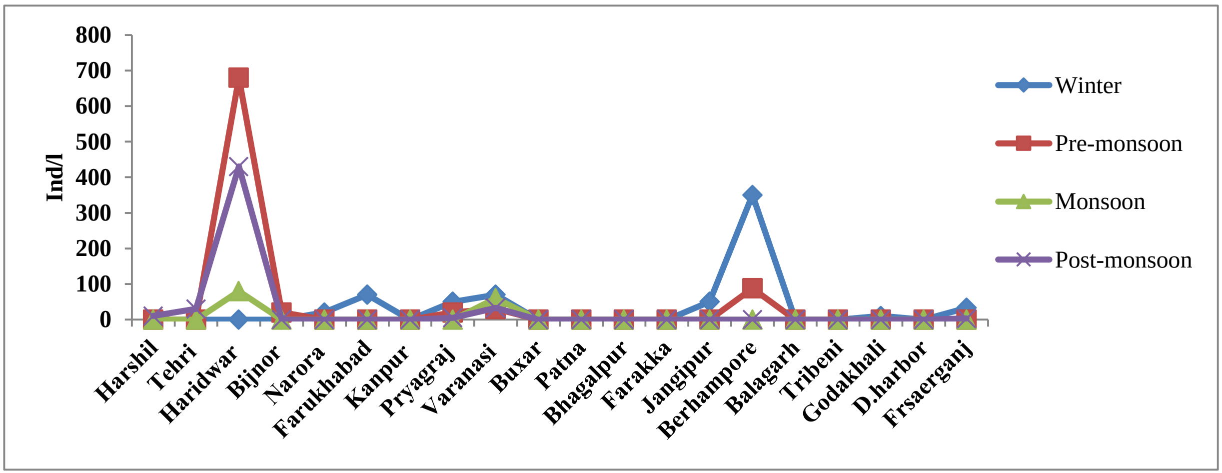


Fig. 131 Seasonal variation in Ciliophora of zoo-plankton at different stretches of river Ganga (2016-2020)

DIVERSITY INDICES

Diversity of phytoplankton in river Ganga were analysed using different diversity indices and it has been shown in Fig.132.

- In the upper stretch, the Shannon–Weiner index (H′) was high (3.06) during post-monsoon and lowest (1.20) during monsoon. Simpson's Species dominance index (D) was also found to be high (0.92) during post-monsoon and low (0.52) during monsoon. Evenness index was also found to be high during post-monsoon i.e., 0.48 and Margalef index was found high (5.11) during pre-monsoon .
- In middle stretch, the Shannon–Weiner index (H′) was high (2.99) during post-monsoon and lowest (1.16) during monsoon. Simpson's Species dominance index (D) was found to be high (0.92) during pre-monsoon and low (0.56) during monsoon. Evenness index and Margalef index were found to be high during post-monsoon i.e., 0.34 and 6.28 respectively.

❖ In lower stretch, theShannon–Weiner index (H′) was high (2.67) during post-monsoon and lowest (1.09) during winter. Simpson's Species dominance index (D) was found to be high (0.88) during pre-monsoon and low (0.40) during winter. Evenness index was found to be high during pre-monsoon (0.35) and Margalef index was found to be high during post-monsoon i.e., 5.90.

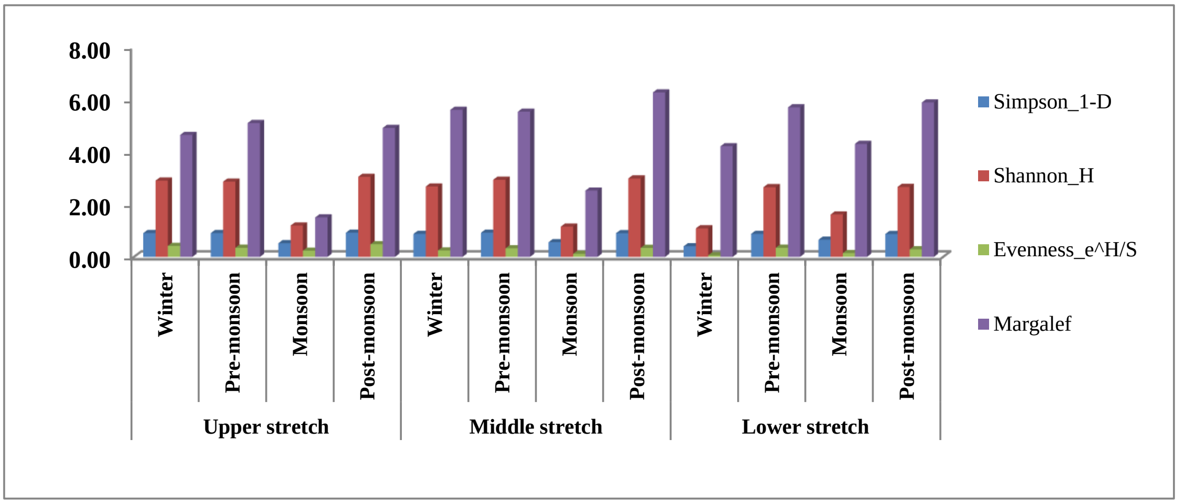


Fig. 132 Diversity indices of phyto-plankton of different sampling stations of river Ganga in different seasons (2016-2020)

❖ In upper stretch, the Shannon–Weiner index (H′) was high (2.56) during pre-monsoon and lowest (0.64) during winter (Fig. 133). Simpson's Species dominance index (D) was also found to be high (0.87) during pre-monsoon and low (0.44) during winter. Evenness index was found to be high during winter (0.94) and Margalef index was found to be high during pre-monsoon i.e., 3.16.

❖ In middle stretch,theShannon–Weiner index (H′) was high (2.21) during post-monsoon and lowest (1.85) during winter. Simpson's Species dominance index (D) was also found to be high (0.83) during post-monsoon and low (0.75) during winter. Evenness index was found to be high (0.54) during monsoon and Margalef index was found to be high during post-monsoon i.e., 2.79.

❖ In lower stretch, theShannon–Weiner index (H′) was high (2.12)during post-monsoon and lowest (1.45) during pre-monsoon and monsoon. Simpson's Species dominance index (D) was also found to be high (0.87) during post-monsoon and low (0.69) during monsoon. Evenness index and Margalef index were found to be high during post-monsoon i.e., 0.76 and 1.78 respectively.

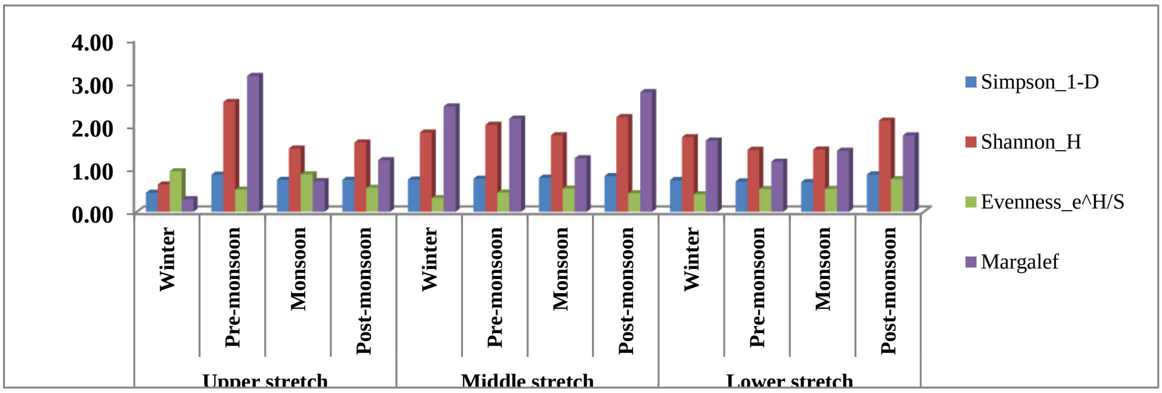


Fig. 133 Diversity indices of zooplankton of different sampling stations of river Ganga in different seasons (2016-2020)

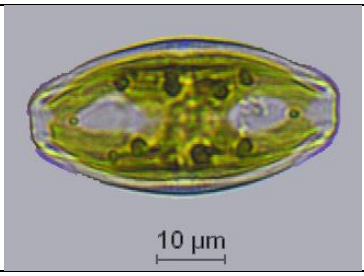


Fig. 134a *Amphora* sp.

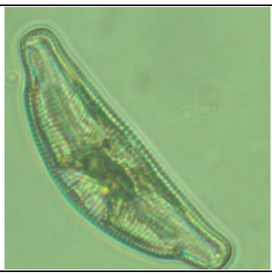


Fig. 134b *Cymbella* sp.

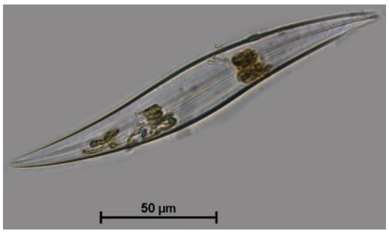


Fig. 134c *Gyrosigma* sp.

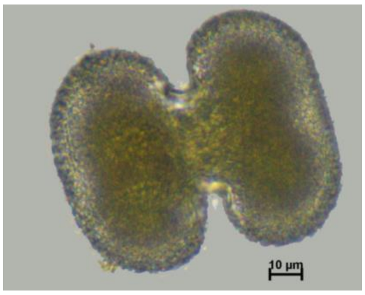


Fig. 134d *Cosmarium* sp.

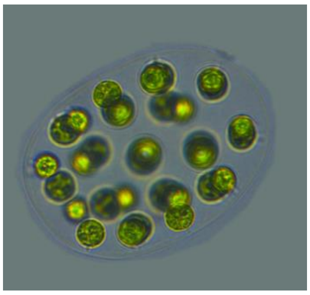


Fig. 134e *Eudorina* sp.

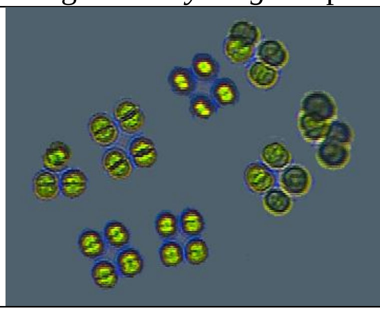


Fig. 134f *Chrococoous* sp.

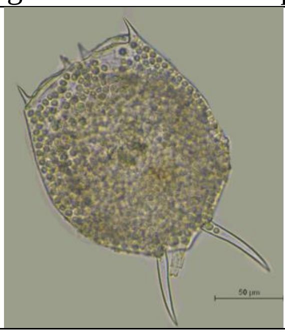


Fig. 134g *Brachionus* sp.

Fig. 134h *Daphnia* sp.

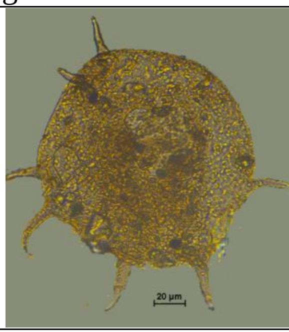


Fig. 134i *Centropyxis* sp.

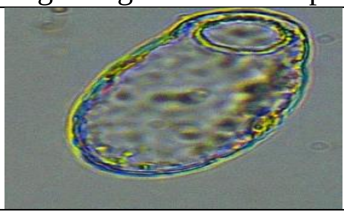


Fig. 134j *Trinema* sp.

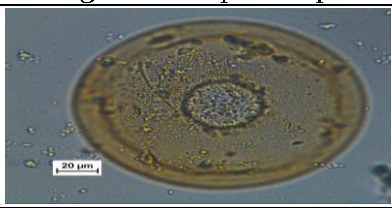


Fig. 134k *Arcella* sp.

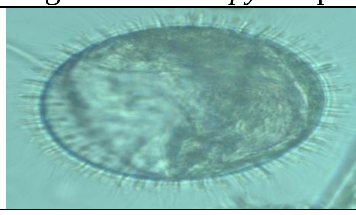


Fig. 134l *Podophrya* sp.

Fig. 134(a-l) Planktonic species of river Ganga

IMPORTANT OBSERVATION

- Noctiluca**,** genus of marine Dinoflagellate in the family Noctilucaceae, is one of the most commonly occurring bioluminescent organisms in coastal regions of the world. In the year, 2017 a bloom of Noctiluca (63 unit/l) was noticed at Fraserganj station of river Ganga, which may be due to high salinity condition by tidal effect of the sea.
- During July 2018, a thick scum *Microcystis aerugenosa* bloom was noticed first at Buxar 2245 unit/l and Bhagalpur 1012 unit/l stretch but in Patna, no bloom was found during the study. Again, during June, 2019 *Microsystis* sp. bloom was once again formed with a comparatively higher density than that of July 2018 at 3 different sampling station i.e.,Buxar (8495 unit/l), Patna (2290 unit/l) and Bhagalpur (15785 unit/l). The result had shown that *Microcystis* sp. showed significant positive correlation with water temp. (r = 0.59), Specific conductivity (r = 0.69). The specieshad positive correlation with some soil parameters, versus Soil specific conductivity (r= 0.67), with Soil organic carbon (r = 0.74), and with Clay% (r = 0.72). *Microcystis* sp. had shown negative correlation with soil pH (r = -0.59), Sand% (r = -0.73). Regression analysis results showed that specific Cond, and Soil organic carbon have positive correlationbut insignificantly, only Soil pH was negatively correlated with *Microsystis* sp. significantly in the Bihar zone of river Ganga.
- Phytoplankton showed higher degree of abundance (90425 unit/l) during winter months from December to January. The phytoplankton was eutrophic and genus *Aulacoseira* forming the largest density. Sudden rise of diatom *A. granulate* has been recorded from all the stations with the highest at Balagarh (45160 unit/l). The species had significant positive correlation with calcium (r = 0.6), Alkalinity (r = 0.55), DO (r = 0.7) and negatively correlated with water temperature (r = - 0.57).

STATUS OF PERIPHYTON COMMUNITY IN RIVER GANGA

Periphyton are the type of organisms that get attached to a substrate in aquatic ecosystem. It is a mixture of autotrophic (algae, cyanobacteria) and heterotrophic (microbes) along with detritus substances. As it also carries algae in high density, it plays a significant role on the productivity of water bodies (Sarwar, 1988; Lowe and Pan, 1996). So, they can provide food for fishes and other aquatic organisms in an aquatic ecosystem (S. K. Saikia & D. N. Das, 2009). One more advantage of periphyton is they can reduce the nutrient in sedimentary material helps maintaining river ecology through increased oxygen supply (Hansson, 1988).

Methodology

These are attached algae growing on a substrate like rock, boat etc. Firstly, an area is selected and measuredby using scale. After which,the samples are collected by scraping with the help of a glass slide and was collected in a container. Preservation is done immediately after collection in 4% Neutral buffer formalin (NBF). Identification is done by employing trinocular microscope (40x and 60x magnification) using standard keys (AlgaeBase).

Result

A total of 9 groups of plankton were recorded, of which 5 groups belong to phytoplankton and 4 groups belong to zooplankton. A total of 93 genera of planktonic group, 75 genera belonging to phytoplankton and 18 generatozooplankton were recorded. Bacillariophyceae dominated the diversity of phytoplankton with a total of 35 genera , followed by Chlorophyceae (26 genera) and Myxophyceae (8 genera).

- In the upper stretch, highest density of periphytic community was found during winter (127835 unit/$cm^{2)}$ and lowest during monsoon (15590 unit/cm^2) (Fig. 135). Bacillariophyceae was found to be dominant during all season, Chlorophyceae and Cyanophyceae during winter and monsoon season respectively.
- In the middle stretch, Baciilariophyceae and Cyanophyceae were recorded highest in number as compared to other groups in all season. The highest density of periphytic community was found during pre-monsoon (150242 unit/cm^2) and lowest during monsoon (83050 unit/cm^2).

❖ In the lower stretch, highest density of periphytic community was found during post-monsoon (94061 unit/cm$^{2)}$ and lowest during winter (44445 unit/cm^2).

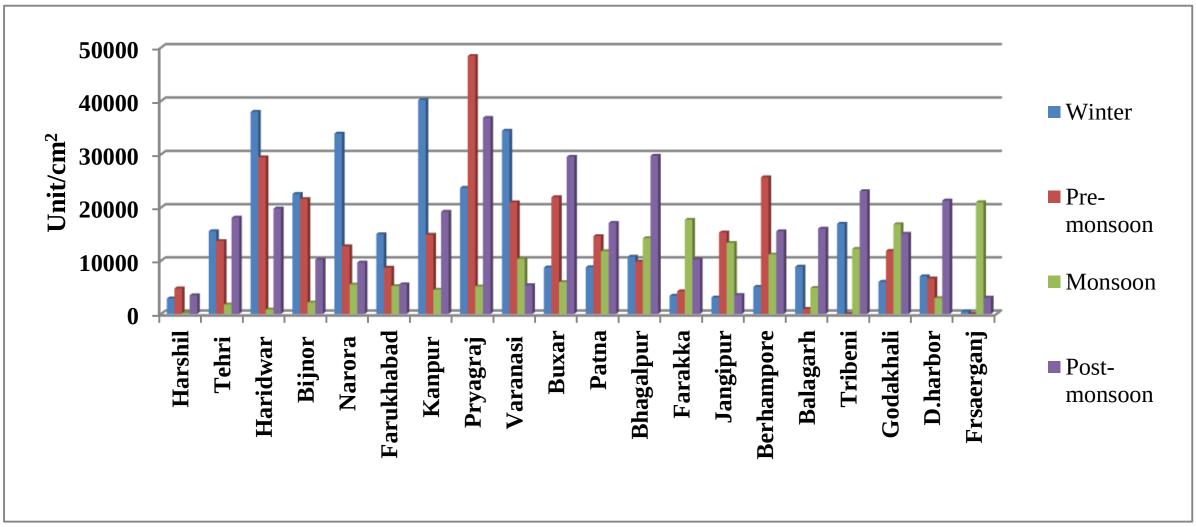


Fig. 135 Seasonal variation of periphytic community at different stretches of river Ganga (2016-2020)

High density of periphytic community was recorded at Prayagraj (48405 unit/cm^2) and lowest at Balagarh (930 unit/cm^2) during pre-monsoon. During monsoon season, highest dominance was recorded at Farakka (17700 unit/cm^2) and lowest at Harshil (150 unit/cm^2). During post-monsoon season, highest was observed at Bhagalpur (29734 unit/cm^2) and lowest at Fraserganj (3050 unit/cm^2) during winter, highest at Kanpur (40150 unit/cm^2) and lowest at Jangipur (3080 unit/cm^2).

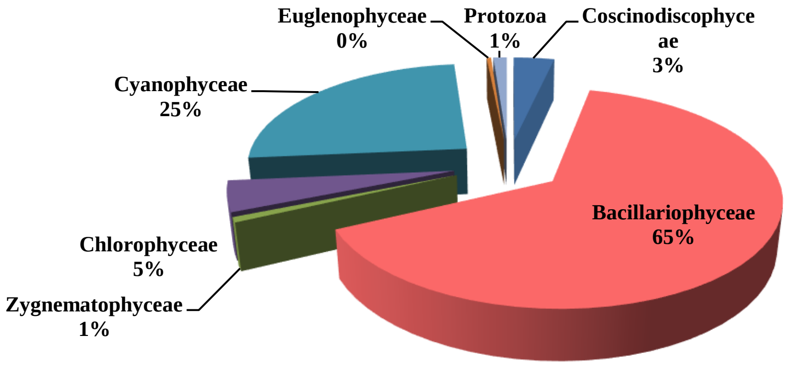


Fig. 136 Percentage density of different algal group of Periphyton of River Ganga

❖ Percentage density of different algal groups was shown in the Fig. 123 the highest abundance was contributed by Bacillariophyceae 65%), followed by Cyanophyceae (25%) and Chlorophyceaee (5%).

Major class wise description of the Periphytic community

Bacillariophyceae

The group Bacillariophyceae was recorded to be dominant in winter (229998 unit/cm^2) followed by post-monsoon (237370 unit/cm^2) (Fig. 137). Haridwar (22415 unit/cm^2) has shown vivid dominancy of Bacillariophyceae during pre-monsoon time and lowest density at Balagarh (620unit/cm^2). During Monsoon highest dominance was recorded at Jangipur (12000 unit/cm^{2}l) and lowest at Harshil (150unit/cm^2). During post-monsoon,thehighest at Prayagraj (33360 unit/cm^2) and lowest at Fraserganj (320 unit/cm^2) and during winter, highest at Haridwar (33350 unit/cm^2) and lowest at Fraserganj (233 unit/cm^2).

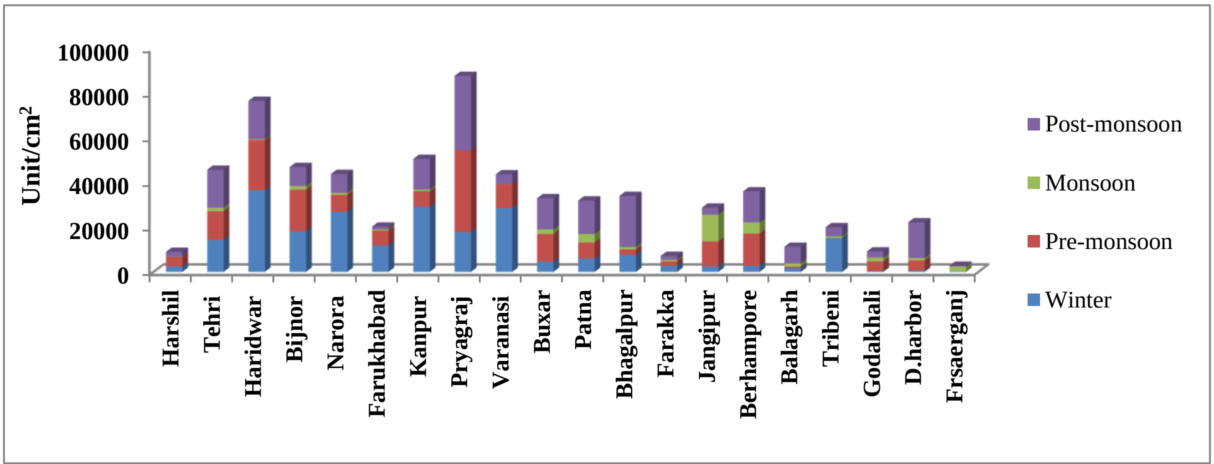


Fig. 137 Seasonal variation of Bacillariophyceae of periphytic community at different stretches of river Ganga (2016-2020)

Chlorophyceae

The class Chlorophyceae belongs to phylum Chlorophyta and highest density was observed during winter (1843 unit/cm^2) followed by pre-monsoon (15633unit/cm^2) (Fig. 138). High density of this class was recorded at Prayagraj (5425 unit/cm^2) and lowest at Harshil (40 unit/cm^2) during pre-monsoon. During monsoon highest dominance was recorded at Kanpur (3075 unit/cm^2) and lowest at Patna (10 unit/cm^2). During post-monsoon highest at Kanpur (1910 unit/cm^2) and lowest at Patna (10 unit/cm^2) during winter highest at Godakhali (4940 unit/cm^2) and lowest at Tehril (10 unit/cm^2).

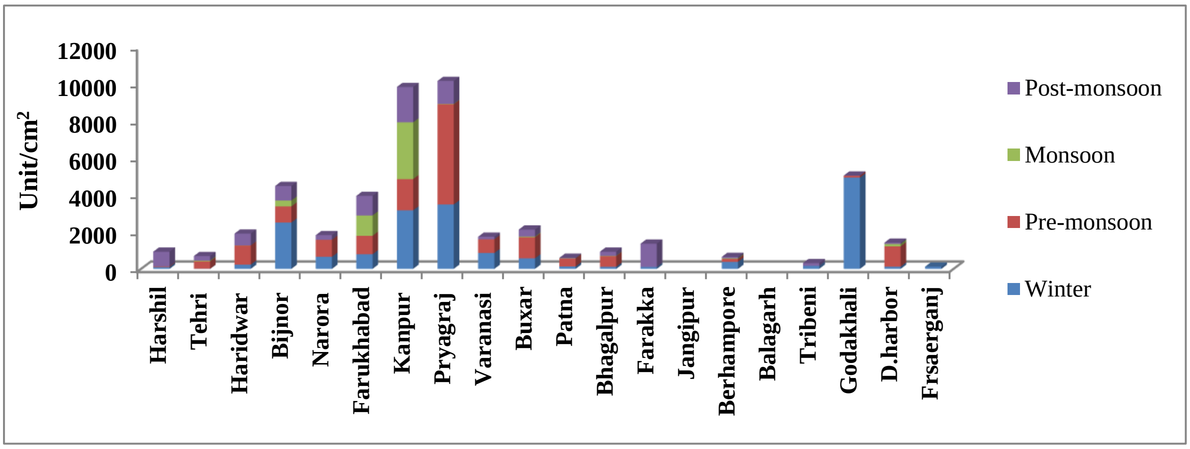


Fig. 138 Seasonal variation of Chlorophyceae of Periphytic community at different stretches of river Ganga (2016-2020)

Cyanophyceae

The class Cyanophyceae belongs to phylum Cyanophyta and highest density was observed during Monsoon (117135 unit/cm^2) followed by post-monsoon (86452 unit/cm^2) (Fig. 139). High density of this class was recorded at Berhampore (10843 unit/cm^2) and lowest at Farrukhabad (20 unit/cm^2) during pre-monsoon. During monsoon, highest dominance was recorded at Buxar (18720 unit/cm^2) and lowest at Tehri (70 unit/cm^2). During post-monsoon highest dominance was recorded at Godakhali (15020 unit/cm^2) and lowest at Harshil (30unit/cm^2). During winter highest density was found at D. Harbour (5320 unit/cm^2) and lowest at Fraserganj (70 unit/cm^2).

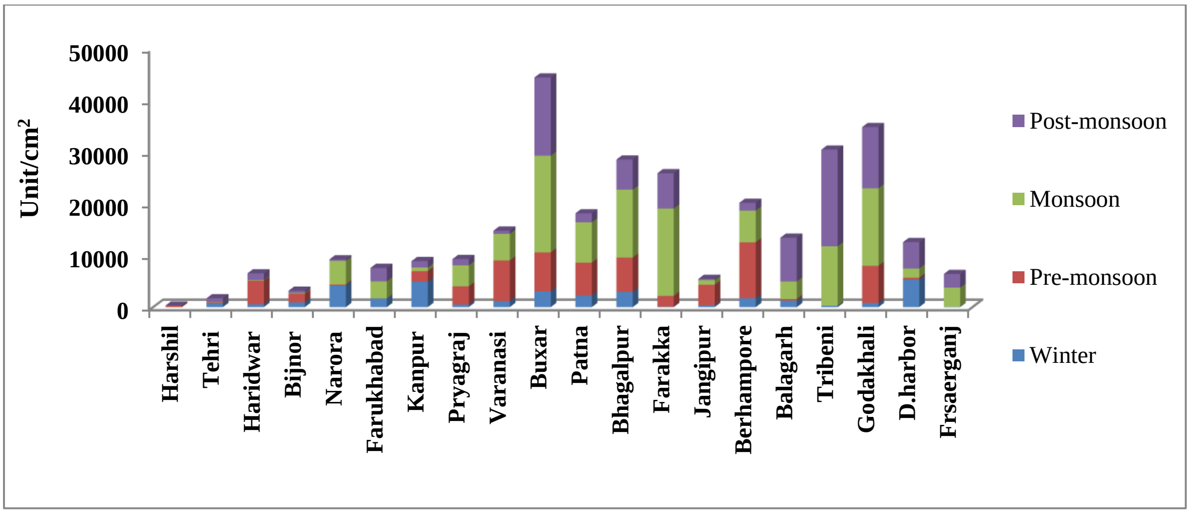


Fig. 139 Seasonal variation of Cyanophyceae of Periphytic community at different stretches of river Ganga (2016-2020)

Abundance Pattern of Periphytic Community

The year wise changes in density of periphytic community had been analyzed (Fig.140).

- ❖ In the year 2017, highest abundance was recorded at Buxar (13267 unit/ cm^2) and lowest at Tehri (1125 unit/ cm^2).
- ❖ In the year 2018, highest abundance was recorded at Prayagraj (41330 unit/ cm^2) and lowest at Jangipur (1160 unit/ cm^2).
- ❖ In the year 2019, highest abundance was recorded at Tribeni (38495 unit/ cm^2) and lowest at Harshil (2720 unit/ cm^2).
- ❖ In the year 2020, highest abundance was recorded at Haridwar (10980 unit/ cm^2) and lowest at Godakhali (320 unit/ cm^2).

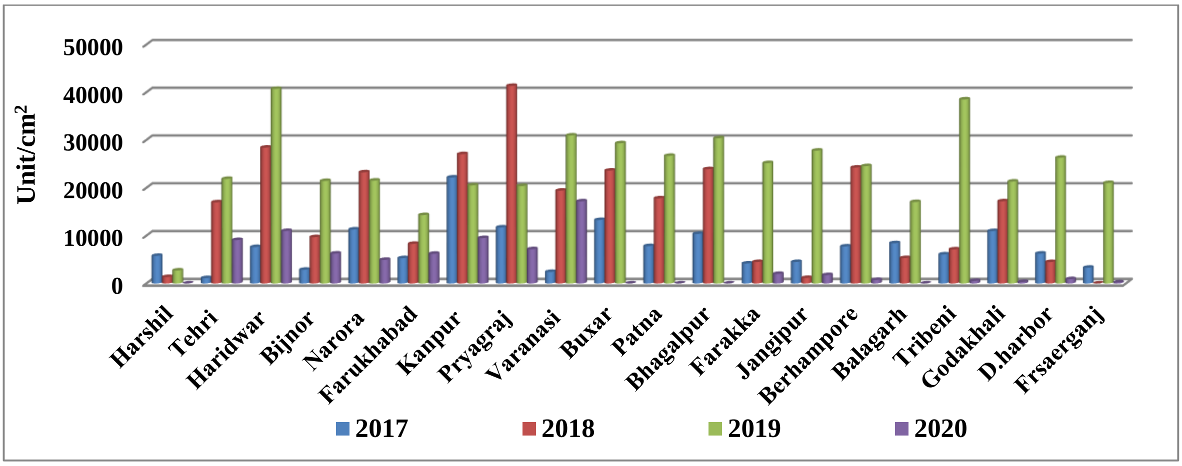
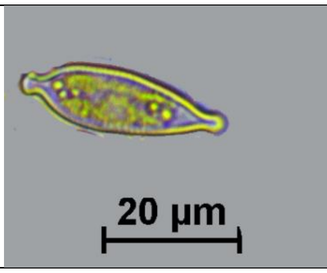
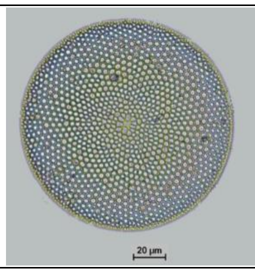


Fig. 140 Year wise changes of Periphytic community at different stretches of river Ganga (2017-2020)

		
Fig. 141a *Navicua* sp.	Fig. 141b *Gomhonema* sp.	Fig. 141c *Coscinodiscus* sp.

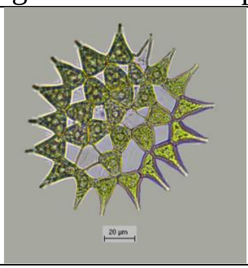
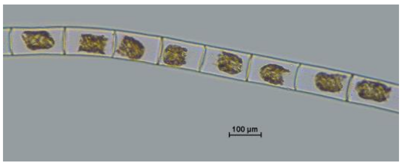
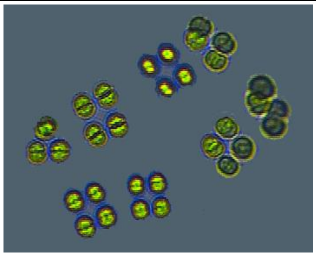

		

Fig. 141d *Pediastrum* sp.	Fig. 141e *Spirogyra* sp.	Fig. 141f *Chrococoous* sp.

Fig. 141(a-f) Periphytic species of river Ganga

BENTHIC DIVERSITY IN RIVER GANGA

Benthic biodiversity of a river is characterized as one of the key organisms for the nutritive analysis of the sediment as well as the water. The physicochemical characteristics of the soil are solely dependent on the available epifaunal and infaunal organisms thriving in the sediment. Benthic organisms take part in biomonitoring of the soil and water quality. They are biological indicators of a polluted ecosystem. Pollution for heavy metals accumulation of industrial effluents or sewage wastes or acidification of the riverine ecosystem is also easily detectable through the study of benthic biodiversity.

Materials and Methods

The samples were collected from the preselected twenty stations along the river. Peterson grab was used to scoop the samples from the bottom sediment. The samples were preserved in 4% formalin in 100 ml sample bottles. Later the samples were brought to the laboratory for further identification and analysis. The assessment of numerical abundance was done in a quantitative analysis by simple counting then converting it to $1m^2$ (Welch, 1948).

$N = O/A.\ S \times 10,000$

Where,

N = No. of macro-benthic organisms/ m^2

O = No. of organisms counted

A = Area of a sampler in square meter

S = No. of samples taken at each station.

Statistical Analysis

The statistical analysis has been done with the help of different analytical software. The diversity indices are analysed with the help of Past Version 4.02. Correlation with different physicochemical parameters was analysed with the help of SPSS Version 22. Species accumulation was performed with the help of PRIMER 6 software.

Observation

The study showed the availability of 69 macrobenthic species belonging to three different phyla viz., Mollusca, Arthropoda, and Annelida, which comprise of four different classes viz., Gastropoda, Pelecypoda, Insecta, and Clitellata. There are 31 gastropod species, of which 19 are freshwater, and 12 are estuarine species.

The diversity of the macrobenthic community varies with season. Freshwater (FW) gastropods were dominating throughout the river stretch in all seasons. Insects were in higher abundance during pre-monsoon and winter season. A detailed abundance of different macrobenthic groups is given in Fig. 142. The abundance of freshwater bivalve was low as compared to freshwater gastropods and insects during pre-monsoon and winter season. Species form class Clitellata was the least recorded macrobenthic organisms from river Ganga.

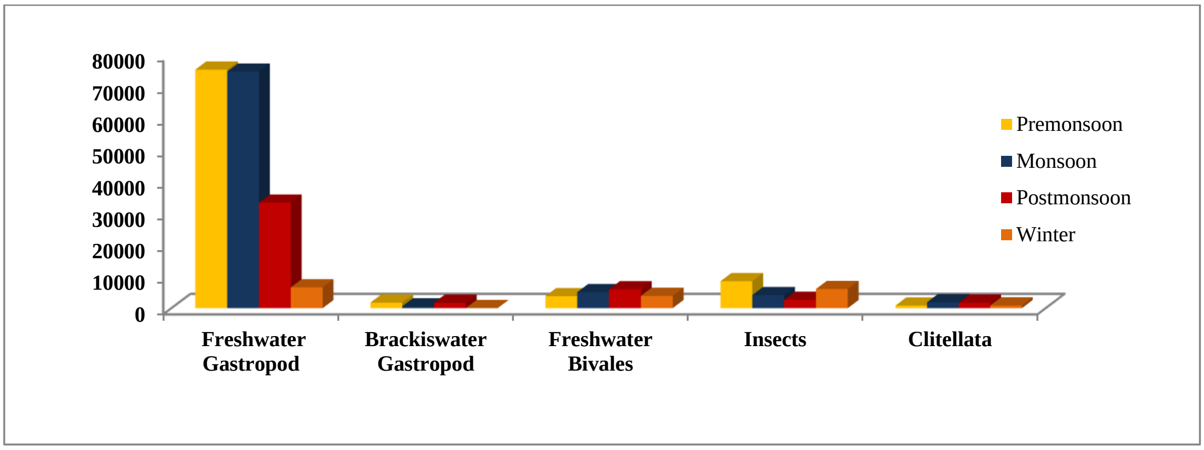


Fig. 142 Seasonal diversity of five different macrobenthic groups from Harshil to Fraserganj

The stretch-wise distribution of benthic organisms showed a dominance of freshwater gastropods in the lower stretch while the class Insecta was dominant in the upper stretch (Fig. 143). The freshwater gastropods and bivalves were commonly available along all the stretches.

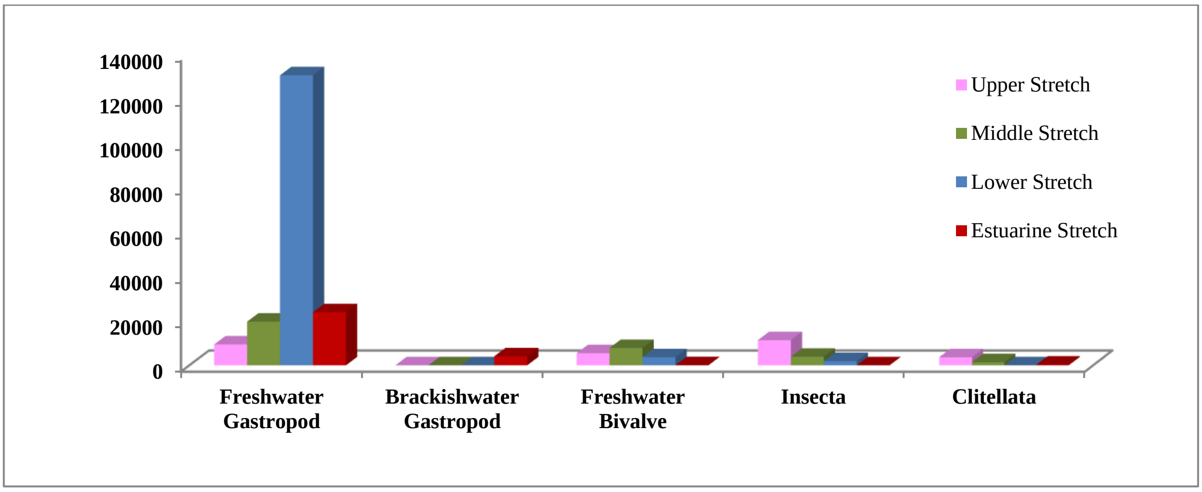


Fig. 143 Stretch wise distribution of five benthic groups from Harshil to Fraserganj

The upper stretch of river Ganga comprise of 10 gastropod species from Harshil to Varanasi, with a dominance of *Filopalaudina bengalensis* (30) followed by *Gyraulus convexiusculus* (19), while *Stenomelania plicaria* contributed only 1% of the total abundance in Fig. 144(a). A maximum abundance of *Parreysia corrugata* (28%) was recorded, while *Parreysia* *annandalei* showed a minimum abundance of 1% in Fig 131(b). In Fig. 144(c), Chironomid larvae (82%) was found to be dominant whereas, *Psephenus* sp. (1 %) and *Leptophlebia* sp. (1 %) both were least dominant among total abundance. Oligochaetes like *Lumbricus terrestris* and *Tubifex tubifex* comprising 41% and 40% amongst the total abundance is depicted in Fig. 131(d). Diversity of the species in the upper stretch is shown in Fig. 145, with a highest Shannon value of 2.722 at Narora while the lowest (0.617) was recorded at Tehri. Simpson dominance index was highest (0.916) at Narora while lowest value of 0.494 was observed at Tehri. The equitability of the species remained constant from Harshil to Varanasi ranging from (0.856 – 0.443). This shows that the diversity and dominance is highest at Narora.

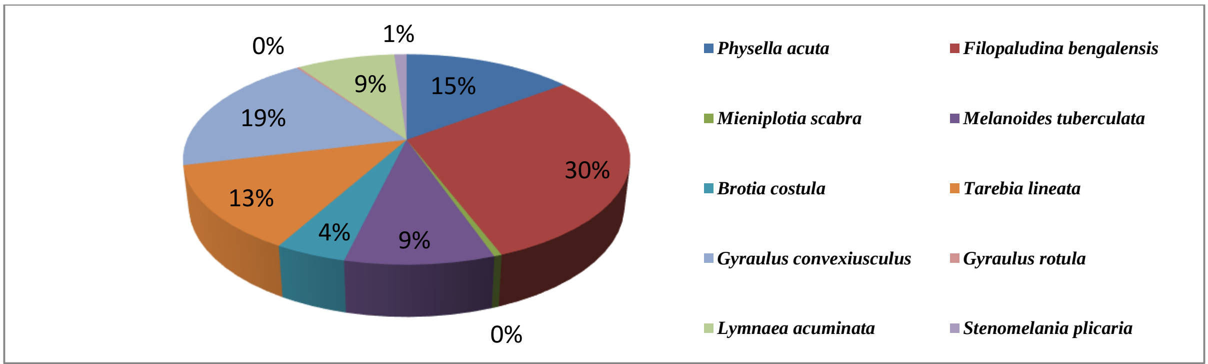


Fig. 144(a) Abundance of gastropod species in the upper stretch from Harshil to Varanas

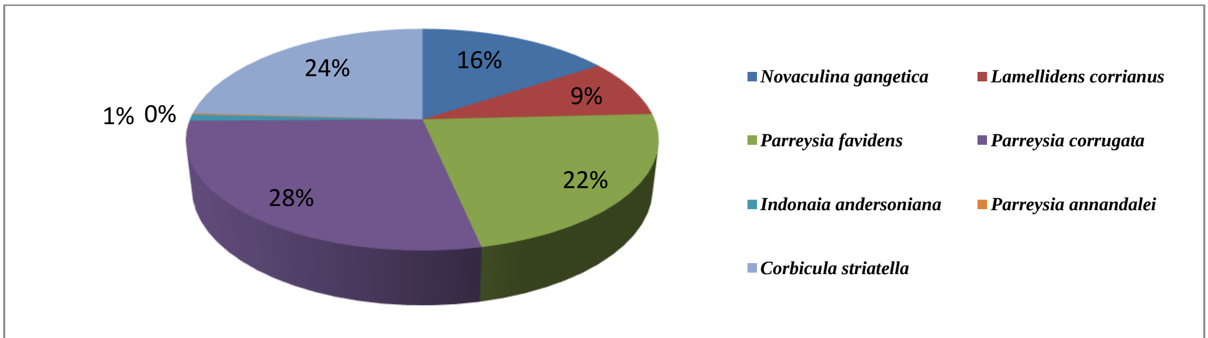


Fig. 144(b) Abundance of bivalve species in the upper stretch from Harshil to Varanasi

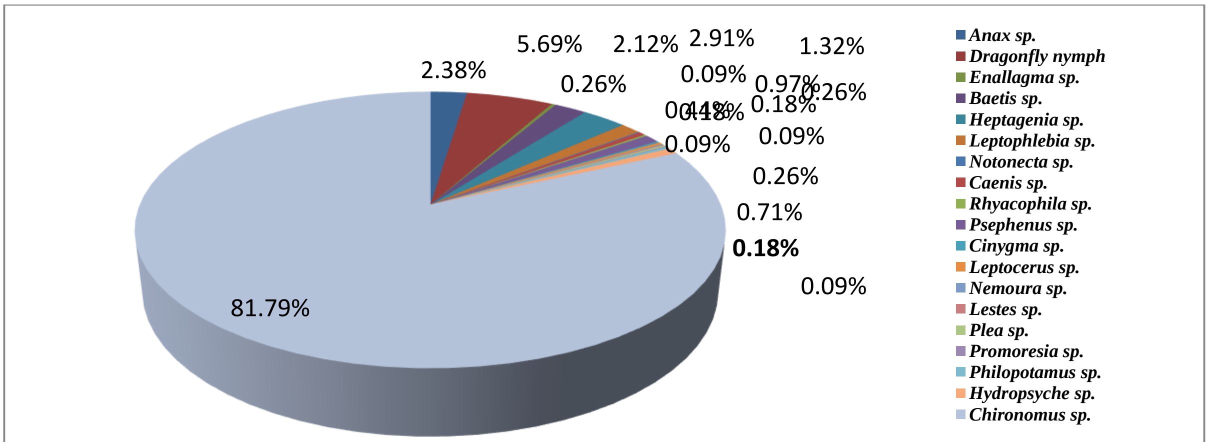


Fig. 144(c) Abundance of insect species in the upper stretch from Harshil to Varanasi

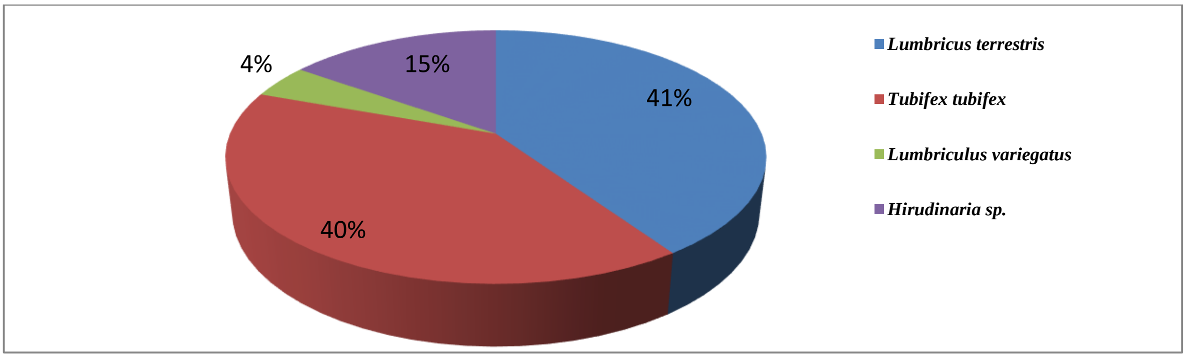


Fig. 144(d) Abundance of clitellata species in the upper stretch from Harshil to Varanasi
Fig. 144 a-d Abundance of different macrobenthic group in Upper stretch of Ganga

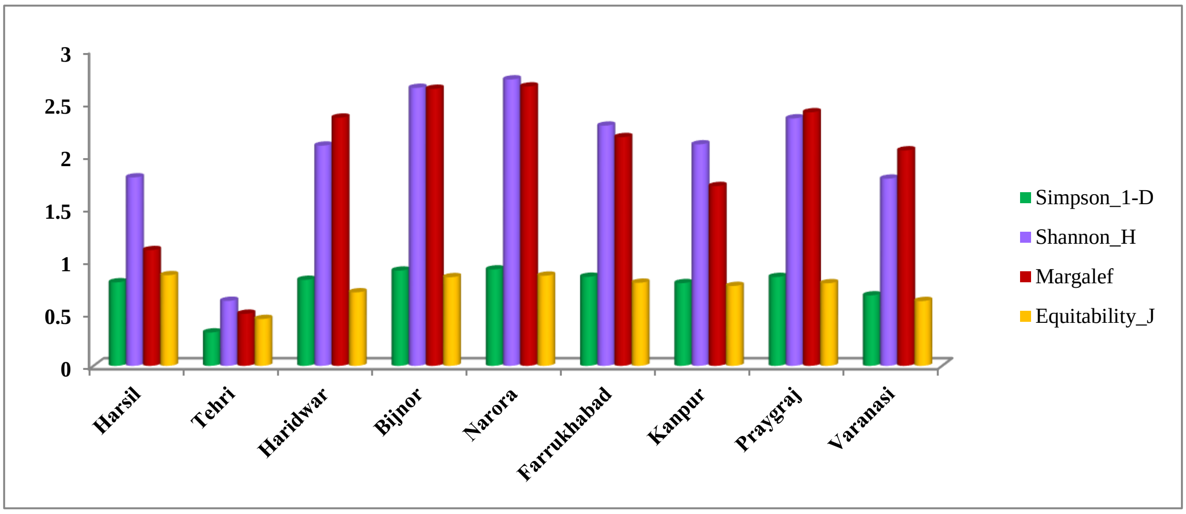


Fig. 145 Diversity Index of different species in Upper Stretch from Harshil to Varanasi

The middle stretch comprises of 14 gastropod species (Fig. 146 (a) and 9 bivalve species (Fig. 146(b) extending from Buxar to Bhagalpur showing the maximum abundance of *Filopaludina bengalensis* (51%) followed by *Gabbia orcula* (19%). The least percentage of gastropod recorded are *Mieniplotia scabra* (1%), *Physella acuta* (1%), *Tarebia lineate* (1%), *Brotia costula* (3%) and *Lymnaea acuminata* (1%). *Racesina luteola* comprising 11% of the total abundnace is found to be higher than its sister species *Lymnaea acuminate*. The maximum percentage of bivalve observed throughout the stretch is *Corbicula striatella* (40%) and *Parreysia favidens* (36%). The least percentage of bivalves recorded are *Lamellidens marginalis* (1%), *Lamellidens corrianus* (1%), and *Novaculina gangetica* (1%). Fig.146(c) depicts the abundance of Chironomid larvae with 95% dominance, while oligochaetes like *Lumbricus terrestris* dominates the middle stretch of the river. The species diversity from Buxar to Bhagalpur is depicted in Fig.147. Shannon's diversity is highest at

Patna with a value of 2.221 and the lowest wasobserved at Buxar (1.821). Margalef species richness index is constant throughout the station with a maximum value at Bhagalpur (1.944). The species equitability is also recorded to be constant with a maximum value of 0.753 which depicts that the evenness of the species distribution is constant in the middle stretch.

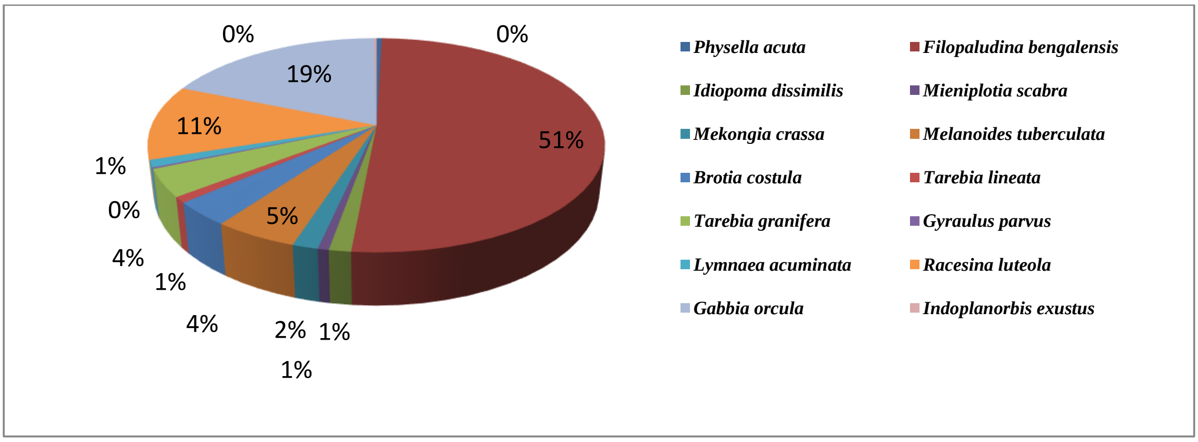


Fig. 146(a) Gastropod species abundance recorded from Buxar to Bhagalpur

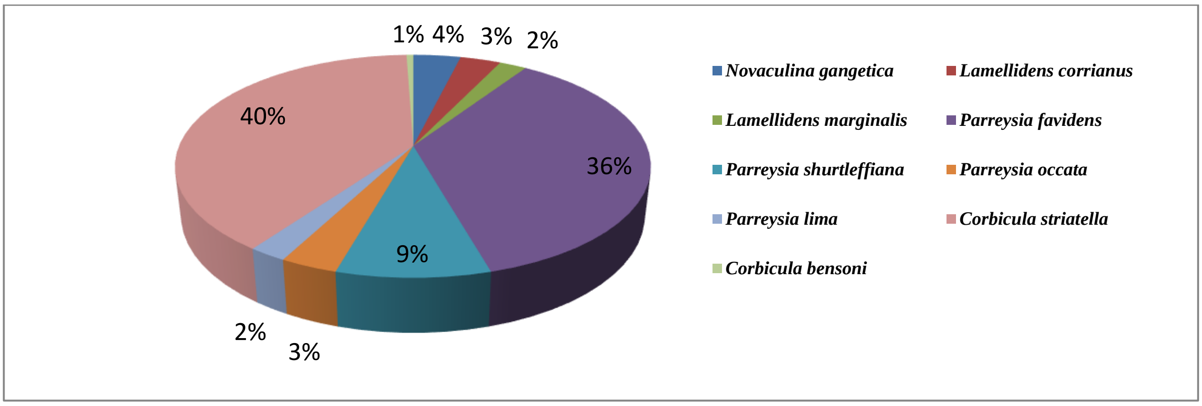


Fig. 146(b) Bivalve species abundance recorded from Buxar to Bhagalpur

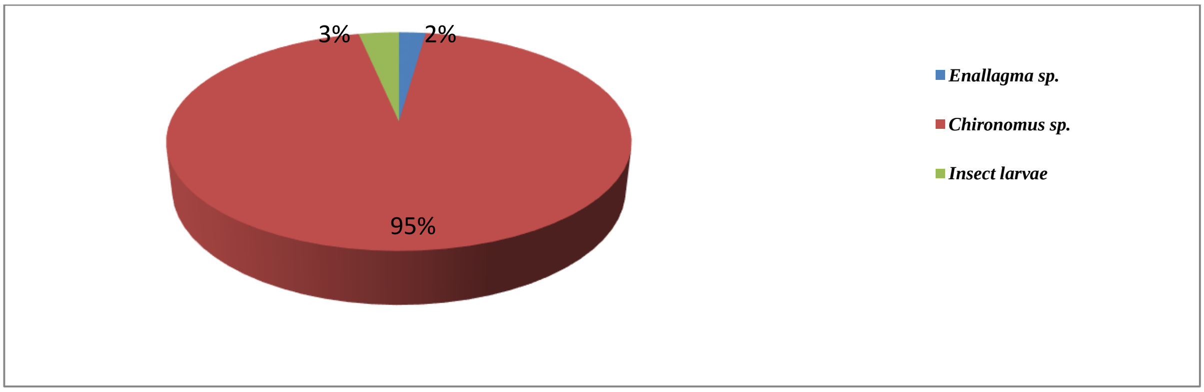


Fig. 146(c) Insect species abundance recorded from Buxar to Bhagalpur

Fig. 146 (a-c) Abundance of different macro benthic group in Middle stretch of Ganga

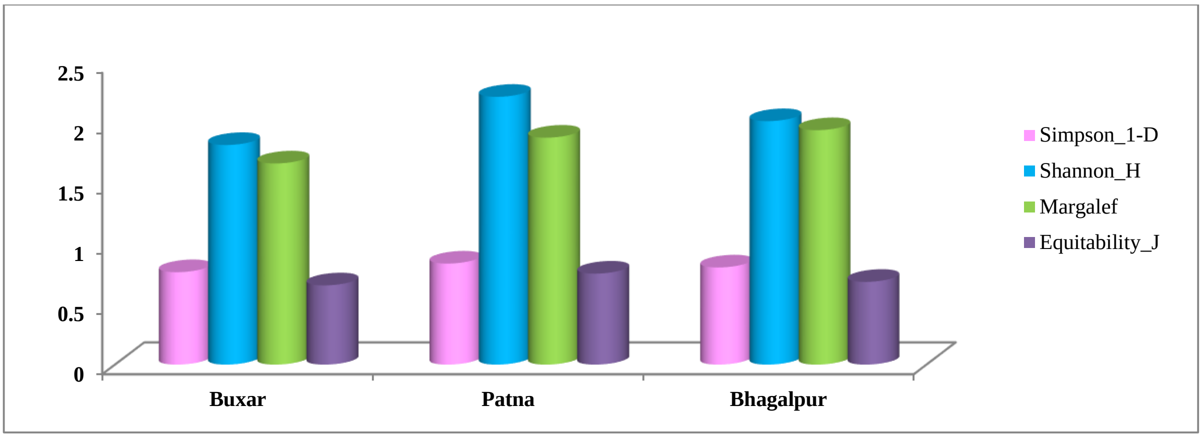


Fig. 147 Diversity Index of different species in Middle Stretch from Buxar to Bhagalpur.

The distribution of the benthic organisms in the lower stretch extending from Farakka to Tribeni shown in Fig.135. A total of 13 gastropod species in Fig. 148(a) have been recorded from this stretch with a maximum abundance of *Gabbia orcula* (36%) and *Melanoides tuberculata* (35%). *Mekongia crassa* (1%) contributed the least abundance. *Tarebia granifera* comprise 8% of the total population while *Tarebia lineate* comprised of 6%. Amongst the bivalves in Fig. 148 (b) *Parreyasia favidens* dominated 45% of the bivalve species. Insects like *Dytiscus* sp. is observed during the study with the least number of 86 inds/m^2, while Chironomid larvae are commonly available insect species in the lower stretch. The diversity indices (Fig. 149) in the lower stretch represented the maximum diversity at Balagarh with a value of 1.412, while the minimum diversity was observed at Jangipur. Jangipur showed the minimum species dominance (0.342) and species evenness (0.334), while recorded highest species richness (0.887). Balagarh and Berhampore/Reginagar revealed a maximum value of the highly diversified area in the lower stretch, only species richness differed by a value of 0.994 and 0.706 respectively.

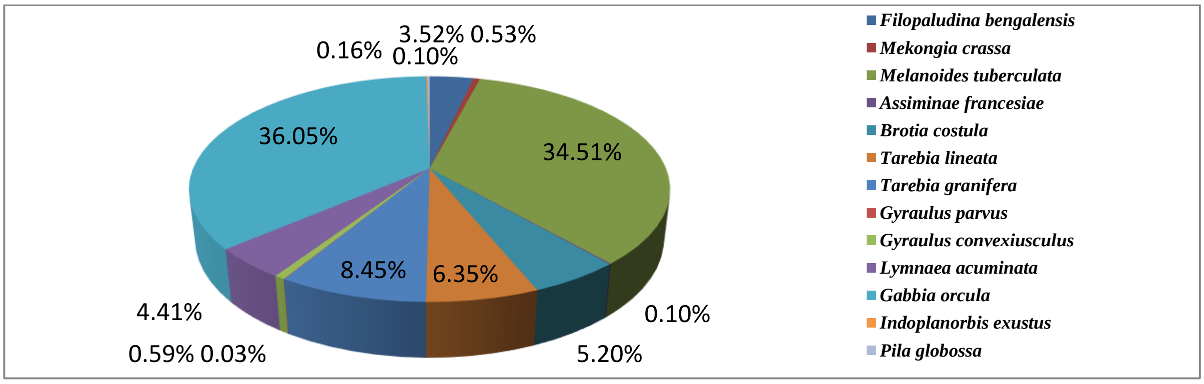


Fig. 148(a) Graphical representing the gastropod species abundance in the lower stretch from Farakka to Tribeni

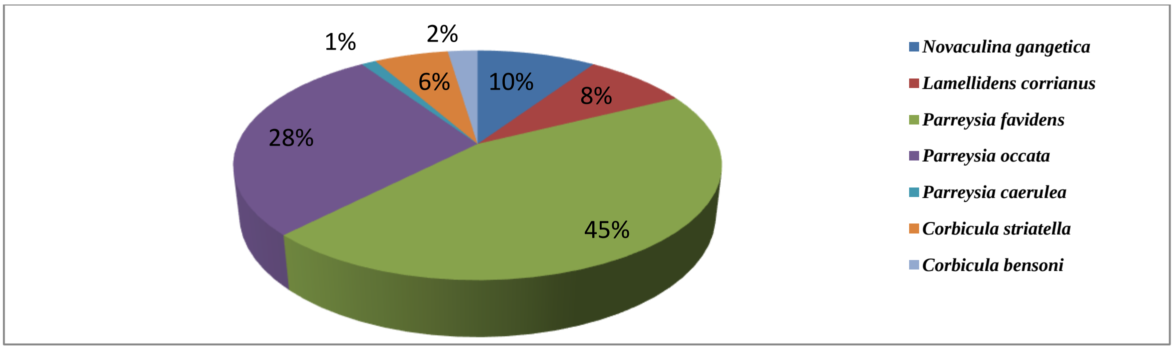


Fig. 148(b) Graphical representing the bivalve species abundance in the lower stretch from Farakka to Tribeni

Fig. 148 (a-b) Graphical representing the gastropod and bivalve species in the lower stretch from Farakka to Tribeni

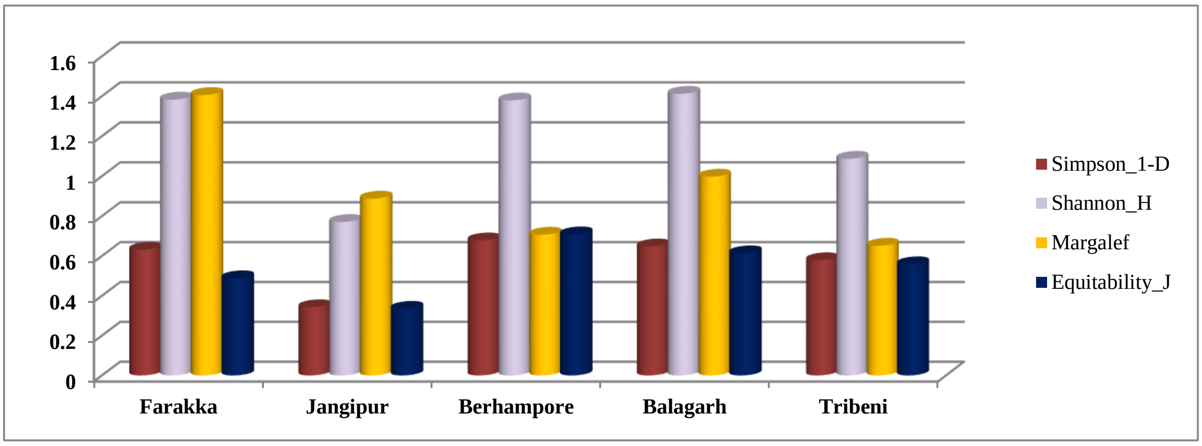


Fig. 149 Diversity Index of different species in Lower Stretch from Farakka to Tribeni

The estuarine stretch consists of Godakhali, Diamond Harbour, and Fraserganj. The maximum dominance of *Assiminae francesiae* (75%) is seen at Godakhali. This region comprises of salt-tolerant species with the least abundance of *Gyraulus parvus*, *Gabbia orcula* and *Brotia costula*. Highly marine species belonging to Ancillaridae family are not frequently found here. Instead, a dominance of Potamidae family is evident in this region like *Pirenellacin gulata*, *Telescopium telescopium*, and *Cerithidea obtusa*. Nassaridae species are also common at Fraserganj like *Nassarius stolatus* and *Nassarius foveolatus*. Fig. 150 shows the dominance of different families like Naridae, Nassaridae, and Potamidae. Fig. 151 shows a maximum diversity of species at Fraserganj (2.523) while Simpson dominance depicted a value of 0.904 resulting in the highest dominance of species at Fraserganj than any other station. The lowest species diversity (0.394), species dominance (0.138), species richness (0.633), and species equitability (0.179) is recorded only at Godakhali. Fraserganj depicted a high diversity of species along with species richness (1.863). The equitability of the species found at Fraserganj is the highest (0.913) stating that species consists of even distribution throughout the stretch.

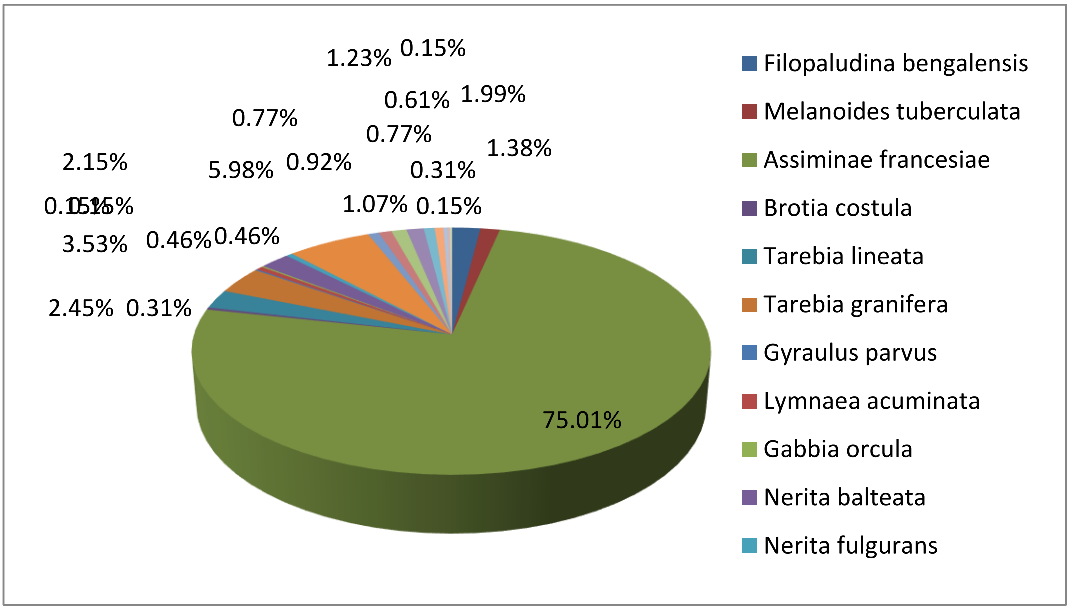


Fig. 150 Gastropod species abundance available in the estuarine stretch from Godakhali to Fraserganj

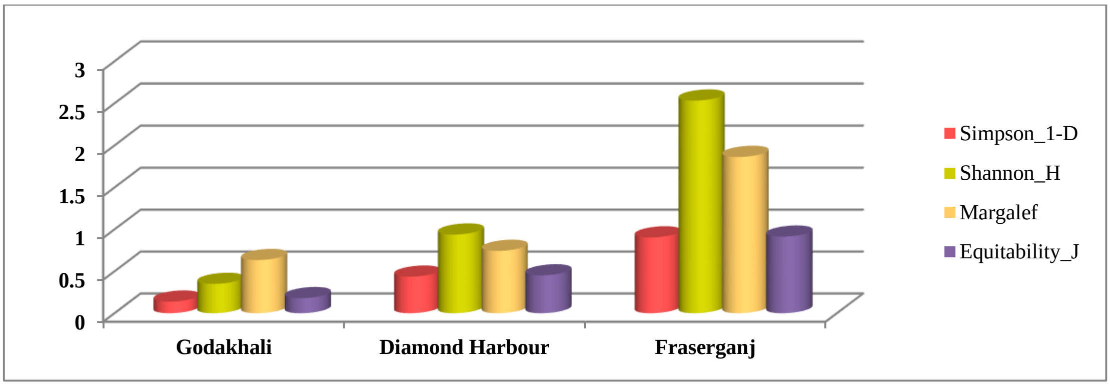
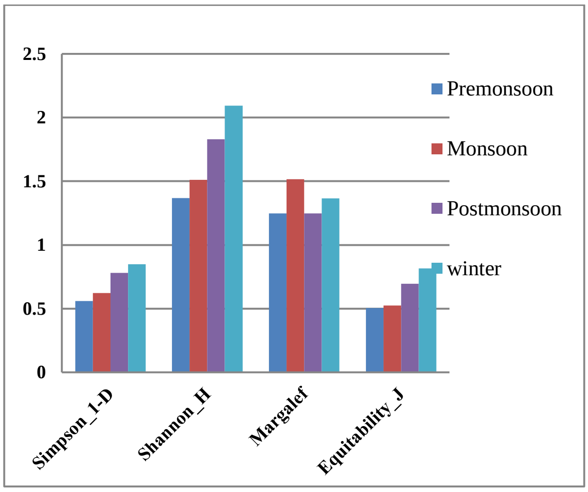


Fig. 151 Diversity Index of different species in Estuarine Stretch from Godakhali to Fraserganj

Seasonal Diversity Index of the Macrobenthic Species

The diversity index of freshwater gastropod in Fig. 152(a) showed the highest value of Shannon diversity of 2.093 during winter while the lowest was observed during pre-monsoon (1.367). Simpson diversity index was observed lowest (0.559) during pre-monsoon and highest at winter (0.848). The Margalef index showed a maximum diversity of 1.515 indicating that there is species richness in the ecosystem. Shannon diversity for brackishwater gastropod species in Fig. 152 (b) ranged between 0.79 to 2.186 during monsoon and post-monsoon and the Margalef index during post-monsoon is recorded 1.342, while 1.34 during monsoon. Moderately rich diversity was observed with an equitability test of 0.913 indicating that the species evenness in the ecosystem is equal during all the seasons with a maximum value during post-monsoon (0.913). Monsoon recorded a diversity of 0.790 for brackishwater species when the salinity reduced due to the inflow of freshwater. Shanon diversity of 1.658 during post-monsoon is recorded for freshwater bivalves depicted in Fig. 153. The dominance of different species ranged from 0.772 during post-monsoon to the least during winter (0.666). The equitability is even throughout the seasons with maximum value during post-monsoon (0.797). Seasonal diversity of class Insecta in Fig 154(a) showed a Shannon diversity of 1.399 during post-monsoon and Margalef index 1.878 during pre-monsoon indicating that richness in the species abundance. The species dominance showed a maximum value of 0.581 during post-monsoon while it reduced during winter (0.064). The evenness of the species showed a maximum of 0.606 during post-monsoon. Class Clitellata in Fig. 154(b) recorded a maximum diversity during winter (1.223) and least during monsoon (0.764). The Margalef Richness indices reduced during all theseasons with a maximum richness recorded during winter (0.443) while the least was recorded during monsoon (0.132).



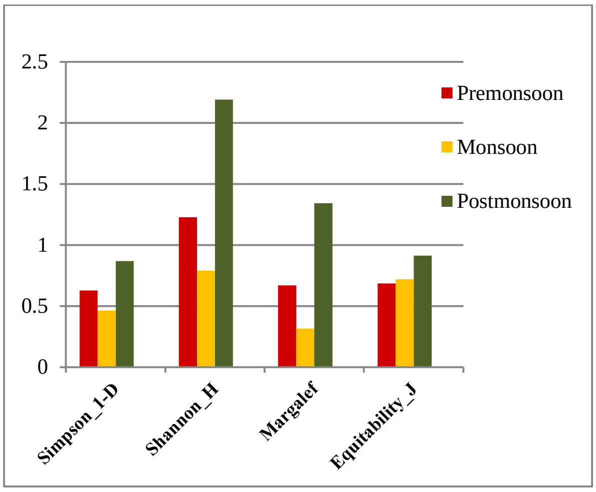


Fig. 152 Seasonal diversity index of Freshwater(a) gastropod in the left and Brackishwater(b) gastropod in the right

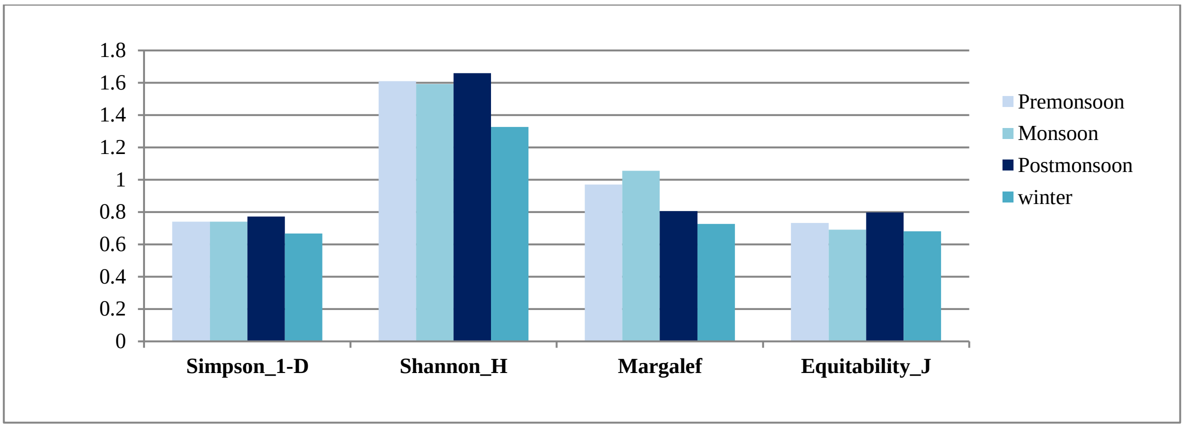


Fig. 153 Seasonal diversity index of Freshwater Bivalves

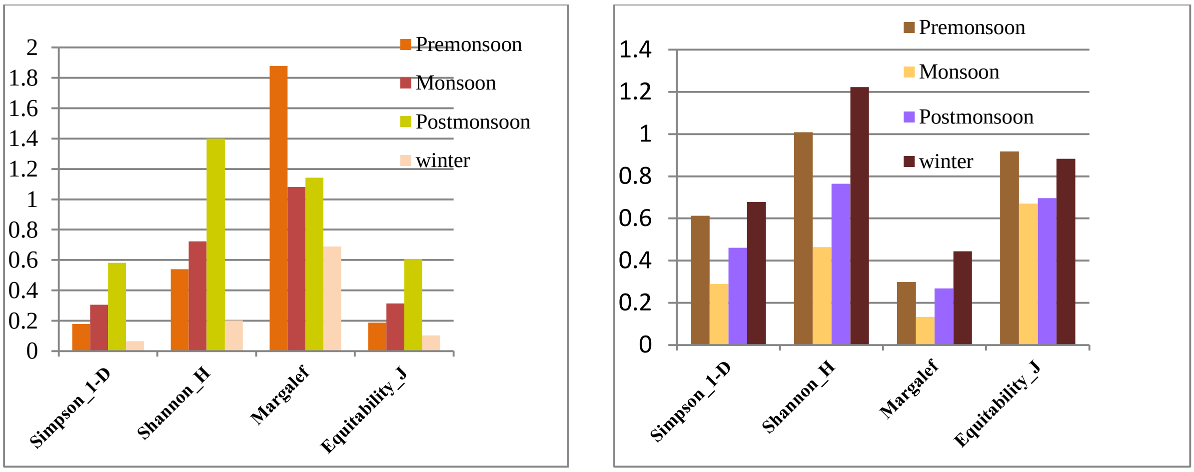
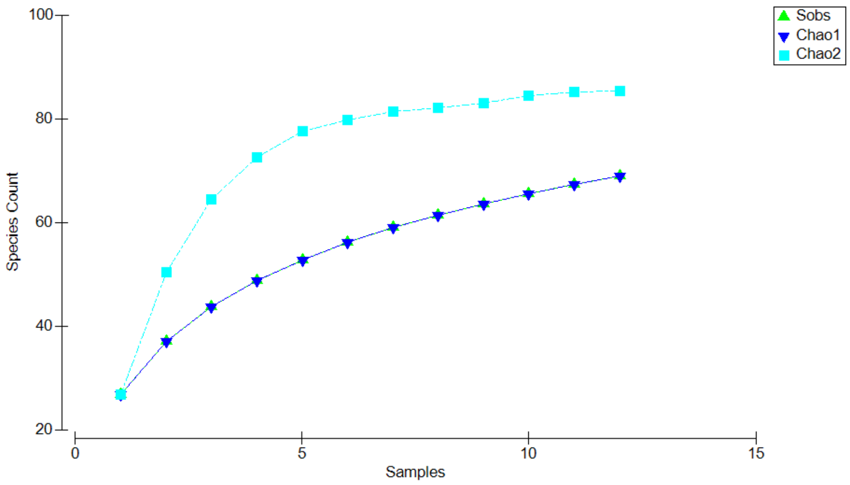


Fig.154 Seasonal diversity index of Class Insecta (a) in the left and Class Clitellata (b) in the right

Species–accumulation curve and estimation of macrobenthic richness

The species-area relationship is concerned with the number of species in areas of different size irrespective of the identity of the species within the areas, whereas the species accumulation curve is concerned with accumulation rates of new species over the sampled area and depends on species identity. Macrobenthicspecies accumulation curve for the Ganga River was obtained through PRIMER 6 (Fig. 155). The result showed that the curve of observed total species count was 69, from this lowest species count recorded during pre-monsoon 2017 (26 species) and the highest during post-monsoon 2019 (33 species). Chao's estimator using just presence-absence data showing that there is a chance to record a maximum of up to 85 macrobenthic species from the river Ganga with high sampling frequency.



Sobs - Curve of observed species counts

Chao 1 - Chao's estimator based on number of rare species

Chao 2 - Chao's estimator using just presence-absence data.

Fig. 155 Species Accumulation Curve of different benthic macro-invertebrate

Pollution Indicator Species

Biomonitoring of the aquatic habitat is the elementary aspect to maintain the health and diversity within the ecosystem. Bottom-dwelling benthic organisms are the principal source for detecting the quality of the river water and sediemnt. The relativity of pollution indicator species have been compared with the physicochemical parameters like total phosphate, total nitrogen, total chlorophyll, and soil organic carbon. These are the key indicators for biomonitoring of the ecosystem. Since the benthic organisms dwell in such a habitat, thus they become a prime source of pollution indicator in that habitat. A significant correlation between species and physicochemical parameters have been analyzed. Thirteen pollution indicating species has been identified throughout the stretch from Harshil to Fraserganj from 2017-2019. Nine species comprising of class Gastropoda, Bivalvia, Insecta and Clitellata were seen to have direct correlation with total phosphate content of the river water. ***Parreysia corrugate, Indonaia andersoniana, Anax* sp., *Dragonfly nymph***, ***Caenis* sp., *Rhyacophila* sp., *Tubifex tubifex*** and ***Lumbriculus variegatus*** are positively correlated with total phosphate i.e. the species are directly proportional to total phosphate in water. ***Mekongia crassa*** is negatively correlated with total phosphate content of water indicating that they grow maximum in phosphate free aquatic environment. Six species i.e. ***Physella acuta, Parreysia corrugate, Dragonfly nymph, Rhyacophila* sp., *Chironomus* sp.** and ***Tubifex tubifex*** have positive correlation with total nitrogen concentration of water. Four species of insects (***Dragonfly nymph***, ***Notonecta* sp.**, ***Philopotamus* sp.**, ***Chironomus* sp.**) and one species of annelid (***Tubifex tubifex***) have also positive correlation with total chlorophyll in water. ***Dragonfly nymph*** and ***Tubifex tubifex*** are positively correlated with soil organic carbon. Insects are one of the primary pollution-indicating species, which is found to be highly dominated in the polluted areas.

Table 39. Correlation of pollution indicator macrobenthic species with water parameter

Benthic organism	Water Total P	Water Total N	Water Total Chlorophyll	Soil Organic C
Physella acuta	-	.461*	-	-
Mekongia crassa	-.446*	-	-	-
Parreysia corrugata	.530*	.589**	-	-
Indonaia andersoniana	.473*	-	-	-
***Anax* sp.**	.504*	-	-	-
Dragonfly nymph	.675**	.676**	.489*	.518*
***Notonecta* sp.**	-	-	.594**	-
***Caenis* sp.**	.502*	-	-	-
***Rhyacophila* sp.**	.536*	.481*	-	-
***Philopotamus* sp.**	-	-	.594**	-

***Chironomus* sp.**	-	.480*	.563**	-
Tubifex tubifex	.578**	.766**	.466*	.768**
Lumbriculus variegatus	.510*	-	-	-

Bioindicator Species of River Ganga

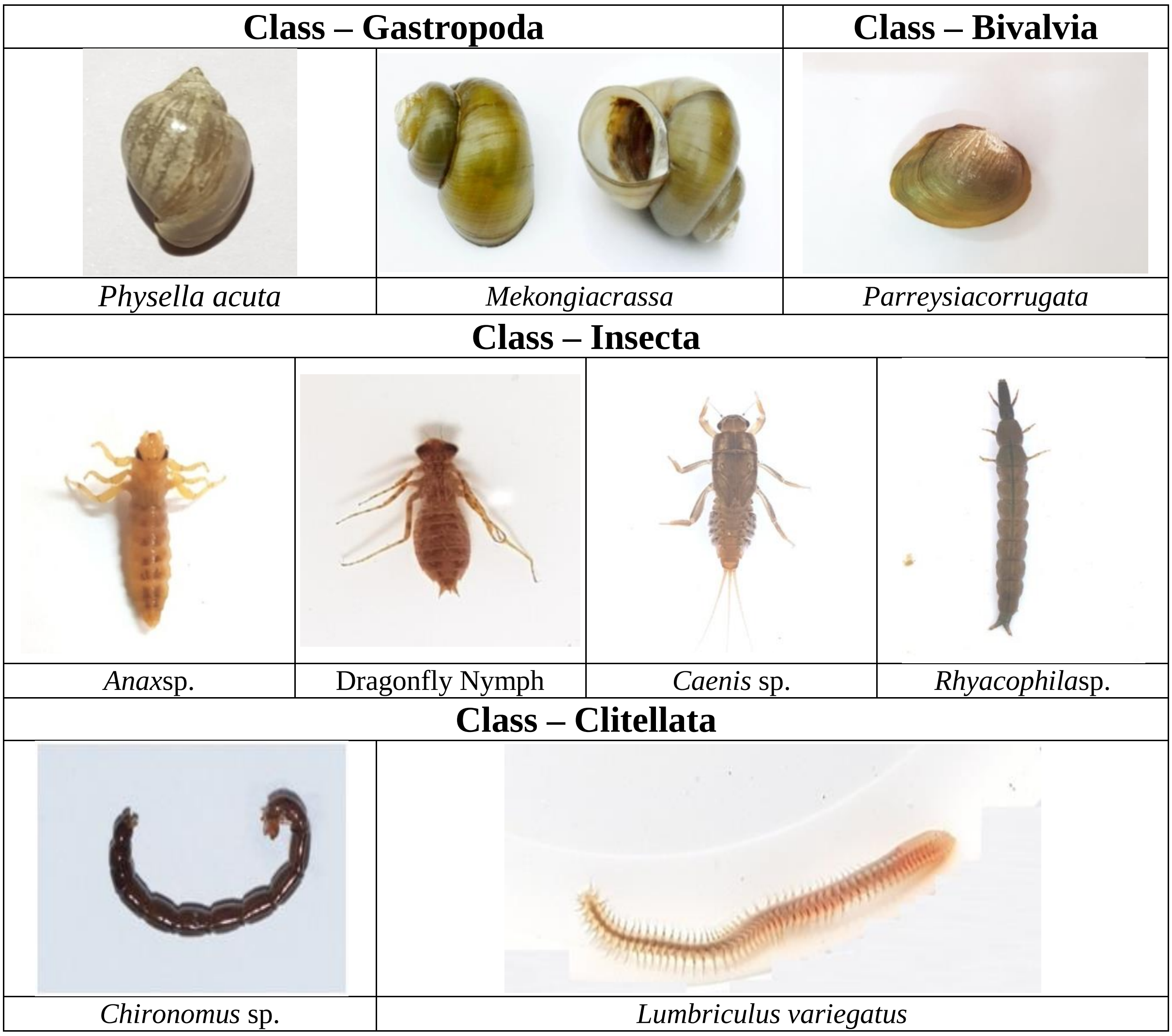


Fig. 156 Bioindicator benthic species of River Ganga

Studies in Open vs Closed Wetlands of river Ganga

The Ganga River basin is recognized as one of the most populated basins in the world and nurtures vast biodiversity (Johnson et al., 2019). The Ganga and Brahmaputra basin endowed with highly diversified floodplain wetlands in the eastern and north-eastern zone of India, covering 0.2 million hectares area (Bhattacharjya and Sugunan, 2000). Ganga basin associated wetlands are mainly formed due to various reasons like sloughs, tectonic depressions, meander scroll depressions and receive surface runoff or fresh waters from the parent river (Kumar et al., 2017). Many wetlands are losing their connection from river due to siltation, encroachment, river bank modification, etc. which has an impact on the biodiversity of both the wetlands as well as the nearby river. River connectivity is often described as a key requirement for supporting the health and biodiversity of associated wetlands including small indigenous fishes (Manna and Aftabuddin, 2007; Manna et al., 2012; Aftabuddin et al., 2017; Manna et al., 2018).

The present study revealed that the status of water quality, sediment characteristics, the nutrient profile of water, and sediment has an obvious effect on the ecosystem of the selected wetlands of both the types. The fish species as well as plankton species diversity was found more in open wetland though macro benthic diversity was the same in both the wetlands. The reason behind the diversity differentiation of open and closed wetlands may be the connection with the river. The linkage channel made the freshness environment of open wetland which causes the ecosystem more productive due to hydrological exchanges. The study revealed that higher organic load and nutrient accumulation is the cause for assembling of pollution indicator phytoplankton group like Bacillariophyta and Euglenophyta in closed beel. Thus, higher load of organic matter in closed wetland may lead to eutrophication in closed wetland. Lack of river connection in closed wetland harms the biodiversity of biotic communities of the wetland ecosystem.

Characteristics of Studied Wetlands

An open and a closed wetland (Beel) situated in lower stretch of river Ganga are being studied to understand the role of wetlands on ecosystem of river Ganga and vice versa. The selected open beel is an open type of wetland having perennial connection with river Ganga whereas Kalobaur beel is permanently disconnected from river Ganga. The area of open wetland is near about 155 ha. whereas the close one is extended upto 29.5 ha. The length of the connection channel of open beel is around 0.59 kilometre and width is 15.17 meter approximately. The main economic activities around these wetlands are fisheries, jute retting and irrigation for paddy and other dry season crops.

Study Area

The present study was conducted in open beel (23°26'50.08"N, 88°19'41.80"E), situated at Purba Bardhaman and Nadia district, West Bengal, India, and closed beel (23°36'45.75" N, 88°10'56.68" E) at Purba Bardhaman district, West Bengal on the bank of river Ganga in same agro-climatic region. Systematic sampling was performed from February 2018 to August 2019 in selected sampling stations in each of the wetland. Three sampling stations C1, P3 and B4 in open beeland K1, K2, K3 in closed beelwere considered (Fig.157).

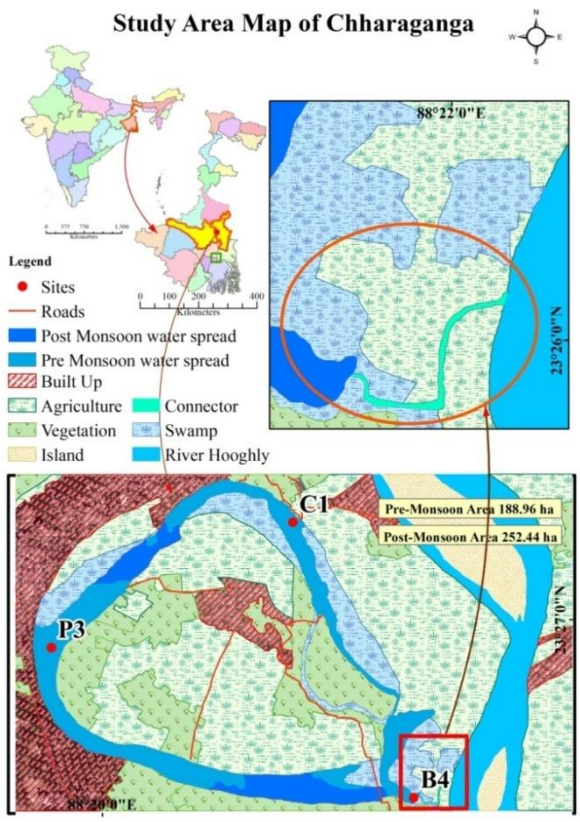


Fig. 157a

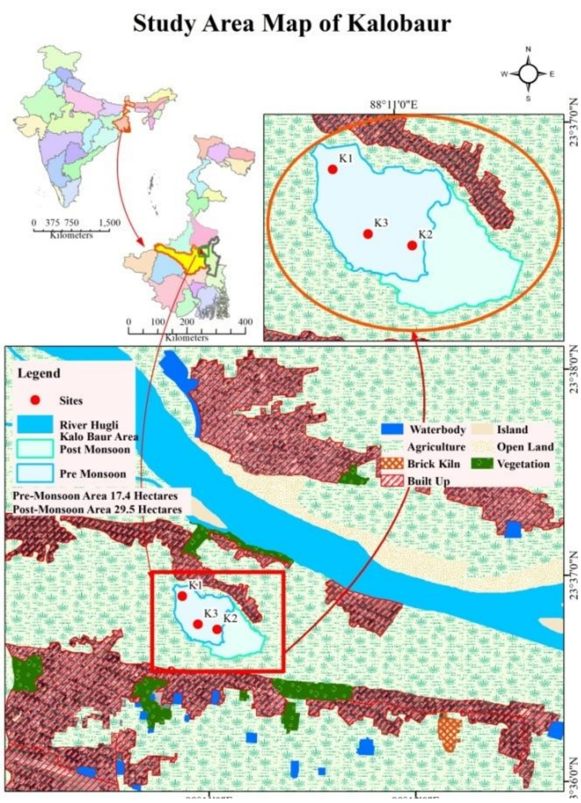


Fig. 157b

Fig. 157 (a-b) Study area map of studied Wetland

Fig.158 A view of an Open wetland

Fig.159 A typical closed wetland in Ganga basin

STATUS OF FISH FAUNA OF WETLAND

The study revealed a total of 45 fish species belonging to 11 orders and 23 families were recoded from the open wetland and 21 fish species belonging to 07 orders and 10 families from closed wetland. Among the total fish species diversity, a total of 31 indigenous fish species having ornamental value from open and 11 from closed beel. According to IUCN Red List (IUCN version 2.2020) 3 species belong tonear threatened and 1 to endangered fish species from open beel whereas 2 Near threatened and 2 Vulnerable fish species were recorded from Kalobaur beel. Family Cyprinidae was found dominant in both the beel as 29% in open beel and 34% in closed beel. Another dominant group were Ambassidae (25%) and Danionidae (9%) from open wetland whereas family Danionidae (26%) and Ambassidae (25%) in closed beel (Fig. 160 & 161). Besides these, two exotic fish group viz. Xenocyprididae and Cichlidae were recorded in closed beel.

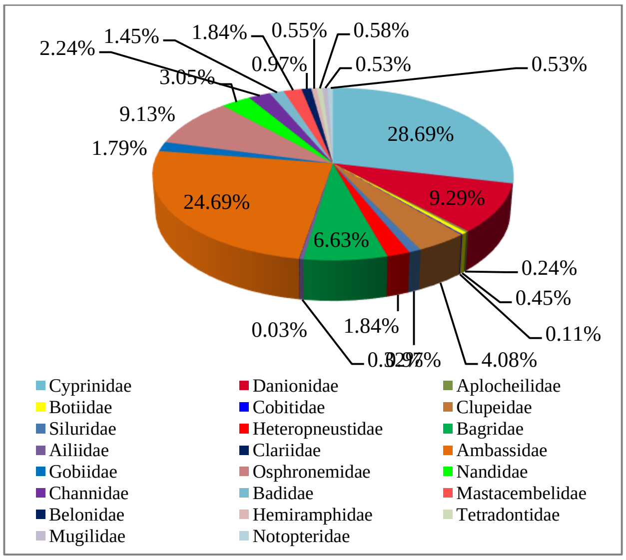


Fig. 160 Percentage contribution of fish family in open wetlands

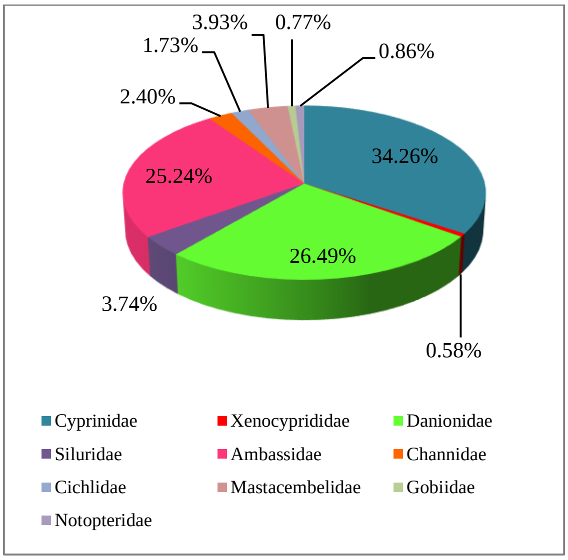


Fig 161 Percentage contribution of fish family in closed wetland

Seasonal changes in abundance of fish species in the selected wetlands

Seasonal changes in abundance of fish species and diversity were studied in the both beels. Family Cyprinidae is dominant in open beel throughout the season. Ambassidae, Bagridae were found dominant in pre-monsoon whereas, Danionidae, Clupeidae in monsoon and Ambassidae along with Clupeidae in post monsoon season (Fig. 162). Fish species like *Parambassis ranga, Parambassis lala, Chanda nama* were found dominant all the season. Apart from these *Puntius sophore, Pethia gelius,* were abundant in premonsoon, *Pethia phutunio, Mystus vittatus,* in monsoon and *Puntius sophore, Gudusia chapra, Trichogaster lalius* in postmonsoon.

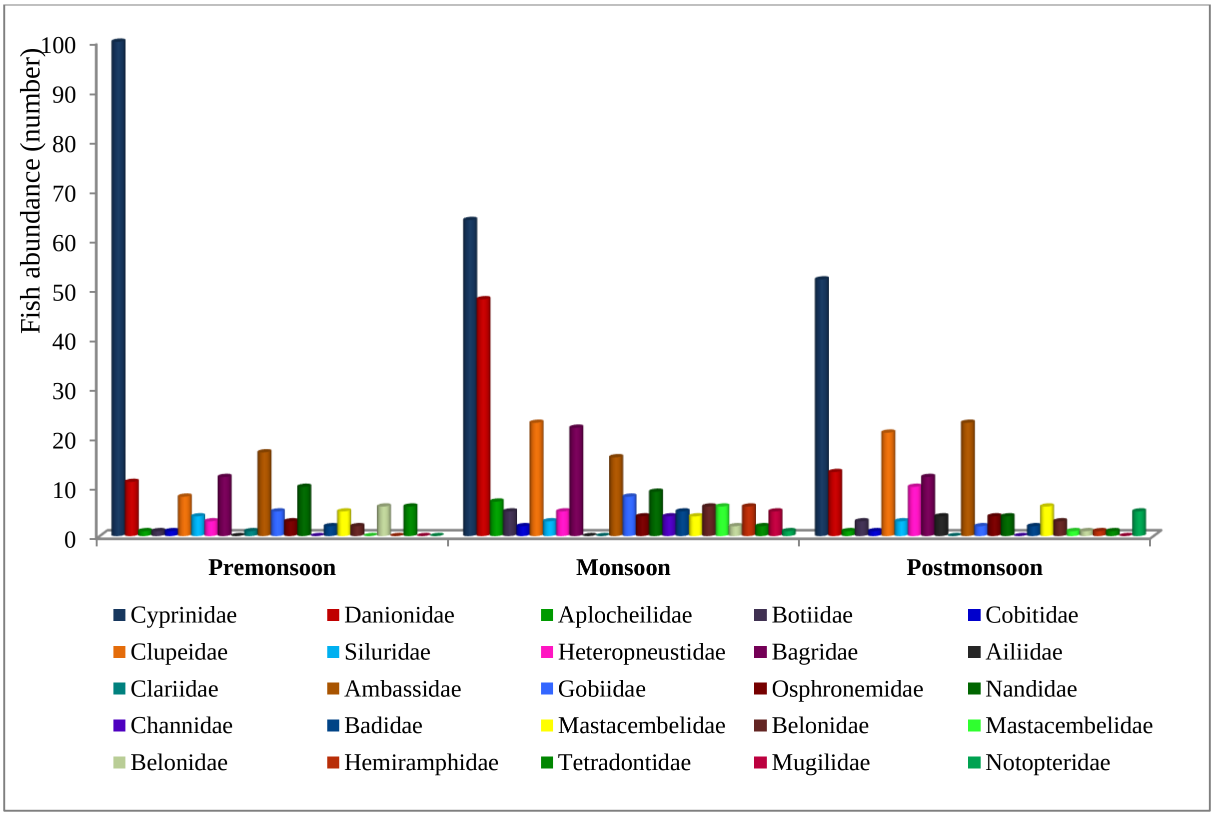


Fig. 162 Seasonal changes of abundance of fish family in open beel

Families like Ambassidae and Cyprinidae were observed dominant in all season in closed beel (Fig. 163). Danionidae is another major group found dominat in pre-monsoon as well as post monsoon season where as Siluridae, Mastacembelidae were recorded abundant only in pre-monsoon season. However, Gobiidae and Notopteridae were found dominant in post-monsoon season. Exotic big head carp (*Hypophthalmicthys nobilis*) belong the family Xenocyprididae were observed during the present study.

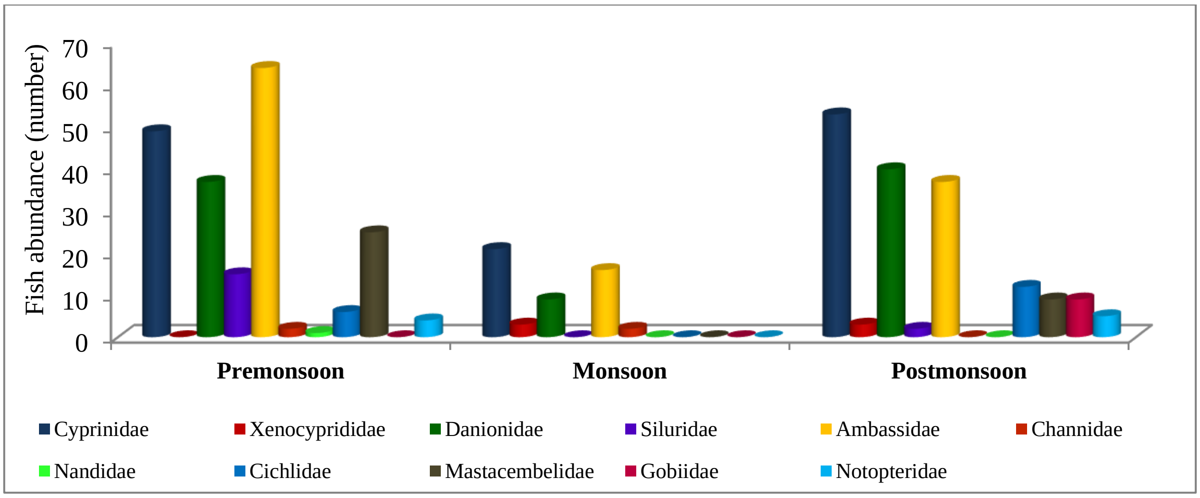


Fig. 163 Seasonal changes of abundance of fish family in closed beel

Diversity status of fish species in the studied beel

Study revealed that Shannon diversity (*H′*), Simpson diversity index (1-*D*) and Margalef species richness index (*d′*) and Equitability index (*J′*) were higher in open beel than closed beel. The study also indicates the rich fish diversity in open beelis due to connection with the parent river Ganga. Only species dominance (*D*) was found higher in closed beel because of low species diversity in the closed environment caused by the loss of connectivity with parent river.

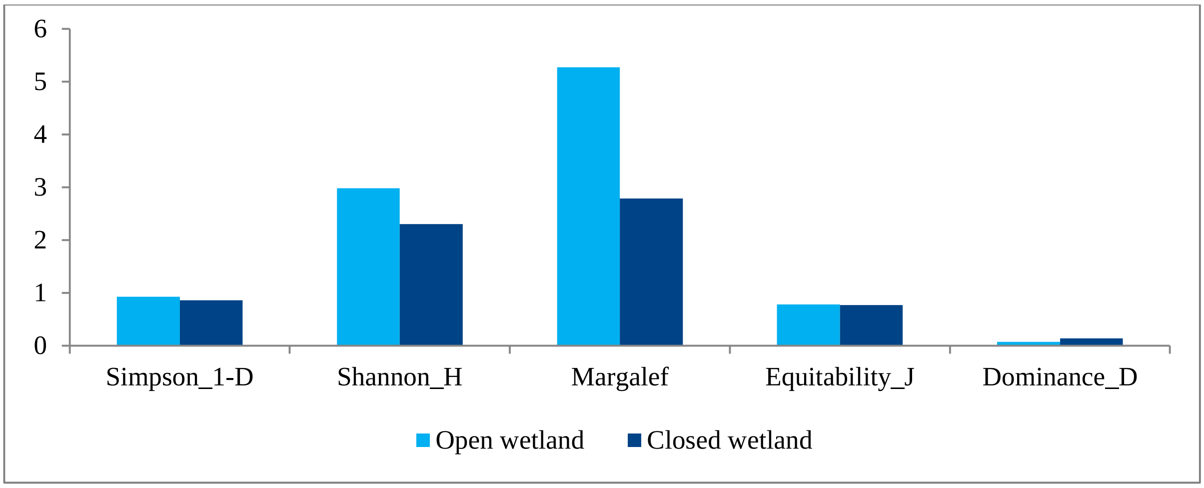


Fig. 164 Diversity status of fish species in the studied beel

Common fishes recorded in Open beel

Fig. 165a *Cirrhinus reba*

Fig. 165b *Gudusia chapra*

Fig. 165c *Aplocheilus panchax*

Fig. 165d *Botia dario*

Fig. 165e *Heteropneustes fossilis*

Fig. 165f *Labeo rohita*

Fig. 165g *Pethia conchonius*

Fig. 165h *Nandus nandus*

Fig. 165i *Glossogobius giuris*


Fig. 165j *Puntius sophore*

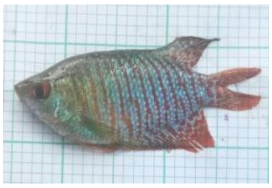


Fig. 165k *Trichogaster lalius*


Fig. 165k *Rasbora daniconius*

Fig. 165 a-k Common fishes recorded in Open beel

Common fishes recorded in Closed beel


Fig. 166 *Hypophthalmicthys nobilis*


Fig. 166b *Labeo rohita*


Fig. 166c *Amblypharyngodon mola*


Fig. 166d *Channa punctata*


Fig. 166e *Chanda nama*


Fig. 166f *Puntius sophore*

Fig. 166 a-f Common fishes recorded in closed beel

Status of phytoplankton in Studied beel

A of total of 56 genera belonging to 7 phyla from open beel and 45 genera belongingto 6 phyla from closed beel were recorded during the present study. Bacillariophyta, Chlorophyta, Cyanobacteria, Euglenozoa, Charophyta and Ochrophyta were recorded from both the wetlands except the genera, Miozoa which was recorded only from open beel. Cyanobacteria (11 genera) was the most dominant group followed by Bacillariophyta (12 genera) and Chlorophyta (21 genera) in open beel. Dominance of Bacillariophyta (12 genera) was observed in Kalobaur beel followed by Euglenozoa (4 genera) and Chlorophyta (18 genera). Total abundance of Bacillariophyta was the highest (15546 units/l) in closed beel followed by Euglenozoa (10063 units/l) whereas, Cyanobacteria was recorded the highest (4731 units/l) in open beel, followed by Bacillariophyta (4152 units/l). The percentage of abundance of different group of phytoplankton of studied beel is depicted in Fig. 167 & 168.

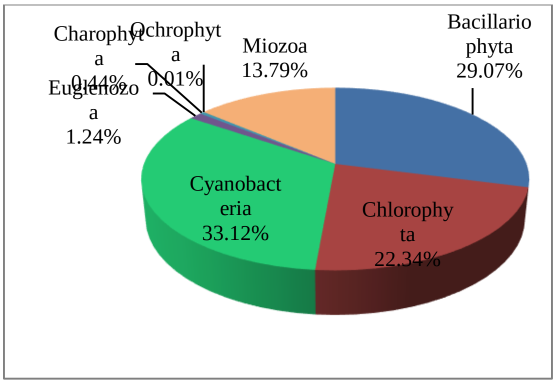


Fig. 167 Percentage of abundance of different group of phytoplankton in open beel

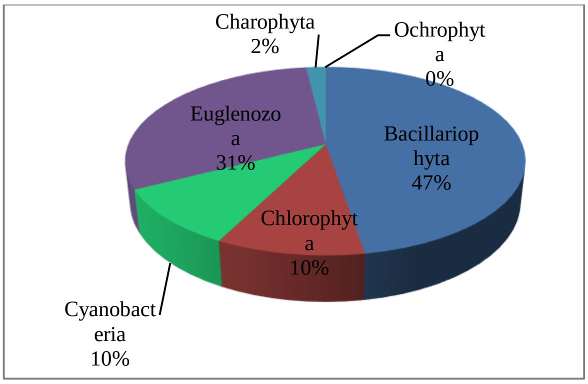


Fig. 168 Percentage of abundance of different group of phytoplankton in closed beel

Seasonal changes in abundance of phytoplankton communities in wetlands

Seasonal changes of abundance of phytoplankton group were studied in open beel (Fig. 169). Bacillariophyta was the most dominant group throughout the season whereas Cyanobacteria was dominant in premonsoon and Miozoa was found second dominant group in post-monsoon season. Among the Bacillariophyta, dominant genus was *Gyrosigma* (120 units/l) in premonsoon and *Melosira* (189 units/l) in post-monsoon but other genus were reported quite less amount in the period of monsoon season. In Chlorophyta, *Kirchneriella* (160 units/l) was dominant in pre-monsoon and *Oedogonium* (299 units/l) in post-monsoon season. *Gloeocapsa* (282 units/l) was the most abundantamong the Cyanobacteria in pre-monsoon whereas *Spirulina* (131units/l) in post-monsoon season. Among Euglenozoa, *Phacus* (42 units/l) was dominant in pre-monsoon but other genera were found in minimum quantity throughout the year. *Spirogyra* (344 units/l) among the Charophyta as well as *Ceratium hirundinella* (735 units/l) in Miozoawas found dominant only in post-monsoon season. However, Ochrophyta was found in least abundant during monsoon season.

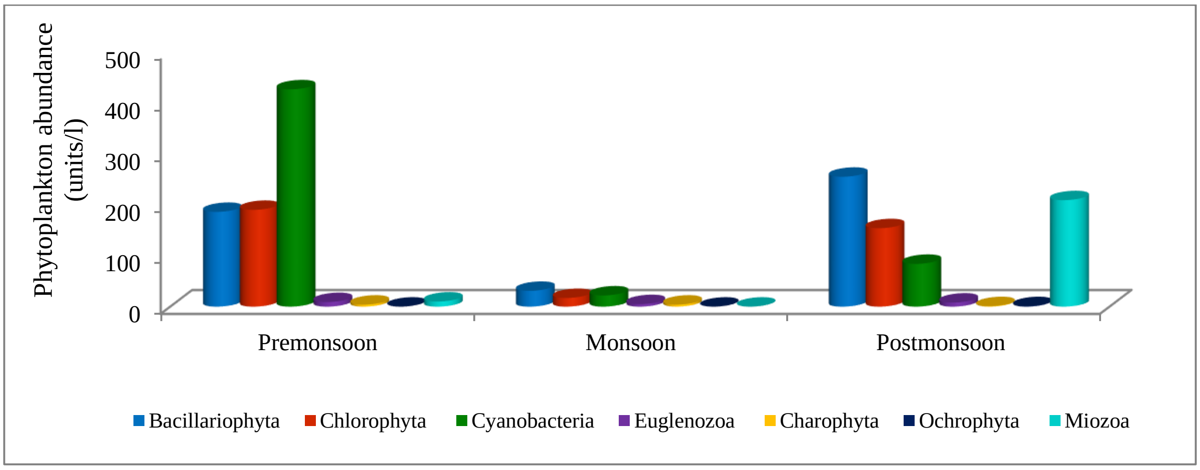


Fig. 169 Seasonal changes of abundance of phytoplankton communities in Open beel

Seasonal changes of abundance of phytoplankton group were also studied in closed beel (Fig. 170). Bacillariophyta and Euglenozoa were the most dominant group throughout the study period. Except these two phylum, Chlorophyta and Cyanobacteria were found abundant in monsoon period. In pre-monsoon, *Melosira* (226 units/l) was found dominant among the Bacillariophyta whereas, *Synedra* (256 units/l) in monsoon and *Pinnularia* (1075 units/l) in post monsoon season. In Chlorophyta, *Pediastrum simplex* (420 units/l) was dominant in pre-monsoon, *Gloeocystis* (274 units/l) in monsoon and *Westella* (800 units/l) inpostmonsoon. Among Cyanobacteria, the *Chroococcus*(554 units/l) in monsoon and *Spirulina* (392 units/l) in post-monsoon were dominant but in pre-monsoon the dominance of genera belong to Cyanobacteria was quite less. *Euglena* among the Euglenozoa was found most dominant in monsoon (668 units/l) as well as in post-monssonseason (1773 units/l). Another major genus *Phacus* was found dominant in post-monsoon (968 units/l). Charophyta found dominant only in monsoon i.e.*Closterium* (204 units/l) and another phylum Ochrophyta was found in least quantity all over the season.

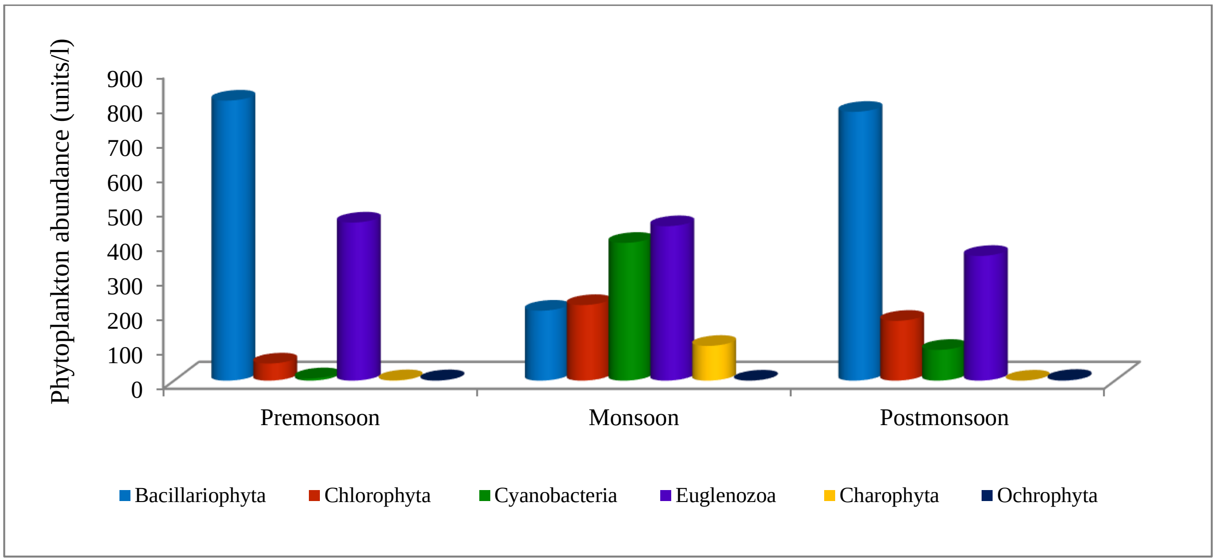


Fig. 170 Seasonal changes of abundance of phytoplankton communities in Closed beel

Shannon diversity (H') of phytoplankton community was recorded high in openbeel (H'=3.207) than closed (H'=3.018) (Fig. 158). Similar observation was also found for Margalef species richness index. The species dominance was also recoded high in openbeel (D= 0.9384) compare to closed (D=0.9297). Equitability index (J′) showed more species evenness of phytoplankton community at openbeel rather than closedbeel. The Shannon diversity and Margalef’s species richness index indicates the well-off status of phytoplankton diversity in open ecosystem.

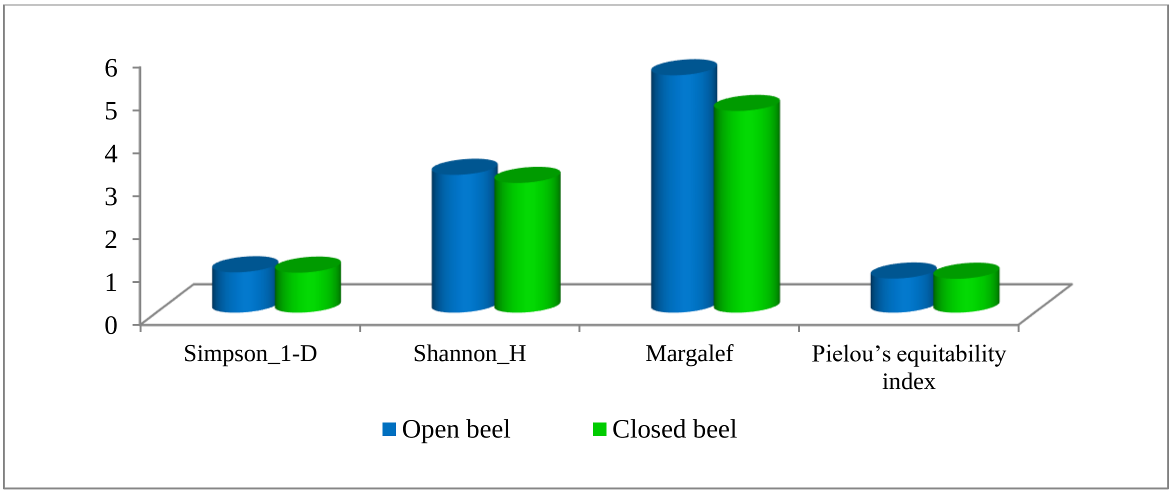


Fig.171 Diversity indices of phytoplankton in the studied wetlands

Status of zootoplankton in Studied beel

Seasonal changes of abundance as well as diversity of zooplankton were also studied along with phytoplankton community in the studied beel. Twentygenera belong to 4 phyla from Open beel and 23 genera belongs to 4 phyla from closed beel. Arthropoda (7 genera) was found the most dominant in both thebeel during present study. The percentage abundance of different group of zooplankton of studied beel is presented in Fig. 172 & 173.

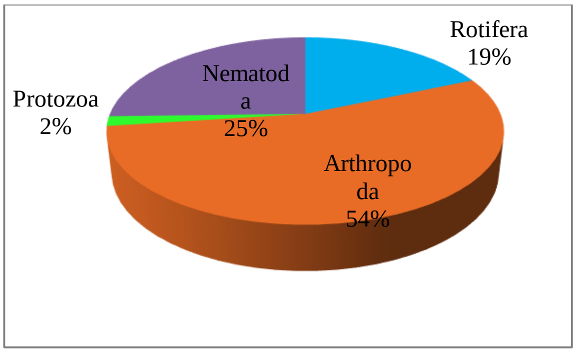


Fig. 172 Percentage of abundance of different group of zooplankton in open beel

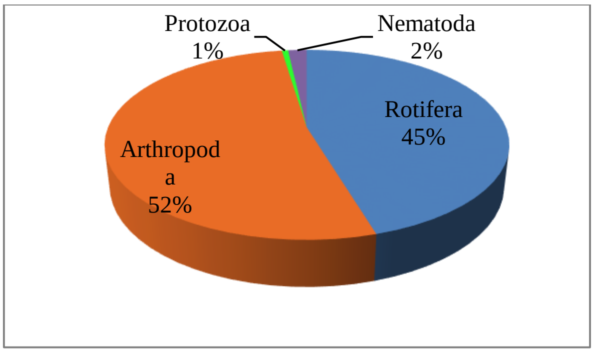


Fig. 173 Percentage of abundance of different group of zooplankton in Closed beel

Seasonal changes inabundance of zooplankton communities in wetlanads

Seasonal changes inabundance of zooplankton were also studied along with phytoplankton community in Open beel (Fig. 174). Arthropoda was the most dominant group throughout the year, followed by Rotifer whereas Nematoda found most abundant in pre-monsoonseason during the present study. *Brachionus* (292 units/l) was found dominant in pre-monsoon and *Keratella* (501 units/l) in post-monsoon among the Rotifera group. In Arthropoda, *Nauplii* (620 units/l) was dominant in pre-monsoon and *Cyclopoid copepods* (946 units/l) in post monsoon. Nematoda was found high in pre-monsoon however,the abundance of Amoebozoa was found vey low in Open beel.

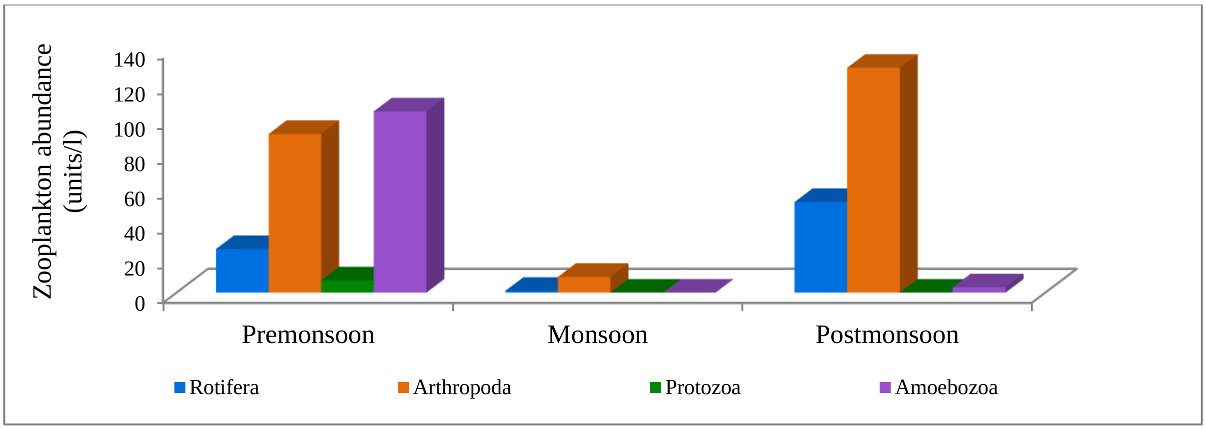


Fig. 174 Seasonal changes of abundance of zooplankton in open beel

Arthropoda was also found dominant in closed beel but Rotifer was dominant in monsoon (Fig. 175). *Brachionus* (444 units/l) was the most dominant genus among the Rotifera in monsson but *Nauplii* (769 units/l) was dominant in post-monsoon. *Diaphanosoma* (212 units/l) was dominant in pre-monsoon among Arthropoda whereas *Cyclopoid copepods* (847 units/l) was abundant in post-monsson. Abundance of Nematoda and Amoebozoa were also found in very lowduring the present study.

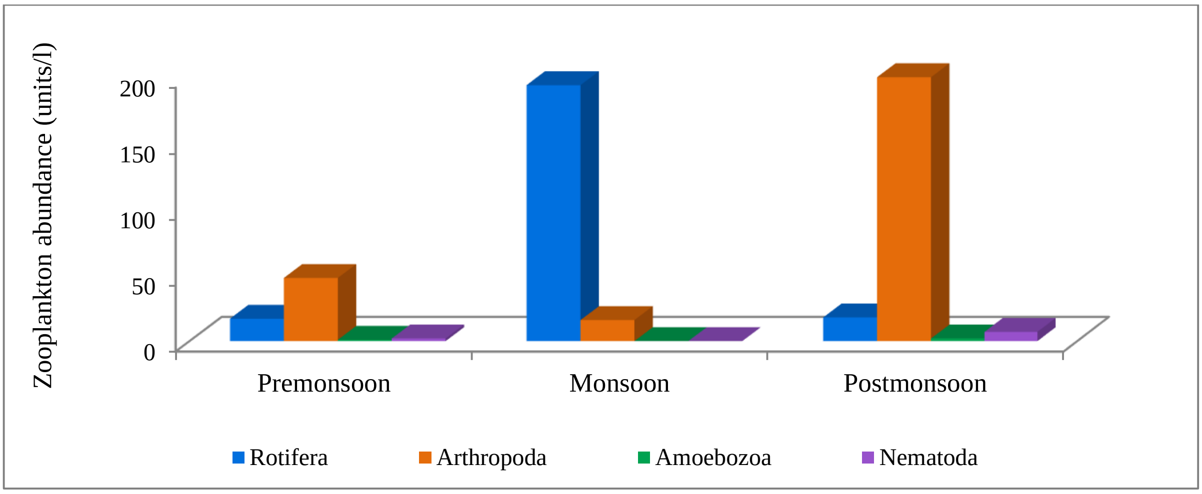


Fig. 175 Seasonal changes of abundance of zooplankton in closed beel

Shannon diversity (H') of zooplankton community was recorded high in closed beel (H'=2.135) than open (H'=1.82) (Fig. 176). Similar observation was also found for Margalef species richness index. The Simpson index was also recoded high in closed beel (1-D= 0.851) compare to open (1-D= 0.795). Equitability index (J′) showed more species evenness of zooplankton community at closed beel rather than open beel.

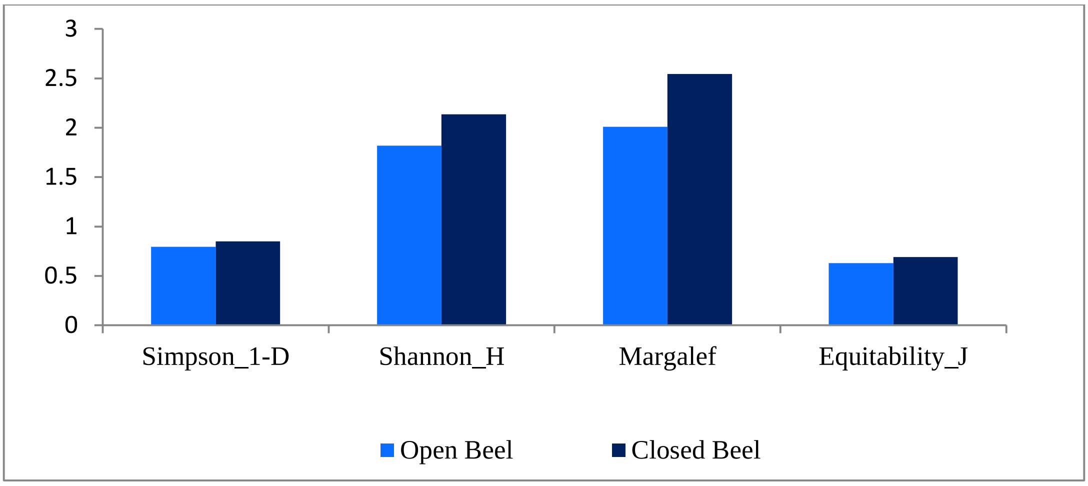


Fig. 176 Diversity indices of zooplankton in the studied wetlands

Common phytoplankton species recorded in wetlands

Fig. 177a *Pandorina* sp.

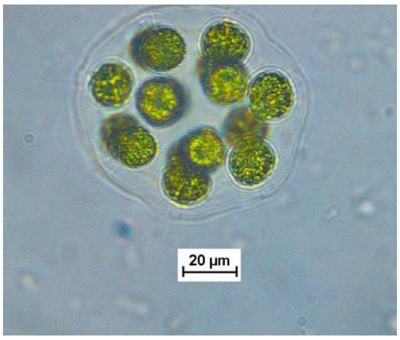


Fig. 177b *Eudorina* sp.

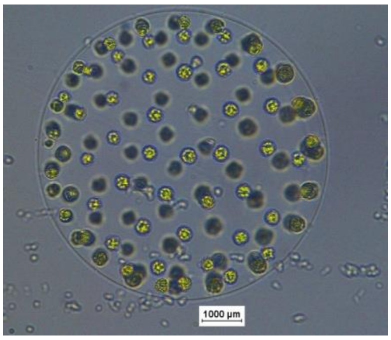


Fig. 177c *Volvox* sp.

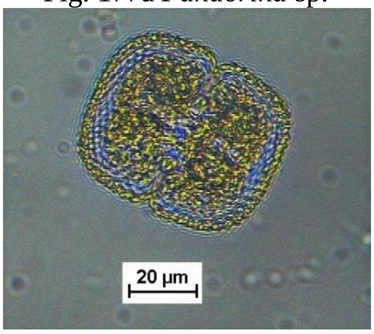


Fig. 177d *Cosmarium*sp.

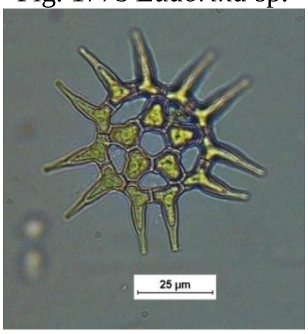


Fig. 177e *Pediastrum simplex*

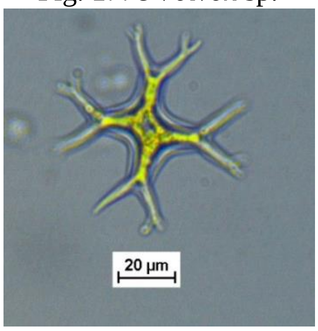


Fig. 177f *Tetraëdron* sp.

Fig. 177a-f Common Phytoplankton in wetlands

Common zooplankton species in wetlands

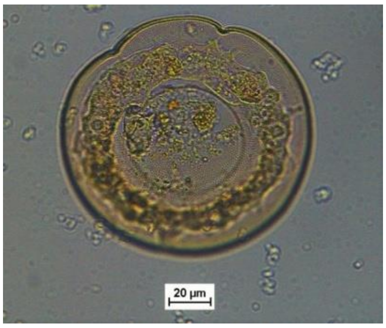


Fig. 178a *Centropyxis aculeata*

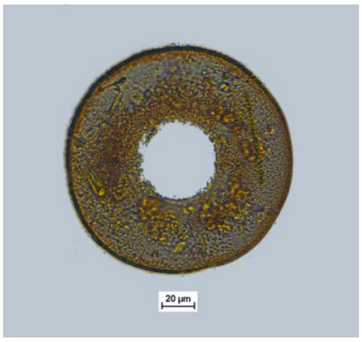


Fig. 178b *Arcella* sp.

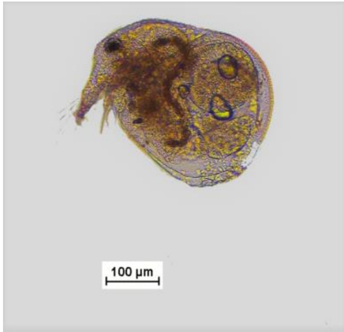


Fig. 178c *Bosmina* sp.

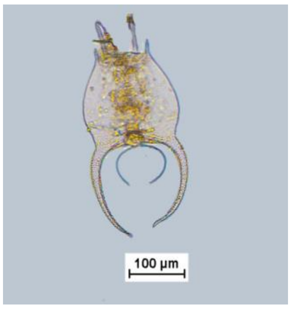


Fig. 178d *Brachionus* sp.

Fig. 178e *Filinia* sp.

Fig. 178 a-e Common Zooplankton in wetlands

Status of benthic fauna in the selected wetlands

A total of 11 macro benthic species belong to 4 orders and 7 families were reported from both the wetlands. Family Viviparidae was found most dominant in both the wetlands as it contributes 31% and 34% of the total diversity in open beeland closed beel respectively. Other dominated families were Thiaridae (16.38%), followed by Planorbidae (16.11%) in open beel whereas, Planorbidae contributing 14.19% as the second-dominated family, followed by Thiaridae (13.60%) in closed beel.

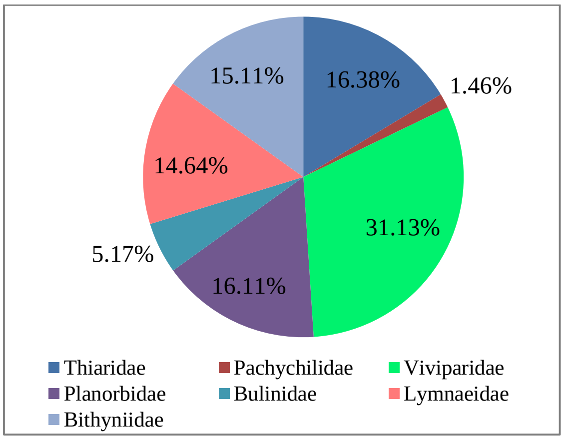


Fig. 179 Status of Benthic Fauna in open wetland

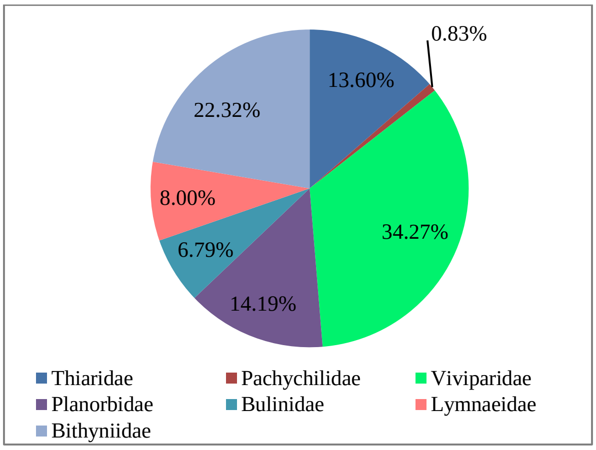


Fig. 180 Status of Benthic Fauna in close wetland

Seasonal changes inabundance of benthic communities in wetlands

Family Planorbidae found dominant in pre-monsoon (364 units/m^2) whereas, Viviparidae was dominant in monsoon (295 units/ m^2) as well as post monsoon season (286 units/ m^2).

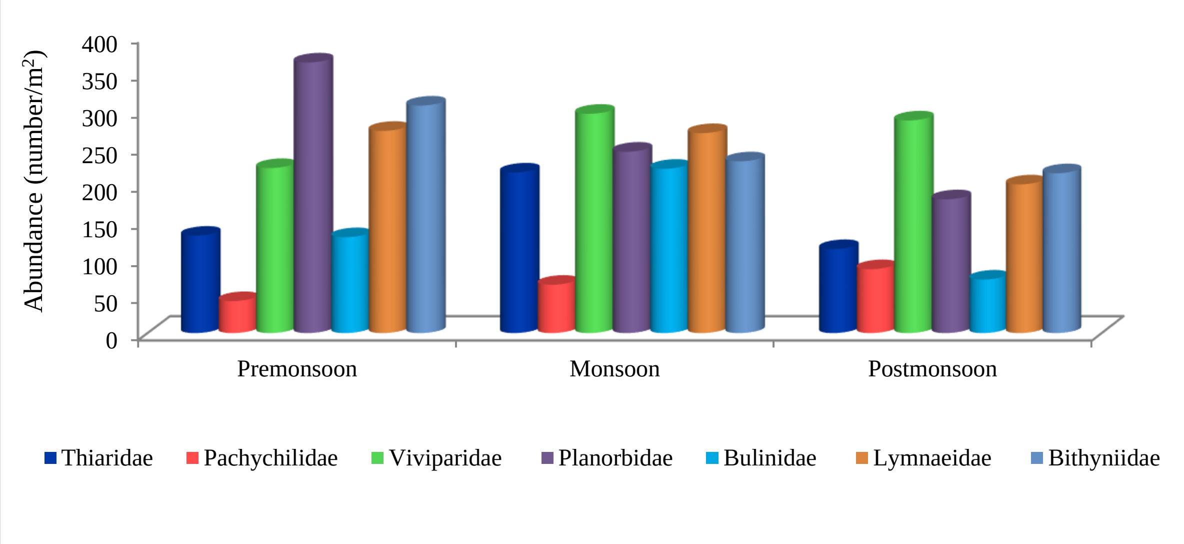


Fig. 181 Seasonal changes of abundance of Benthic Faunna in open wetland

whereas, family Bithyniidae was found dominant in pre-monsoon (346 units/m^2) and monsoon (357 units/ m^2) but family Viviparidae found dominant in post-monsoon (276 units/m^2).

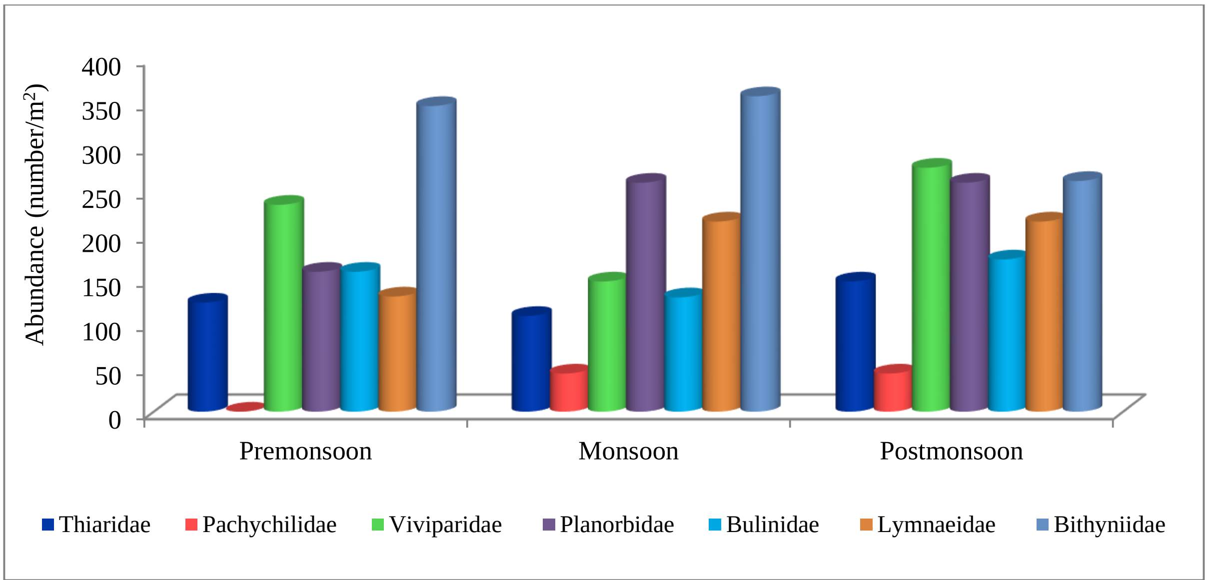


Fig. 182 Seasonal changes of abundance of Benthic Faunna in close wetland

Study revealed that Shannon diversity (*H'*), Simpson diversity index (1-*D*) and Equitability index (*J'*) were higher in open beel than closed beel (Fig. 183). However, Margalef species richness index (*d'*) was found high in closed beel.

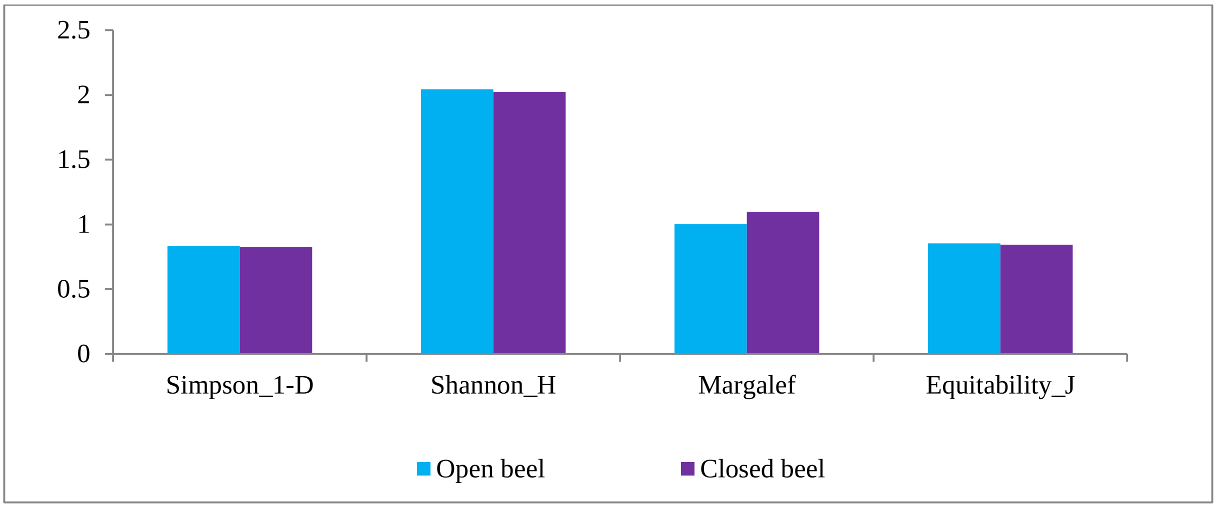


Fig. 183 Species diversity index of Benthic Faunna in studied beel

Some common benthic fauna recorded in selected wetlands

Fig. 184a *Melanoides tuberculata*

Fig. 184b *Brotia costula*

Fig. 184c *Filopaludina bengalensis*

Fig. 184d *Gabbia orcula*

Fig. 184 a-d Common macro-benthic fauna in wetlands

Water quality in the studied wetlands

The average estimated water quality parameters such as water temperature, pH, DO, turbidity, water transparency, specific conductivity, free CO_2, water depth, total hardness, alkalinity, sulphate, total nitrogen, NO_3-N, phosphate, silicate (Si), calcium (Ca), magnesium (Mg), chlorophyll a (Ca), chlorophyll b (Cb), chlorophyll C (Cc) and total chlorophyll of both the wetland are summarized in Table 40. It was found that average Water temperature in open wetland i.e., open wetland was ranges from 24.4 °C to 32 °C. In closed wetland i.e., Kalobour wetland the Water temperature varies from 21.1°Cto 31°C. In open wetland pH was ranges from 7.1 to 8.5 and highest in the month of February, 2018. In closed wetland the pH varies from 7.3 to 8.6 and highest in the month of February, 2019. In both the wetlands, water pH was slightly alkaline in nature. In open wetland, DO varies from 2.3 to 7.4 ppm and closed wetland varies from 2.4 to 7.3 ppm. In both the wetland, sometimes we got the higher DO may be due to the high concentration of submerged plants. In open wetland, turbidity varies from 1.6 to 4.9 NTU and closed wetland varies from 4.4 to 5.6 NTU. In open wetland, conductivity was ranges from 209 to 364 µS/cm and highest in the month of February, 2019. In closed wetland it was ranges from 456 to 559 µS/cm. In open wetland hardness was ranges from 91 to 130 ppm and closed wetland 134 to 162 ppm. In open wetland alkalinity was ranges from 103 to 154 ppm and closed wetland 133 to 143 ppm. Nitrate -N, Total nitrogen, Phosphate content in water were more in closed wetland than open wetland. Nitrate -N content in open wetland ranges from 0 to 0.2 ppm and in closed wetland from 0.4 to 0.7 ppm. Total Nitrogen content in open wetland ranges from 0.1 to 1.0 ppm and in closed wetland from 0.9 to 1.5 ppm. Phosphate content in open wetland ranges from 0 to 0.1 ppm and in closed wetland from 0.3 to 0.5 ppm. Calcium content in open wetland ranges from 17 to 29 ppm and in closed wetland from 29 to 45 ppm. Magnesium content in open wetland ranges from 8 to 25 ppm and in closed wetland from 15 to 27 ppm. Total Chlorophyll content in open wetland varies from 0.7 to 4.4 mg/m3 and closed wetland 1.5 to 8.8 mg/m3.

Table 40. Water quality of Studied wetlands

Indicators	Openbeel		Kalobaurbeel	
	Average	Std. error	Average	Std. error
Water Temperature (oC)	28.55	0.65	29.2	0.3
pH	7.92	0.11	7.81	0.16
DO (ppm)	5.04	0.34	4.4	0.23
Turbidity (NTU)	3.39	1.05	5	0.17
Transparency (cm)	145.89	12.63	74.33	4.75
Conductivity(µS/cm)	269.26	11.15	483.63	6.73
Free CO_2 (ppm)	2.83	0.43	2.96	0.29
Depth (m)	4.32	0.24	5.55	0.2
Hardness (ppm)	110.41	2.71	146.04	3.19
Alkalinity (ppm)	126.74	3.54	136.07	2.43
NO_3-N (ppm)	0.08	0.01	0.6	0.03
Total Nitrogen (ppm)	0.6	0.07	1.28	0.05
Phosphate (ppm)	0.03	0	0.47	0.02
Silicate (ppm)	5.6	0.59	8.13	0.22
Calcium (ppm)	24.24	0.88	34.62	0.8
Magnesium (ppm)	12.43	0.86	20.14	0.8
Sulphate (ppm)	0.37	0.15	0.08	0.04
Ca (mg/m^3)	2.05	0.3	2.17	0.35
Cb (mg/m^3)	1.34	0.49	0.67	0.19
Cc (mg/m^3)	1.14	0.21	0.62	0.18
Total Chlorophyll(mg/m^3)	4.44	0.8	3.45	0.61

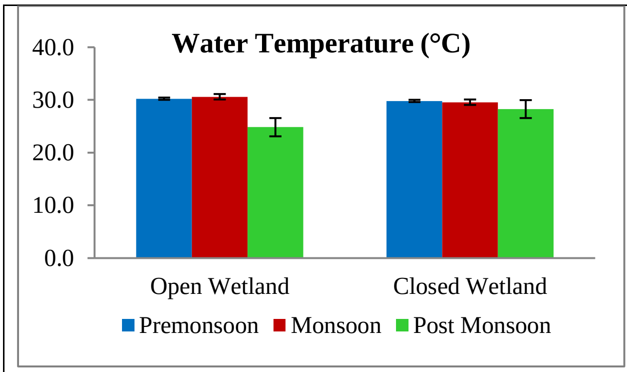


Fig. 185 a

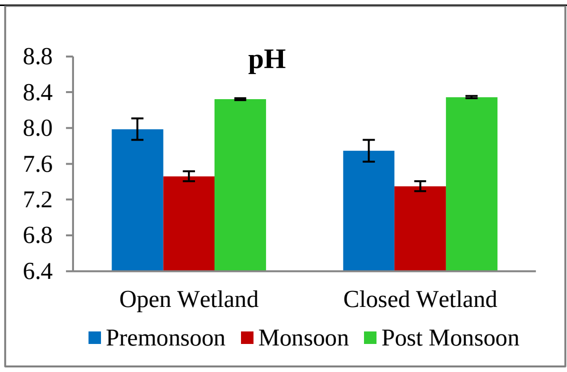


Fig. 185b

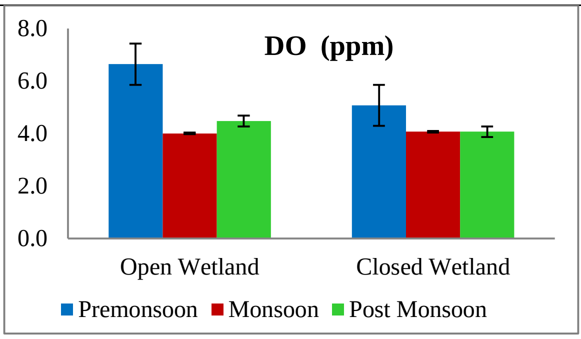


Fig. 185c

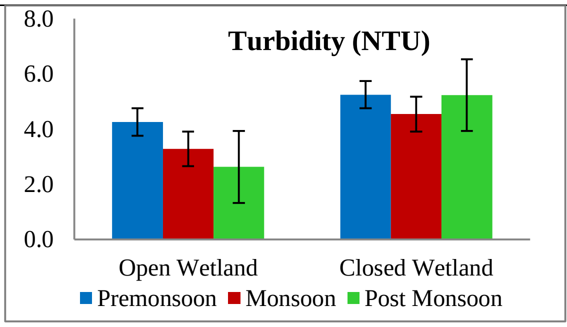


Fig. 185d

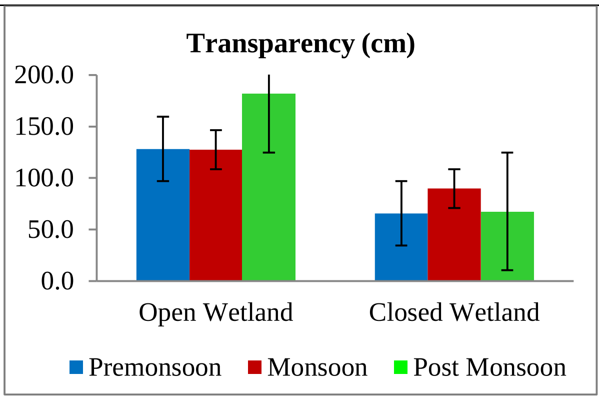


Fig. 185 e

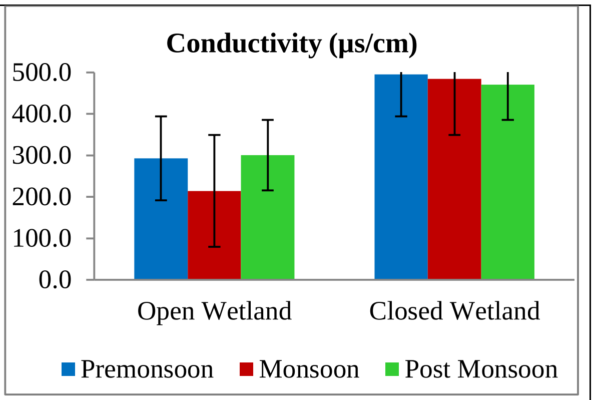


Fig. 185 f

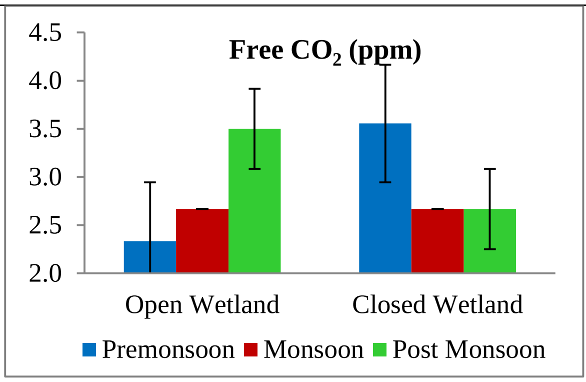


Fig. 185 g

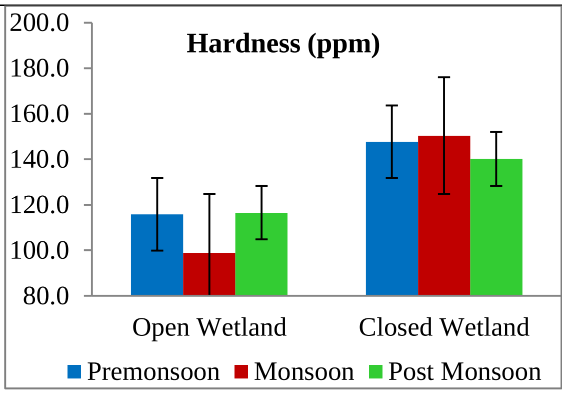


Fig. 185 h

Fig. 185 a-h Seasonal variation of different water quality parameters of studied wetlands

Sediment quality in the studied wetlands

The general physiochemical features of the sediment samples in the open and closed wetlands are presented in Table 41. Sediment samples from both the wetlands were mild to moderately alkaline (7.15 – 8.13 in open and 7.63-8.20 in a closed wetland) during pre-monsoon, monsoon and post-monsoon season. Specific conductivity of sediment was also towards the higher side and more in the open wetland as compared to a closed wetland with an average of 1286.6 ±52.0μScm^{-1} in pre-monsoon, 819.1 ± 38.1μScm^{-1} in monsoon and 1074.7 ± 28.0 μScm^{-1} in post-monsoon season in the open wetland. Sediments were also found rich in carbon content with higher carbon content in the closed wetland.The experiment indicated amplification in organic carbon during post-monsoon in both the wetlands. The closed wetland sites with a higher duration of saturation at or near the soil surface has a higher amount of organic carbon, apparently owing to the anoxic environment and high levels of submerged and floating macrophytes which contributes higher levels of wetland biomass and area (Samanta et al., 2015). Organic Carbon content varied in open wetland and closed wetland with higher levels in post-monsoon > monsoon > pre-monsoon. Total N and available N were found to be higher in closed wetlands. Mud percentage (combined silt and clay) was found to be higher by 17.74 % in the closed wetland as compared to open wetland. A relatively higher percent of clay content was found in closed wetland attributing to higher organic carbon content.

Table 41. Sediment quality in open and closed wetlands

	Open wetland		**Closed wetland**	
Parameters	**Average**	**Std. Error**	**Average**	**Std. Error**
pH	7.64	0.05	7.74	0.03
EC (µS/cm)	1060	39.3	824	34.02
OC (%)	0.74	0.14	2.08	0.10
Free $CaCO_3$ (%)	16	1.23	16.6	3.03
Total N (%)	0.11	0.01	0.17	0.01
Available Nitrogen (mg/100g soil)	14.6	0.81	20.9	0.30
Sand (%)	44	1.54	32	0.78
Silt (%)	13	0.48	16	0.28
Clay(%)	43	1.5	52	0.97

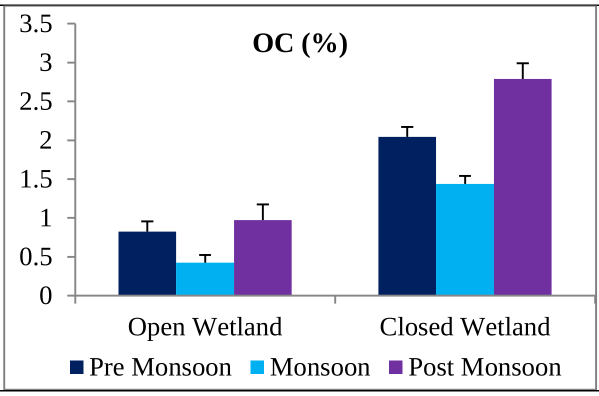


Fig. 186 Organic Carbon variation in open and closed wetland

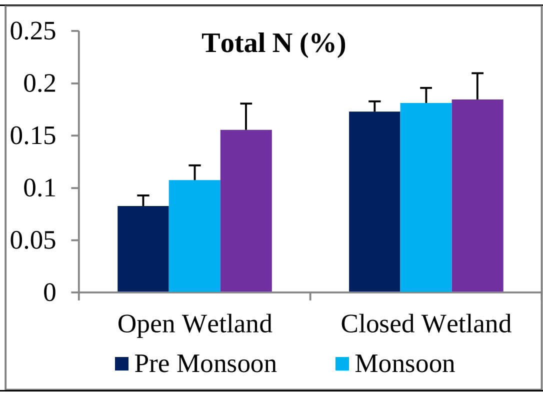


Fig. 187 Total nitrogen variation in open and closed wetland

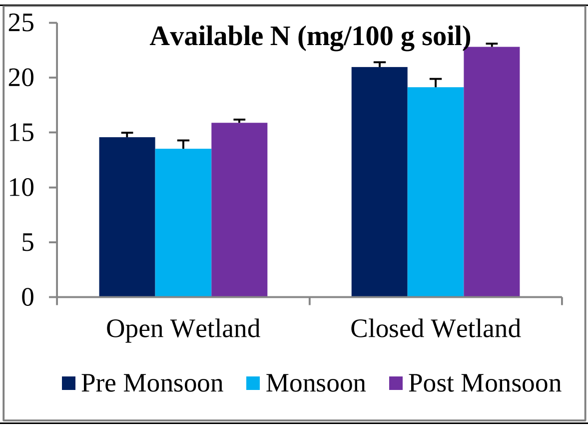


Fig. 188 Available nitrogen variation in open and closed wetland

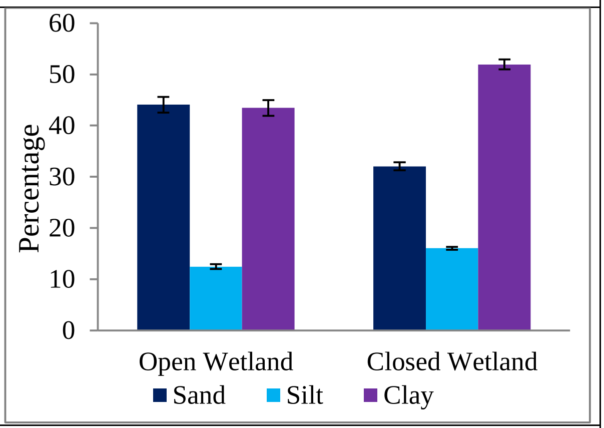


Fig. 189 Texture variation in open and closed wetland

Correlation of environmental variables and biotic parameters in the studied wetlands

Karl Pearson's correlation coefficient was performed in SPSS version 22 to understand the influence of water parameter on abundance of fish, benthos and plankton. Fish fauna and benthos community show a positive correlation with turbidity ($r=0.461$; $p<0.05$;$r=0.462$; $p<0.05$) whereas plankton has a positive correlation with Nitrate-N ($r=0.445$; $p<0.05$), Phosphate ($r=0.421$; $p<0.05$), Silicate ($r=0.643$; $p<0.01$) and Mg^{++}($r=0.492$; $p<0.05$) in open wetland. In closed wetland, water parameters didn't exhibit any positive influence to fish, benthos and plankton community.

Identification of breeding and nursery requirement of fish species in the studied wetlands

Floodplain wetlands are rich in biodiversity and physical characteristics are generally controled by hydrological connectivity with adjacent river. Open or floodplain wetlands are main habitat of small indegenus fishes, which often considered as breeding and nursery ground for self recruiting fish species. Of the total fish species recorded from these wetlands during the study period, size spectrum of 5 fish species viz., *Gudusia chapra, Ailia coila, Botia dario, Botia lohachata* and *Rasbora daniconius* were recorded in the catch were in juvenile stages (<11 cm) specifically during monsoon and post-monsoon season from open wetland. From this observations, it is recommended to conservethese fish species in these wetlands by artificial breeding or protecting their nursery grounds of these juveniles within the wetlands.

Table 42. Size spectrum of the identified fish species required for breeding and nursery in open wetland

Sl No.	Fish species	Recorded size class from open wetland	Max. Size (https://www.fishbase.se/)
1.	*Gudusia chapra*	4.3 -10.6 cm	20.0 cm
2.	*Ailia coila*	3.1-5.6 cm	30.0 cm
3.	*Botia dario*	4.2-6.1 cm	15.1 cm
4.	*Botia lohachata*	1.2-1.7 cm	15.4 cm
6.	*Rasbora daniconius*	3.9-9.1 cm	15.0 cm

Conclusion

The wetland plays an important role by proving several ecological services, maintains the ecological sustainability of a particular region and are considered as the most productive ecosystem. A wide range of aquatic animals habituates in this enriched ecosystem as a part of their lifecycle. The wetlands also provide shelter to a huge number of finishes, shellfishes, and other aquatic animals as well as supports capture and culture-based fisheries. Local fishers extremely depend on the wetlands as the fisheries of wetlands are the major source of their expenditure of daily livelihood and nutritional support. The present study signifies the importance of river connectivity with wetland influencing the species diversity of fish and plankton due to regular hydrological flushing and thereby freshness caused by river water in open wetland. Therefore, strategies should be designed to implement proper management plans for developing the restoration of river connectivity to improve the health of the disconnected wetlands.

Depth and velocity requirement of selected six fishes for designing of fish ladders/passes and e-flow

Depth and velocity of entire Ganga stretch were studied during the period. The selected six important fish species as *Schizothorax richardsonii, Tor putitora, Labeo rohita, Labeo catla, Cirrhinus mrigala* and *Labeo calbasu* are warm water habitant recorded from Bijnaur to Tribeni where as *Schizothorax richardsonii*, and *Tor putitora* are cold water species recorded from Harshil, Tehri and Haridwar stretch of river Ganga.

Table 43. Depth and velocity requirement of selected fish species

STATION	DEPTH (m)	VELOCITY (m/sec)	FISH SPECIES
Harshil	0.69	1.2	*Schizothorax richardsonii, Tor putitora*
Tehri	6.80	0.12	*Tor putitora*
Haridwar	4.11	0.93	*Schizothorax richardsonii, Tor putitora*
Bijnor	4.46	0.57	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Narora	2.71	0.63	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Farrukabad	1.64	0.52	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Kanpur	2.26	0.43	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Pryagraj	1.60	0.36	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Varanasi	2.24	0.33	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Buxar	7.19	0.35	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Patna	3.35	0.45	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Bhagalpur	5.34	0.34	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Farakka	7.35	0.18	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Jangipur	10.77	0.54	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Berhampore	7.40	0.58	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Balagarh	10.72	0.81	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*
Tribeni	10.10	1.10	*Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu*

OBJECTIVE–VI

SEED PRODUCTION (IN-SITU) OF SELECTED FISH SPECIES AND RANCHING IN THE DEPLETED RIVER STRETCHES

Seed Production of selected commercially important fish species of river Ganga

Conservation and restoration of rivers is vital for harnessing direct and indirect benefits from such ecosystem on sustainable basis. In order to increase the abundance of fishes in river Ganga, ex-situ conservation (Fig. 190) for the restoration of indigenous fishes in depleted stretches might be an excellent approach to revive the fish population in its own habitat. , the brooders are to be collected from the wild for ex-situ conservation of wild fish germplasm and rear was well as bred in captivity for getting good quality and genetically pure strain of seed. The four commercially important fish species (*Labeo rohita*, *Labeo catla*, *Cirrhinus mrigala* and *Labeo calbasu*) of river Ganga, commonly known as Indian Major Carp (IMC), were selected for this programme. ICAR-CIFRI has conducted massive breeding programme under this project since 2017; the same activity was continued every year till date.

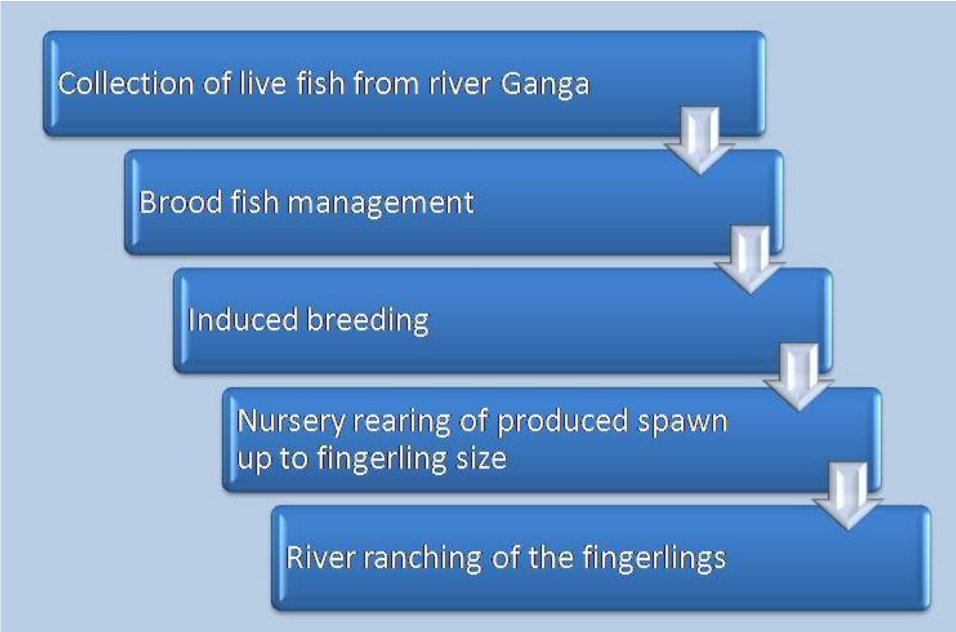


Fig. 190 Different steps of ex-situ conservation of Gangetic wild fish germplasm

Brooder Collection

The wild fishes were collected from different stretches of river Ganga (Nabadwip, Nadia district, to Balagarh, Hooghly district, West Bengal) and adjacent floodplain wetlands (Fig. 191). A river connected oxbow lake Chharaganga at Nabadwip area was found suitable for IMC live fish collection. The IMCs brooders, were collected from the catch of an indigenous Fish Aggregating Device known as *Komor Jaal*, which mainly operates in river channel of shallow and sluggish region with low water current stretch ofBalagarh to Nabadwip stretch of river Ganga and its associated wetlands. *Komor Jaal* generally set up in low water depth area of the river (<20ft). In this device, different tree branches are set in the water with the help of bamboo poles to make an artificial shelter for the fishes. Fishes are accumulating inside the structure for shelter and food. After 15-30 days, fishes are collected from *Komor Jaal* in live condition.

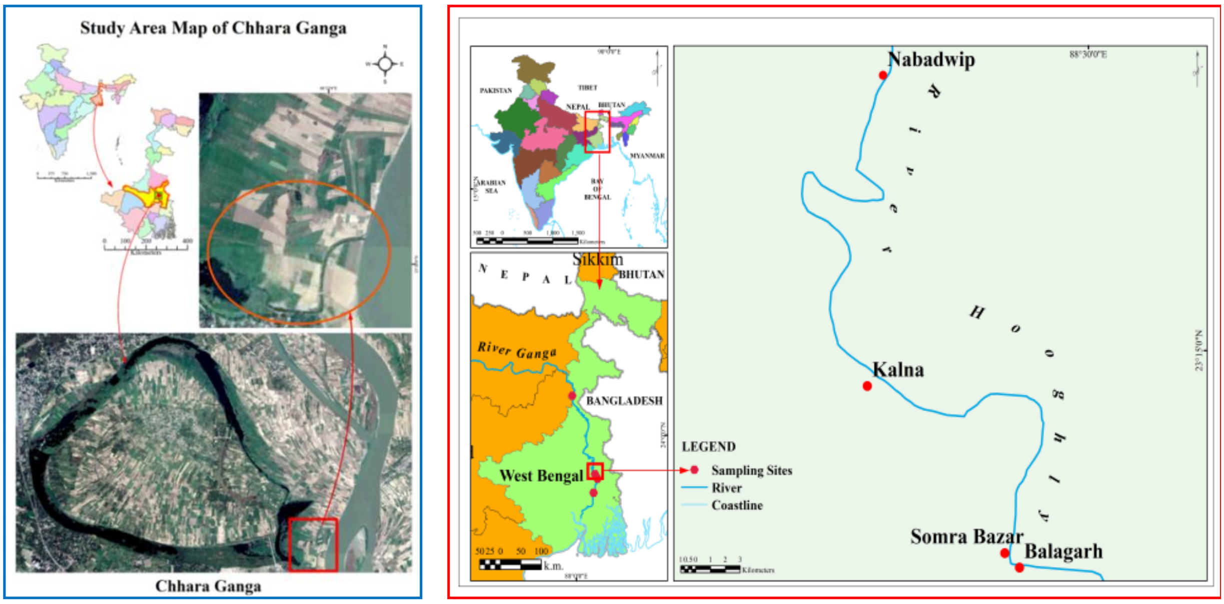


Fig. 191 Brooder collection site

Brood fish transportation

After collection, the brood fishes were transported to nearby brood stock pond. During transportation, proper care was taken for safe transport and better survival of the collected brooders (Fig. 192). For this, the brooders were transferred in themetallic transportation tank filled with aerated water, fitted in the vehicle. Continuous aeration was provided by manual method or battery-operated aeration system fitted in the tank to maintain the optimum dissolved oxygen level inside the tank. The water volume was maintained to 10litre/kg fish for transportation with proper aeration. In case of absence of battery-operated aeration system, dissolved oxygen level was manually increased by continuous beating with hand in the water. When fishes brought to the brooder pond, they were kept in aluminium *handi* and gave dip treatment with Potassium permanganate ($KMnO_4$) solution. The fishes were then stocked in a nylon happa fitted in the pond for acclimatization. After one hour of acclimatization with the pond water, fishes were released in the pond. The live fishes had been segregated as per their sizes and species and then accordingly stocked in different brooder ponds.

Fig. 192a

Fig. 192b

Fig. 192 a-b Brooder collection &transportation

Broodstockmanagement

Brooders are the most important component for seed production programme and it requires a good management practice for its better health and maturity. The brood fishes were stocked in brooder ponds adjacent to river at Nabadwip and Balagarh area of West Bengal. The area of brood pond was 0.2 ha area with 1.5 m depth. Water was added from time to time in brooder pond through bore well to maintain the water level. Almost 1200 kg of live fishes were collected during the three years period (2017-20) and reared for brood stock development. The brooders were fed with CIFA Brood diet and a mixture of Mustard Oil Cake:Groundnut Oil Cake:Rice Bran having 1:1:2 ratio, fortified with vitamins and minerals at the rate of 3-5% of their body weight for gonadal development to get better reproductive performance like better egg quality, quantity, fertilization rate and hatching percentageat the time of breeding.

Fig. 193 Treatment of stocked brooders in pond

Fig. 194 Application of $KMnO_4$in pond water

Induced Breeding

The breeding programme was scheduled in the monsoon. Repeated netting was done in brooder pond to check the maturity level of stocked fishes in every fortnight before two months of breeding. At the day of breeding programme, after examining the maturity level of the brooders, only fully matured fishes were selected for the breeding. The weights of brooders were varied between 300g to 3kg. The selected fishes were kept in a happa for one hour, for acclimatization to the netting stress and then transported to the nearby hatchery.In hatchery, the fishes were weighed and segregated as per their sex (male and female) and released in separate circular cemented tanks for acclimatisation with the environment. The optimum water quality parameters were maintained in the tank. The dosages of Crude Pituitary Extract (CPE) were determined based on the body weight of brooders. During evening hours, the female fishes were injected with initial dose of CPE @ 2-4 mg/kg body weight through intra-peritoneal injection and released them into the separate tank. After five hours interval, the second dose of CPE was injected to the female fishes @ 6-8 mg/kg body weight and at the same time a single dose of CPE was administered to the male fishes @ 2-4 mg/kg body weight. After five hours of second dose of CPE injection, the stripping was done by gently pressing on the lower abdominal portion of the fishes and eggs and milt were collected in a plastic tray. Immediately after stripping, the eggs and milt were mixed properly for fertilization and transferred to the hatching pool. The fertilized eggs were hatched between sixteen to eighteen hours. The hatchlings were kept undisturbed in hatching pool for three days after hatching. During this period, the spawns would get nourishment from the energydeposited in the egg yolk. After that period, the spawns were collected and stocked in outer cemented cistern for further transportation and stocking in prepared nursery ponds.

Table 44. Total numbers & weight of brooders using in breeding (2017-2020)

Fish Species	Male								Female							
	Total Number				Total Weight (kg)				Total Number				Total Weight (kg)			
	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020
Rohu (*Labeo rohita*)	**6**	12	19	25	5	13.9	22.9	22.8	8	16	28	42	6.8	21.8	36	38.9
Mrigal (*Cirrhinus mrigala)*	5	22	19	36	5	14.9	12.8	19.4	8	24	6	39	5.9	21.2	3.0	20.0
Catla (*Labeo catla*)	_	1	_	5	_	2.7	_	8.0	_	2	_	4	_	6	_	8.1
Kalbusu (*Labeo calbasu*)	_	_	18	_	_	_	11.4	_	_	_	17	_	_	_	13.4	_

Fig. 195 a

Fig. 195 b

Fig. 195 c

Fig. 195 d

Fig. 195 e

Fig. 195 a-e Different steps of Induced Breeding

The fertilization rate, hatching rate and spawn survival rate of the four species observed during the study period (2017-2020) are tabulated in Table 49 and the fecundity in Table 45.

Table 45. Fertilization rate, Hatching rate and Spawn survival rate of different species during 2017-2020.

Species	***Labeo rohita***				***Labeo catla***				***Cirrhinus mrigala***				***Labeo calbasu***			
Year	**2017**	**2018**	**2019**	**2020**	**2017**	**2018**	**2019**	**2020**	**2017**	**2018**	**2019**	**2020**	**2017**	**2018**	**2019**	**2020**
Fertilization rate (%)	**98**	**97**	**98**	**98**	_	**96**	_	**96**	**97**	**96**	**98**	**97**	_	_	**98**	_
Hatching rate (%)	**90**	**94**	**90**	**92**	_	**90**	_	**94**	**91**	**90**	**90**	**94**	_	_	**90**	_
Spawn Survival rate (%)	**93**	**96**	**96**	**92**	_	**92**	_	**92**	**88**	**94**	**96**	**92**	_	_	**88**	_

Table 46. Fecundity of different IMC species

Species	**Fecundity (eggs/kg of fish)**
Labeo rohita	2,70,000 – 2,90,000
Cirrhinus mrigala	1,75,000 – 2,16,000
Catla catla	1,40,000 – 2,00,000
Labeo calbasu	1,78,000 - 2,10,000

Almost 2 crore spawn was produced during 2017-2020through induced breeding programme. Annual spawn production ranges between 12 lakh/year to 79.4 lakh /year.

Fig. 196 Produced IMC spawn

Table 47.Year wise spawn production

Species	***Indian major Carps***			
Year	**2017**	**2018**	**2019**	**2020**
Spawn Production (Lakh)	**12**	**57**	**50**	**79.4**

Transportation, stocking and rearing of spawn

Fig. 197a Open tank (Circular) transportation of spawn

Fig. 197b Open tank (Square) transportation of spawn

Fig. 197c Transportation of spawn in oxygen filled packets

Fig. 197d Releasing of spawn in nursery pond

Fig. 197e Growth monitoring of the stocked fish after 15 days

Fig. 197f Early fry after two weeks of stocking

Fig. 197 a-f Spawn Transportation and growth monitoring of fingerlings

After three days, the spawns were ready to be released into the nursery ponds for further rearing to fry or fingerling stage. The spawns were transported & stocked into threeprepared nursery ponds. After three days of stocking, netting was carried out in these three ponds for checking the spawn health, growth and survival. After seven days of stocking, 50 percent of spawnwere shifted to the remaining four nursery ponds to reduce the crowding stress on spawn. The spawns were fed with milk powder & eggyolk mixture for next two days afterstocking. From forth day, commercial powdered feed was applied for better growth.

Nursery rearing

For better growth and survival of the fish, seeds in the nursery pondsneed to be maintained carefully. There are different issues like aquatic weed management, eradication of aquatic insects and unwanted predatory fishes, etc. Prior to stocking of fish, the soil and water quality were maintained as per standard level. Adequate natural feed supply for the fishes and supplementary feeding also given to the fishes throughout the rearing period. The stocking density of the stocked fishes must be maintained for better growth performance.

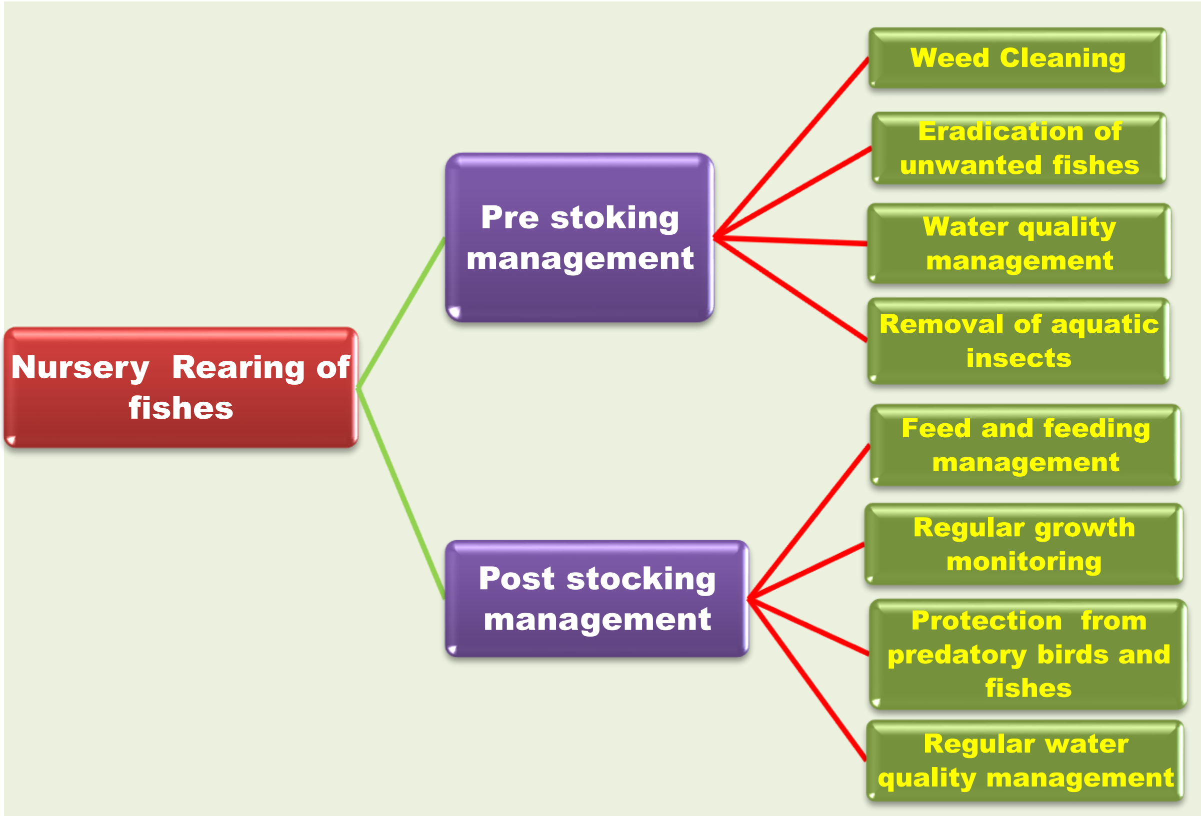


Fig. 198 Different steps followed during nursery rearing of fishes

Weed Cleaning

	
Fig. 199a Aquatic weed cleaning	Fig. 199b Pond dyke cleaning
Fig. 199 a-b Management of fish pond	

As it is mandatory to remove the aquatic weeds before fish stocking, weed cleaning was done manually in the nursery pond as an important step of nursery pond management. In case of nursery ponds, the manual weed cleaning is more effective than chemical, biological, mechanical method. Some of the aquatic weeds mainly found in the nursery ponds at Balagarh are *Eichhornia, Pistia, Lemna* and *Azoll*a. The Dykes of the ponds are commonly infested by some weeds like *Ipomea, Ottelia, Alternenthera, Colocasia* and *Jussia*. A rope prepared with rice straw is used for accumulating the floating macrophytes in one corner of the pond and then netted out with the help of a zero-mesh ny

Predatory fish eradication

The complete eradication of predatory & weed fishes is very important prior to stocking of the seed for better survival & growth. The first process is dewatering and drying of the pond and if the ponds are not able to be dried then use of pisicide is recommended. Mahua (*Brassia latifolia*) oil cake is used as pisicide in the ponds for removal of the fishes. The dose of the Mahua oil cake is fixed as per recommended concentration (200-250 ppm). After application of the Mahua oil cake, the dead fish removal is important otherwise the dead fishes decompose and worsen the pond water quality. The ponds are left for three weeks before stocking of fish to avoid the toxic effect of the oil cakes.

Water quality management of the ponds

Water quality parameters play an important role for better survival and growth of the stocked fishes. Before stocking of the spawn in nursery pond, all the necessary water quality parameters were analysed and proper corrective measures were taken to maintain the parameters at recommended level.

Table 48. Water quality maintained in nursery ponds

Water quality parameter	Value
Dissolved Oxygen(mg/l)	>5.5
pH	7.5 – 8.2
Water Temperature (°C)	28-34
Total Alkalinity (mg/l)	60-90

Fertilization of the pond

Planktons are the main food for the IMC spawn and it is essential to maintain a good plankton density in the ponds for better feed availability for the stocked fishes. The Mahua oil cake which was previously used for predatory fish removal act as fertilizer and Raw Cow

Dung (RCD) was also used @ 5tonnes/ha. Fermented mixture of oilcakes and brans is used for manuring in the ponds. This mixture is prepared with Groundnut oil cake, Mustard oil cake, Rice Bran, Jaggery and Yeast powder. All the ingredients are mixed properly and added water for fermentation. After 48 hours, the mixture is broadcasted throughout the ponds. A mild first dose of this manure is applied 15 days prior to stocking followed by second dose applied in the pond 3-4 days prior and the second dose is calculated after checking the plankton densities in the pond.

Removal of aquatic insects

The population of aquatic insect rapidly increases after fertilizationin the nursery ponds. These insects can cause a severe harm to the stocked spawns. For removal of these insects, soap-oil emulsion (Soap & vegetable oil) was applied to the pond as these insects are come to the surface of the water for respiration and killed due to gill chocking by these layers. Instead of soap–oil emulsion sometimes kerosene oil & detergents were also used as insecticide. The emulsion is applied by broadcasting throughout the pond two days prior to the seed stocking.

Fig. 200 Aquatic insects netted out after application of insecticide

Post stocking management

Post stocking management is very crucial step for better survival and growth of the stocked fishes. Proper feeding management is very important after the stocking of the seed. Daily feed ration was determined based on the body weight basis of the stocked fishes and increased fortnightly after sampling in the ponds.

After two weeks of stocking, the early fries are netted out and the stocking density were lowered by shifting the fries in other ponds. Regular monitoring of water quality has been done and applied different water quality maintaining agents as per requirement.

Fig. 201a Feeding of fish

Fig. 201b Netting in pond

Fig. 201 a-b Post stocking management

Fingerling transportation

Once the seed/fingerlings attained more than 100 mm size then they are ready for ranching. Small size fishes should not be preferred for ranching because of lower survivality and prone to predation. The fingerlings were transported to the different ranching sites and then ranching was carried out. There are some pre & post-transportation management that must be followed before, during and after transportation of the fingerlings. The process of conditioning of the fingerlings was started two days prior to transportation. Pre-netting was done two days before transportation and the fishes were kept in happa for 2-3 hrs for acclimatization to the netting stress. The Mahua oil cake was applied in pond at low dose for strengthening of the seed. The supplementary feeding was stopped one day before ranching. On the day of transportation, the fishes were netted out and kept in happa for at least 2-3 hours for gut evacuation, continuous water shower was given in the happa to minimize the stress. Fingerlings were transported mostly in open tank transportation vehicle.

Fig. 202a Open tank transportation of Fingerling

Fig. 202b Oxygen packed transportation of Fingerling

Fig. 202 Fingerling transportation

River Ranching Programmes of Indian Major Carp fingerlings for sustainable fisheries

As a comprehensive part of the CIFRI-NMCG project entitled '*Assessment of fish and fisheries of the Ganga River System for Developing Suitable conservation and restoration plan'*, fish ranching programmes were initiated in different depleted stretches of river Ganga. Under this activity, ICAR-CIFRI conducted 43 ranching programmesduring the project period and released more than 30 lakh of IMC fingerling (produced through induced breeding of Gangetic brooders) & Mahseer in river Ganga inorder to conserve and restoration of IMC & Mahseer in the river. During this ranching activity, ICAR-CIFRI has also organized the mass awareness programmes involving the fishers and other stakeholders. The fishers were sensitized on the detrimental effects of destructive methods of fishing like use of mosquito net, toxic chemicals, etc for fishing and were advised not to catch the juveniles and brooders especially in the breeding seasons (June-August) for their sustainable fisheriesin River Ganga. CIFRI's initiation with the aim to restore the prized fishes of river Gangaunder the project has created an impact among the local fishers.

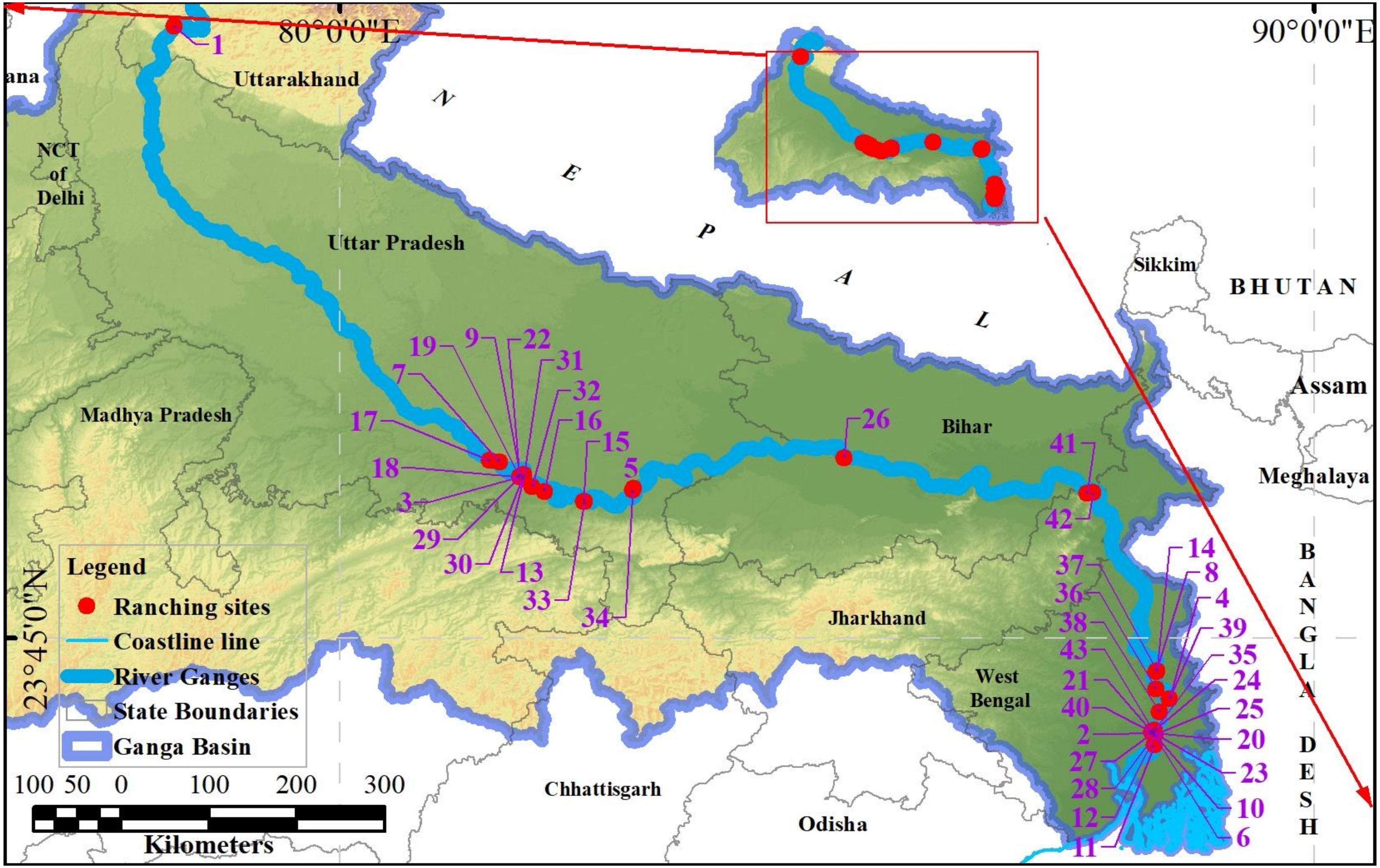


Fig. 203 Map showing different ranching sites throughout the river Ganga

River ranching Programme at Rishikesh; Uttarakhand (23rd May, 2017)

Objectives and mandate of the programme of ranching at Rishikesh and its likely implications on restoration and conservation of biodiversity in river Ganga focusing Mahseer and Trouts in hilly stretch was briefly described by Dr. B. K. Das, Principal Investigator of the project. Five hundred numbers of Mahseer seed (*Tor putitora*) ranched in river Ganga in this programme. Scientist and officials of different Central and state government departments, several non-governmental organizations, students from different universities, fishers of nearby areas and local fish traders attended the programme.

Ranching at Rishikesh, Uttarakhand

River ranching Programme at Barrackpore, West Bengal (26th May, 2017)

Honourable Union Minister of Water Resources, River development and Ganga Rejuvenation Sushri Uma Bharti ji visited ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, Kolkata on 26th May, 2017. On this occasion 2,500 no of two main prized warm water fishes Rohu (*Labeo rohita*) and Catla (*Labeo catla*) have been released under the project by Sushri Uma Bharti ji, in river Ganga at Barrackpore, West Bengal.

Ranching at Barrackpore by Hon. Former MIC Sushri Uma Bharti ji

River ranching Programme at Prayagraj; Uttar Pradesh (1st August, 2017)

Ranching of seed of Indian Major Carps like Catla (*Labeo catla*), Rohu (*Labeo rohita*), Mrigal (*Cirrhinus mrigala*) in the Ganga River was organized by ICAR-Central Inland Fisheries Research Institute (Regional Centre Prayagraj) under its pilot project NMCG (National Mission for Clean Ganga). The event was attended by the students of from nearby University, fishers of nearby villages, fish traders of Sadiapur, Daraganj&Mehdauri and local people living on the bank of the Ganga and Yamuna. The event was graced by Hon. Minister of State (Dept. of Animal Husbandry and Fisheries) Shri Jai Prakash Nishad. Dr. B. K. Das, PI of the project, expressed his concern of recruitment over fishing of brooder stock during the breeding season and growth over fishing of the child of the fishes (fingerling) during raining season which in turn hampers biodiversity finally affecting the livelihood of fishermen community. Expressing their views, representatives from GangaVicharManch and several other NGOs suggested measures to reduce pollution and to increase the fishes in the river. During this process pamphlets known as “Ganga Ko Aviral Bahne Do” as a guiding principle to restore Ganga and livelihood of fishermen community was released by the Minister during programme.

Ranching at Prayagraj, Uttar Pradesh

River ranching Programme at Balagarh; West Bengal (03rd November 2017)

ICAR- Central Inland Fisheries Research Institute, Barrackpore under its mega project '*Namami Gange'* and under cooperation with Sripur Balagarh Matsyajibi Cooperative Society (Balagarh, West Bengal) ranched 60,000 seeds of Indian Major Carps in River Ganga. Participation of more than 100 local fishermen for the sustainable development of aquatic life was the reflection. Besides stressing upon self-reliance of the fishers, Dr. Basanta Kumar Das (Principal Investigator) urged to utilize the invaluable resource of river Ganga by just adopting the conservation practices. He demanded more pro-activism and mentioned that Ganga fishery can only be restored through 'Community participation' where Govt. organizations and fishermen have to work together to achieve the goal. Local Member of Legislative Assembly (M.L.A) Mr. Ashim Majhi requested to avoid littering activities in river Ganga and highlighted that traditional practices should not be over powered by prejudice.

Ranching at Balagarh, West Bengal

River ranching Programme at Varanasi; Uttar Pradesh (11th November, 2017)

ICAR-CIFRI organized a fish ranching event on 11th November 2017 at Dasaswamedh Ghat, Varanasi, Uttar Pradesh. During this program ranching of 5000 nos of advanced fingerling of IMCs was done in River Ganga at Dasaswamedh Ghat, Varanasi. Dr. Rakesh Singh (Banaras Hindu University, Varanasi) was the chief guest at the event where he have shared his experiences and presented suggestions regarding restoration of fisheries of river Ganga. Fishers were also awaked about the rising concerns of river pollution and their impacts on the ecosystem. Event was attended by large numbers of students and local people.

Ranching at Varanasi, Uttar Pradesh.

River ranching Programme at Sringverpur, Prayagraj (05th December, 2017)

Fish ranching and awareness programme organized by ICAR- CIFRI, Prayagraj Centre on 05.12.2017. 10000 nos. of IMC fingerlings were released in river Ganga. Mr. P.S. Pandey, Ex-MLA, U.P. graced the occasion and give his comments to the fishers who were present there.

River ranching Programme at Barrackpore; West Bengal (21st November, 2017)

ICAR-CIFRI has celebrated 'World Fisheries Day' at Barrackpore on 21.11.2017. In this occasion, a total of 20,000 (Twenty thousand) Indian Major Carp seed has been released in river Ganga at Daspara Ghat, Barrackpore under '*Namami Gange'* Project. Dr. D. K. De, renowned expert in Hilsa (*Tenualosa ilisha*) fisheries highlighted about construction of huge number of barrages/ dams causing water abstraction and thereby hindering migration of fishes. Director CIFRI mentioned about the importance of ranching which can increase fishers' income from rivers that can yield 'Green fish in Blue economy' and thereby improved livelihood of very poor fisher folks.

Ranching at Barrackpore, West Bengal

River ranching Programme at Nabadwip; West Bengal (21st January, 2018)

The institute has performed ranching of 50,000 (Fifty thousand) seed of Indian Major Carp in river Ganga at Nabadwip, West Bengal. The entire event took place in the holy place at Prachin Mayapur, Nidaya Ghat. Mr. Nibasi Ch. Das, Assistant Fishery Officer, Govt. of West Bengal requested fishers not to use zero mesh drag net and described about different Government schemes which may improve the livelihood of fishers who have to come forward to take advantages of those schemes. Mr. Pundarikakhya Saha, MLA, Nabadwip who visited the meeting site and extended his full support to the program. On his behalf, Mr. Sukumar Rajbanshi, local councilor, Nabadwip Municipality requeste the State and Central Govt. officials to take immediate measures to stop severe river bank erosion in the area. He requested fishers not to kill the released fishes immediately but allow them to growand breed so that, the fish stock can be restored.

Ranching at Nabadwip, West Bengal

River ranching Programme at Barrackpore; West Bengal (15th March, 2018)

ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata celebrates its Platinum Jubilee for having completed its Glorious Presence. On this grand occasion, and to restore prized Major Carp fisheries of river Ganga, a total of 50,000 (fifty thousand) Rohu, Catla, Mrigal fingerlings have been released in the river at Barrackpore. The event was graced by number of eminent scientists and officials including Deputy Director General (Fy. Science) Dr. J.K. Jena, Padmashree Awardee & Dolphin man of India Prof. R. K. Sinha. Dr. Sandeep Behera, Consultant, Biodiversity, NMCG, New Delhiemphasized the need for ranching, conservation of wetlands in Ganga basin and conducting awareness programmes to sensitize the community living in the vicinity.

Ranching at Barrackpore, West Bengal

River ranching Programme at Prayagraj; Uttar Pradesh (27th March, 2018)

ICAR-CIFRI, Prayagraj conducted a mass awareness programme cum ranching of IMC seed in Gangariver at Fatepurghat on 27th March, 2018 under NMCG (National Mission for Clean Ganga) to restore and conserve the depleting fish stock in the river Ganga. A total of 20,000 (twenty thousand) advanced fingerling of IMC seed were ranched in the river. Dr. R. S. Shrivastava, Head of the division, ICAR-CIFRI, Prayagraj enlightened the different causes for the depleting of fish diversity of the river Ganga to the different fishers of the region. The fishers were informed about the ranching programme which is an important component of *Namami Gange* programme. Scientist–fishers interaction was held in the event. More than 60 fishers participated in the programme.

Ranching at Fatehpur Ghat, Prayagraj, Uttar Pradesh

River ranching Programme at Bally, West Bengal (05th September, 2018)

Ranching cum awareness campaign was organized on 5th September, 2018 at Barendrapara Ghat, Bally, Howrah, West Bengal. A total of 5 lakh fry of species like Rohu, Catla, Mrigal and Calbasu were ranched in the event. Dr. B. K. Das, Director of the Institute and Principal Investigator, CIFRI-NMCG project highlighted about the progress made by the institute under the project covering habitat data, biotic communities, fish diversity, stock assessment etc. He highlighted the need of ranching in river Ganga which in turn will ensure unremitting livelihood for the fishers encompassing the biodiversity and ecological integrity. On the occasion, Swami Atmapriyananda ji Maharaj, Vice Chancellor, Ramakrishna Mission Vivekananda Educational and Research Institute, Belur addressed the gathering. He stated that the preaching's of Swami Vivekananda regarding the purity of our Holy River Ganga. He said purity of the river will sustain only if we can make a coordinated approach. Swami Girashananda ji Maharaj, Manager, Ramkrishna Matha and Ramkrishna Mission, Belur Math, delivered the presidential address on the event. Giving credit to the efforts of Central Inland Fisheries Research Institute, Swami ji reckoned about the ongoing degrading situation of the holy river and urged the local people to initiate active coordination.

Ranching at Bally Ghat, West Bengal

River ranching ProgrammeatBarrackpore; West Bengal (02nd October, 2018)

To commemorate 150th Birth anniversary of Mahatma Gandhi, and as a part of NamamiGange initiative ICAR-CIFRI created a fish ranching programme on 2nd October, 2018 at three consecutive Ganga ghats (Seoraphully, Mangal pandey and Gandhi ghat) at Barrackpore, Kolkata, West Bengal.On the occasion, Shri Nabin Naik, Director, Neheru Yuva Kendra Sangathan graced the event as a guest. As a part of the event, total of 2.8 Lakhs of fingerling of Rohu, Catla, Mrigal were released in river Ganga in different adjacent ghats. Bilingual pamphlets were distributed among the local fishermen & were awaked regarding the rising concern.

Ranching at Gandhi Ghat, West Bengal

Ranching at Bally Ghat, West Bengal

River ranching Programme at Sangam, Prayagraj (02nd October, 2018)

Five thousand of IMC (Rohu, Catla and Mrigal) seed were ranched in river Ganga on this programme.

River ranching Programme at Mayapur, West Bengal (06th November, 2018)

ICAR-Central Inland Fisheries Research Instituteorganized a river ranching cum fishermen awareness programme on 6th November, 2018 at Swarupganj Ghat, Nabadwip, Nadia,West Bengal under the 'Namami Gange' programme. As a part of the programme, 03 lakhs seed of fishes like Calbasu, Mrigal & Rohu were released in the river Bhagirathi (Ganga) in front of the holy ISKCON temple, Mayapur.The programme was attended by more than 150local active fishermen and their family members. The event was well covered by several local print media and electronic media. As a part of the programme, 03 lakhs seed of fishes like Calbasu, Mrigal & Rohu were released in the river Bhagirathi (Ganga) in front of the holy ISKCON temple, Mayapur.

Ranching at Mayapur, West Bengal

River ranching ProgrammeatBarrackpore, West Bengal (20th November,2018)

A ranching cum awareness programme was organized on the occasion of World Fisheries Day at Daspara Ghat, Barrackpore, West Bengal on 20th November, 2018. As a part of this programme 02 lakh IMC fingerling were released in river Ganga. Shri Nabin Naik, Director, Neheru Yuva Kendra Sangathan was expressed his view in fisheries of river Ganga to the fishers.

Ranching at Barrackpore, West Bengal

River ranching ProgrammeatRamayaghat, Mirzapur (26th November,2018)

Another fish ranching programme at Ramayaghat, Mirzapur was conducted on 26th November 2018. 10000 IMC (Rohu, Catla, Mrigal) were released in river Ganga. Dr.Varshi, DDF, Govt. of U.P. was preset in this occasion and aware the fishers about the fish & fisheries of river Ganga.

River ranching Programme at Sirsa, Prayagraj (04th December, 2018) & Karaghat, Kousambi, Prayagraj (05th December, 2018)

Concurrence ranching cum mass awareness program at Sirsaghat (Prayagraj) and Kade dham ghat (Kaushambi), Uttar Pradesh was organized on 4th and 5th December, 2018 respectively. A total of 30000 advance Indian Major Carp (Rohu, Catla & Mrigal) fingerlings were ranched in the river Ganga with wide mass media coverage. Mr. M. N. Pathak, Ret. Principal, Sirsa Inter College delivered his valuable comments on fish and fisheries of river Ganga at Sirsaghat.

Ranching at Prayagraj, Uttar Pradesh

River ranching Programme at Kumbh Mela, Prayagraj (15th January to 4th March 2019)

In the presence of Honourable Minister Mr. Nitin Gadkari (Ministry of Water Resources, River development and Ganga Rejuvenation, Govt. of India) a total of 10,000 juveniles of Indian Major Carp were ranched in river Ganga on 08.02.2019 in the event of Kumbh Mela, 2019 at Prayagraj.

Ranching at Kumbh Mela, Prayagraj

River ranching Programme at Barrackpore, West Bengal (15.03.2019)

A total of 10,000 juveniles of Indian Major Carp were ranched in river Ganga at Barrackpore, West Bengal on 15.03.2019.

River ranching Programme on the occasion of Matsya Samriddhi Mela & CIFRI Foundation Day celebration at Barrackpore, West Bengal (17.03.2019)

17th March, 2019 marked the 73rd Foundation Day of the Institute. On this occasion a total of 50000 IMC seeds were released in River Ganga at Ghatak para Ghat, Barrackpore, West Bengal on 17.03.2019.

River ranching Programmeon the occasion of Kumbh mela-2019 in Prayagaraj (26.02.2019)

Honourable Member of Parliament and chairperson of Parliamentary committee on Official Language, Shri Prashanna Kumar Patshaniji released high quality wild stock fish seed of IMC into the river Ganga. While his visit to Kumbh mela-2019 in Prayagaraj on special invitation to grace the occasion of ranching cum mass awareness programme on 26th February, 2019 organized by ICAR-Central Inland Fisheries Research Institute, Prayagraj addressed the wide spectrum of audience and stakeholders devoted to cause of Mission Namami Gange and rejuvenation of river Ganga.

River ranching Programmeat Sangam, Prayagraj (29.03.2019)

Ranching cum mass awareness program was organized at Sangam (Prayagraj) on 29th March, 2019. A total of 15000 advance IMCs fingerlings were ranched in the river Ganga.

River ranching ProgrammeatBarrackpore, West Bengal (10.07.2019)

A river ranching programme and mass awareness campaning was organised by ICAR-CIFRI, Barrackpore on the occassion of National Fish Farmers Day at Daspara Ghat, Barrackpore. A total of 30000 IMC fingerlings were ranched in presence of Sri Bankim Hazra, Honourable MLA, Sagar Island, Dr. V. V. Sugunan, Former ADG (In. Fy.), ICAR, Dr. Madhumita Mukherjee, Additional Director (Technical), Govt. of West Bengal and Dr. B. C. Jha, Former HOD, ICAR-CIFRI, Barrackpore. More than 100 fishers, entraprenures participated from West Bengal, Bihar , Jharkhand & Madhya Pradesh.

Ranching at Barrackpore, West Bengal

River ranching ProgrammeatNawabganj Ghat, Icchapur, West Bengal (27.07.2019)

A ranching cum awareness programme was organized at Nawabgunj Ghat, Ichapur, West Bengal on 27th July, 2019. As a part of this programme 60000 IMC fingerling were released in river Ganga. Dr. C. Vasudevappa,Vice Chancellor, NIFTEM, Haryana and other dignitaries, were expressed their views in fisheries of river Ganga to the fishers.

River ranching Programme at Nawabganj Ghat, Icchapur, West Bengal

River ranching Programme at Gandhi Ghat, Barrackpore (Team NMCG, Delhi) (10.11.2019)

ICAR-CIFRI along with NMCG expedition team, *'Ganga Amantran'* performed a river ranching programme at Gandhi Ghat, Barrackpore. Beside highliting about the project activities to the team members, more than 40000 fingerlings of Indian major Carps were ranched on the occassion.

River ranching Programme at Gandhi Ghat, Barrackpore

River ranching Programme at Law college Ghat, Patna (20.11.2019)

ICAR-CIFRI , Barrackpore with the support from Department of Fisheries, Govt. of Bihar performed a river ranching programme at Law College Ghat, Patna, Bihar. The programme was attended by several officials from state fisheries department including Mr. V. S. Gunjiyal, Director of Fisheries, Bihar. The event was attended by more than 50 no. Of local fishermen. More than 40,000 fingerlings of Indian Major Carp seeds were ranched in the river.

River ranching Programme at Law college Ghat, Patna

River ranching Programme at Barrackpore, West Bengal (12.12.2019)

A ranching cum awareness programme was organized at Daspara Ghat, Barrackpore, West Bengal on 12th December, 2019. As a part of this programme 10000 IMC fingerlings were released in river Ganga. Dr. Huang Jie, Director General, Network of Aquaculture Centres in Asia-Pacific and other dignitaries, were expressed their views in fisheries of river Ganga to the fishers.

River ranching Programme at Barrackpore, West Bengal

River ranching Programme at Gandhi Ghat, Barrackpore (26.01.2020)

On the occassion of 71st Republic Day, ICAR-CIFRI under NMCG project ranched 50,000 fish fingerlings of Indian Major Carps at Gandhi Ghat, Barrackpore, Weest Bengal. The occassion was graced by Mr. Dipankar Bhattacharyya (IPS) and other senior officials from West Bengal police.

River ranching Programme at Gandhi Ghat, Barrackpore

River ranching Programme at Narayani Ashram, Prayagraj (28.01.2020)

A total of 10,000 number Indian Major Carps fingerlings were ranched at Prayagraj with a huge & productive mass awareness generation among local fishers residing beside the Ganga river bank.

River ranching Programme at Dashashwamedh Ghat (Prayagraj) (06.02.2020)

Ten thousand fingerlings of Indian major carps (*Labeo catla, Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala*) were ranched on 6th February 2020 at *Dashashwamedh Ghat,* Prayagraj.Colonel Amit Pandey, commanding officer Ganga Task Force was the chief guest ofthe program. A Hindi leaflet on riverine ranching was released during the program with a huge and productive mass awareness generation with local fishers residing beside the Ganga river bank, students and several Magh Mela pilgrims.

River ranching Programme at Dashashwamedh Ghat, Prayagraj

River ranching Programme at Sangam (Prayagraj) (11.02.2020)

Twenty thousand fingerlings of Indian major carps (*Labeo catla*, *Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala*) were ranched at *Sangam Nose (Ganga river & Yamuna river confluence point),*Prayagrajon 11th February 2020.Mr. Atharv Raj, NMCG, Ministry of Jal Shakti, Govt. Of India was the chief guest of this program. Mr. Rajesh Sharma (Ganga Vichar Manch), Mr. Sanjay Mamgai (Zonal Ofiicer), Mr. K. P. Upadhaya, Dr. Nityanand Pandey & Delegates of Ganga Prahari, WWI, Dehradun, Uttrakhand were also participated in this program. Two Hindi leaflets on *Fish diversity* & *Contibution of women in fisheries and optional earning* was released during the programme.

River ranching Programme at Sangam, Prayagraj

River ranching Programme at Manaiyaghat, Prayagraj (25.02.2020)

Fifteen thousand fingerlings of Indian major carps (*Labeo catla, Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala*) were ranched at *Manaiya Ghat,* Jhunsi, Prayagraj on 25th February 2020.Dr. S.C. Tiwari, Pro. Vice chancellor, Nehru Gram Bharti Deemed University (NGBU), was the chief guest of this program He released a Hindi leaflet on Golden Mahseer: An effort toward Conservation. During this occasion Prof. Ramkripal (Dean Science, NGBU), Dr. Asish Shivam (Head Zoology Department, NGBU) were also present. Several Students of NGBU, Fishermen (residing along the Ganga River) were also participated in this programme.

River ranching Programme at Manaiyaghat, Prayagraj

River ranching Programme at Vindhyanchal (29.02.2020)

Fifteen thousand fingerlings of Indian major carps (*Labeo catla, Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala*) were ranched at *Divan Ghat,* Jhunsi, Prayagraj on 29th February 2020. Dr. K.W. Warsi, Deputy Director, Fisheries Department, Uttar Pradesh was the chief guest of this program He released a Hindi leaflet on Phytoplankton - A Source of Oxygen in Riverine ecosystem. Fisheries inspector Mirzapur, Mr. Sarang was also present in this program. Several other staff of fisheries department, Fishers, Pilgrims, Priest &river bank side shopkeepers were also participated in this program.

River ranching Programme at Vindhyanchal

River ranching Programmeat Assi ghat (Varanasi) 05.03.2020

Twenty thousand fingerlings of Indian major carps (*Labeo catla, Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala*) were ranched on 5th March 2020 at AssiGhat,Varanasi. Mr. Ravindra Prasad (C.E.O.) Department of fisheries Govt.of Uttar Pradesh, Varanasi, chief guest ofthe program was aware to fisherman for the conservation and restoration of the river Ganga through valuable speech.

River ranching Programme at Varanasi, Uttar Pradesh

River ranching Programme at Barrackpore, West Bengal 17.03.2020

ICAR-CIFRI under its ongoing NMCG Project celebrated its 74th Foundation Day on 17th March, 2020 with a river ranching programme at Barrackpore, West Bengal. The ceremony was culminated with ranching of 50,000 advance fingerlings of Indian Major Carps (IMC) in River Ganga. The occasion was graced by Dr. (Smt) Vijayalakshmi Saxena, General President (Elected) of Indian Science Congress and Dr. Ashok Kumar Saxena, Former President of Indian Science Congress Association. The program was over all guided by Dr. B. K. Das, Director, ICAR-CIFRI and PI, NMCG project.

River ranching Programme at Barrackpore, West Bengal

River Ranching Week (11.06.2020 -16.06.2020)

As a part of the campaign, a total of 2.20 Lakh number fishes have been released during the entire ranching week. Sites namely Nabadwip, Kalna, Balagarh, Tribeni and Barrackpore were covered within a period of 7 days for the campaign.Ranching can increase fishers' income from rivers that can yield 'Green fish in Blue economy' and thereby improved livelihood of very poor fisher folks, he added. The event was successful and the efforts made by CIFRI under its National Mission for Clean Ganga Project (NMCG) was highly appreciated by both local authorities and fisher communities residing along close proximity of the river.

Table 49. List of Ranching Week

Sl No.	Sites	Date	Species	Number released
1.	Kalna (Dist- Burdwan)	11.06.2020	IMC	40000
2.	Nabadwip (Dist-Nadia)	12.06.2020	IMC	50000
3.	Balagarh (Dist- Hooghly)	13.06.2020	IMC	30000
4.	Tribeni (Dist-Hooghly)	14.06.2020	IMC	50000
5.	Barrackpore (Dist- North 24 Parganas)	16.06.2020	IMC	50000




River Ranching Week (11.06.2020 -15.06.2020)

River Ranching programme at Farakka, West Bengal (23.09.2020)

Ranching of more than 1,20,000 advanced fingerlings of Rohu (*Labeo rohita*), Catla (*Labeo catla*), Mrigala (*Cirrhinus mrigala*), and Calbasu (*L. calbasu*) was conducted in river Ganga at Farakka, West Bengal on 23rd September, 2020. Shri D.S.G.S.S. Babji, Executive Director, NTPC, Farakka, West Bengal; Dr. B.K. Das, Director, ICAR-CIFRI, Barrackpore, Kolkata; Shri R. K. Singh, Superintending Engineer, Farakka Barrage Authority and Shri Sanjeev Kumar, Assistant Director, IWAI were present as the Special Guests on the occasion.

River Ranching programme at Farakka, West Bengal

River Ranching programme at Maharajpur & Sahebgunj (Jharkhand) 24.09.2020

Consecutive two ranching programme at Maharajpur & Sahebgunj, Jharkhand was conducted in presence of local fishers and fishermen Co- operative societies.Total 2,00,000 advanced fingerling of Indian Major Carps are realeased in two sites.

River Ranching programme at Maharajpur & Sahebgunj (Jharkhand)

Table 50. List of Ranching programmes

Details of fish ranching programme by ICAR- CIFRI under NMCG Project in River Ganga (2015-2020)					
Sl No.	Date	Place	Species	No.	Species ratio (R:C:M:K)
01	23.05.2017	Rishikesh, Uttarakhand	Mahaseer	500	-
02	26.05.2017	Barrackpore, West Bengal	IMC	2,500	1:2:2:2
03	01.08.2017	Narayani Ashram, Prayagraj	IMC	10,000	3:1:1:1
04	03.11.2017	Balagarh, West Bengal	IMC	60,000	1:2:1:1
05	11.11.2017	Dasashwamedh Ghat, Varanasi, Uttar Pradesh	IMC	5,000	2:1:1:1
06	21.11.2017	Barrackpore, West Bengal	IMC	>20,000	3:2:2:1
07	05.12.2017	Sringverpur, Prayagraj	IMC	10,000	2:2:1:1
08	21.01.2018	Nabadwip, West Bengal	IMC	>1,00000	3:1:1:1
09	27.03.2018	Fatehpurghat, Kausambi Prayagraj, U.P.	IMC	10,000	2:2:1:1
10	15.03.2018	Barrackpore, West Bengal	IMC	50,000	3:1:1:1
11	05.09.2018	Barendrapara Ghat, Bally, Howrah, W.Bengal	IMC	5,00000	1:1:2:1
12	02.10.2018	Barrackpore, West Bengal	IMC	2,80,000	2:1:1:1
13	02.10.2018	Sangam, Prayagraj	IMC	5000	2:1:1:1
14	06.11.2018	Mayapur, West Bengal	IMC	3,00000	2:1:1:1
15	26.11.2018	Ramyaghat, Mirzapur	IMC	10000	1:2:1:1
16	04.12.2018	Sirsa, Prayagraj	IMC	10000	3:1:1:2
17	05.12.2018	Karaghat, Kausambi	IMC	20000	1:1:3:1
18	08.02.2019	Prayagraj	IMC	10000	2:1:1:1
19	26.02.2019	Sangam, Prayagraj	IMC	15000	3:3:1:1
20	15.03.2019	Barrackpore	IMC	10,000	2:2:2:1
21	17.03.2019	Barrackpore	IMC	50,000	1:1:1:2
22	29.03.2019	Sangam, Prayagraj	IMC	15000	2:1:2:1
23	10.07.2019	Barrackpore, West Bengal	IMC	30000	2:1:3:1
24	27.07.2019	Nawabganj Ghat, Icchapur, West Bengal	IMC	60000	2:1:3:1
25	10.11.2019	Gandhi Ghat, Barrackpore (Ganga Amantran Team NMCG, Delhi)	IMC	40000	1:2:1:1
26	20.11.2019	Law college Ghat, Patna	IMC	40000	2:1:1:1
27	12.12.2019	Barrackpore, West Bengal	IMC	10000	1:1:1:1
28	26.01.2020	Gandhi Ghat, Barrackpore	IMC	50000	1:2:2:1
29	28.01.2020	Narayani Ashram, Prayagraj	IMC	10000	1:2:2:1
30	06.02.2020	Dashashwamedh Ghat (Prayagraj)	IMC	10000	2:2:1:1
31	11.02.2020	Sangam (Prayagraj)	IMC	15000	1:2:2:2
32	25.02.2020	Manaiyaghat (Prayagraj)	IMC	20000	3:2:2:1
33	29.02.2020	Vindhyanchal	IMC	15000	2:1:1:1
34	05.03.2020	Assi ghat (Varanasi)	IMC	20000	3:1:1:2
35	17.03.2020	Barrackpore, West Bengal	IMC	20000	2:2:2:1
36	11.06.2020	Kalna, West Bengal	IMC	40000	1:2:2:1
37	12.06.2020	Nabadwip (Swarupganj Ghat), West Bengal	IMC	50000	3:2:2:1
38	13.06.2020	Tribeni, West Bengal	IMC	30000	1:2:2:1
39	15.06.2020	Balagarh, West Bengal	IMC	50000	2:1:3:1
40	16.06.2020	Barrackpore, West Bengal	IMC	50000	3:1:2:1
41	23.09.2020	Farakka, west Bengal	IMC	120000	2:1:1:1
42	24.09.2020	Sahebgunj, Jharkhand	IMC	100000	2:1:1:1
43	24.09.2020	Maharajpur, Jharkhand	IMC	100000	2:1:1:1
		Total fish seed released till October 2020 (IMC*- Indian Major Carps) R=Rohu, C= Catla, M=Mrigal & K=Kalbasu		>30.00 (Lakhs)	

FISH SPAWN PROSPECTING STUDY IN RIVER GANGA

Fish spawn collection is a popular and traditional method of fish seed collection from river across the country. From time immemorial local resident fishers used to collect fish seed from river and culture in the nearby ponds, but with the advancement of breeding technologies resulted in the introduction of Bundh breeding, Chinese circular hatchery, etc. which has decreased the activity of spawn collection from the river and the major factor behind the decreased spawn collection rate from river is cost efficiency which is higher in the case of riverine spawn collection than that of other sources of spawn production. It has also been observed that rate of fish landing in the river regularly decreased which may be due to deterioration of river health by the increased anthropogenic activities and pollution sources in the river. River Ganga was source of 91.67% fish seed collection and culture during 1964-65. Similarly, the rate of production of Indian Major Carps from the river have also been decreased to greater extent as, on 1956-67 it contributed around 51.21% of total fish catch from the river. Which decreased to 16.04 % of the total fish catch during 2005-2015. So, to investigate the actual present situation of fish spawn availability in river Ganga, ICAR-CIFRI initiated a study on ‘Qualitative and quantitative evaluation of fish spawn of river Ganga’in 2018 under the NAMAMI GANGE Programme.

Site Selection

For site selection following primary data were collected:

- ❖ Pre-monsoon survey for collecting information from the nearby residents and local fishers to know the expected spawn collection sites.
- ❖ Previous Study sites of ICAR-CIFRI during 1964-65.
- ❖ Major river tributaries and their confluence points.

The study site is selected on the basis of various factorsi.e., previous survey reports of ICAR-CIFRI, Pre-monsoon survey data onavailability, distribution and composition of fishers residing nearby villages, River tributaries and their confluence point. For the purpose 31 different study sites (Table 55) and (Fig. 200) were selected from the 4 major states i.e., Uttar-Pradesh, Bihar, Jharkhand and West Bengal along the River Ganga. Study siteswere categorized into five different study zones i.e., Varanasi Zone, Patna Zone, Bhagalpur Zone, Rajmahal Zone and Farraka Zone (Table 55) &(Fig. 200).

Table 51. GPS coordinates of spawn prospecting study site

Sl. No	District, State	Sites	GPS coordinates
1	Baliya, U.P	Bharauli Pool	25°33.763´N 83°59.021´ E
2	Baliya, U.P	KotwaNarayanpur	25°33.819´N 83°56.310´ E
3	Ghazipur, U. P	Birpur Ganga Ghat	25°31.342´N 83°51.341´ E
4	Buxar, Bihar	Ahrauli Pool	25°35.741´N 83°51.341´ E
5	Ghazipur, U.P	Jamalpur Bridge (Veer Abdul Hameed Bridge)	25°35.301´N 83°36.306´ E
6	Ghazipur, U.P	Collector Ghat	25°34.689´N 83°35.027´ E
7	Ghazipur, U.P	Mahaveer Mandir Ghat	25°33.787´N 83°33.697´ E
8	Ghazipur, U.P	Koyla Baba Ghat	25°36.672´N 83°41.998´ E
9	Patna, Danapur, Bihar	Pipa pool ghat	25°38.368´N 85°2.492´ E
10	Vaishali, Bihar	Mahnar Ghat	25°35'11.08"N 85°30'56.76"E
11	Saran, Bihar	Rasulpur Ghat	25°45'23.51"N85° 5'51.74"E
12	Patna, Bihar	Math kedarGhat	25°37'19.46“N85°10'15.39"E
13	Patna, Bihar	Jethuli Ghat	25°32'0.88"N 85°17'16.11"E
14	Patna, Bihar	Masan Ghat	25°31'21.70"N 85°17'45.03"E
15	Patna, Bihar	Triveni Ghat	25°31'2.40"N 85°18'1.03"E
16	Patna, Bihar	Mohamadpur Ghat	25°31'2.40"N 85°18'1.03"E
17	Patna, Bihar	Nawada Gaon	25°30'14.66"N 85°43'47.11"E
18	Patna, Bihar	Railipachmala	25°30'18.99"N 85°46'2.47"E
19	Mokama, Bihar	Mokama Ghat	25°23'37.98"N 85°57'4.91"E
20	Munger, Bihar	Yaduvanshi Ghat	25°18'18.71"N86°24'5.93"E
21	Bhagalpur, Bihar	Jhangira	25°14'35.74"N 86°41'57.31"E
22	Bhagalpur, Bihar	Sultanganj Ganga Ghat	25°15'15.77"N 86°44'18.33"E
23	Katihar, Bihar	Tin gharia ghat	25°26'14.82"N 87°16'5.70"E
24	Sahibganj, Jharkhand	RajmahalGhat	25°3'15" N 87°49'11" E
25	Sahibganj, Jharkhand	Maharajpur Ghat	25°12'26" N 87°44'58" E
26	Murshidabad, WB	Farakka Ghat	24°47'51" N87°54'38" E
27	Murshidabad, WB	Lalbagh Hajar Duari Ghat	24°11'0" N 88°16'5" E
28	Murshidabad, WB	JangipurSadaipur Ghat	24°27'4" N 88°6'31" E
29	Murshidabad, WB	Lalgola Ghat	24°7'45" N88°14'58" E
30	Hooghly, WB	Guptipara Kya Ghat	23°12'19.8" N 88°24' 17.892" E
31	Bardhaman, WB	Uddharampur Ghat, Katwa	23° 24' 15.48" N 88° 49' 8.4" E

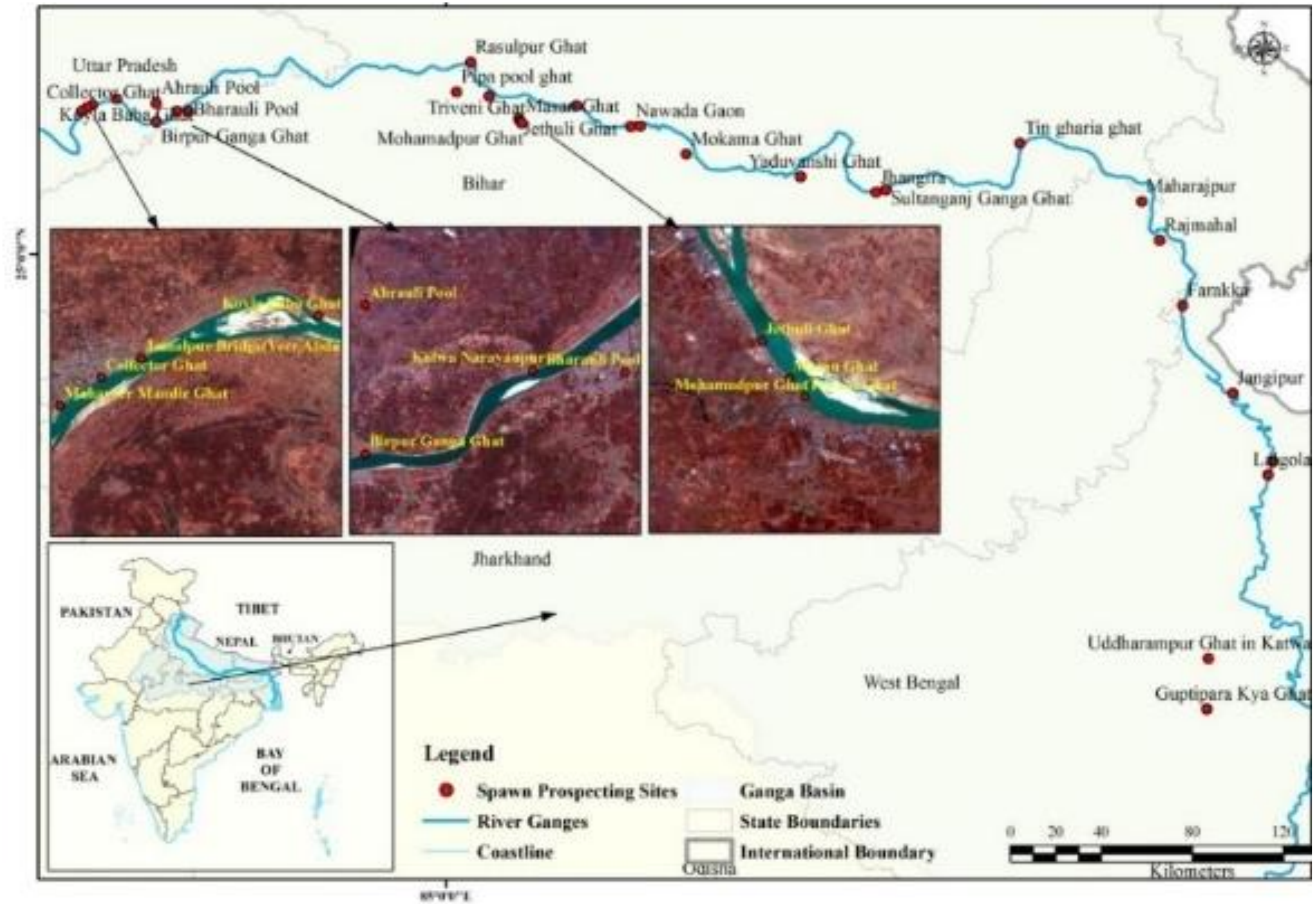


Fig. 204 Map depicting spawn prospecting sites

Fig. 205 a

Fig. 205b

Fig. 205 a-b Temporary huts constructed on the bank of river for spawn collection during

METHOD OF SPAWN COLLECTION

Description of Gear

The number of nets being operated chiefly depends upon the amount of spawn collection which encourages the spawn collection processes i.e., greater the number of spawns being collected more will be the number of net operations. The shooting net used for spawn collection is generally made of nylon and is having common tail cum Happa chamber which is generally made up of cotton (gamchas) or with synthetic cloths (sarees) which also acts as short-term storage chamber of spawn. The length of the net varies from 280-660 cm. The width of the net varies from 240-564 cm. The ring diameter varies from 17-24 cm. The net is operated in the depth of 2.5 to 10.2 ft. For this, purpose there are altogether 7-9 bamboos are used during the operation of shooting net.


Fig. 206a Shooting net used for operation

Fig. 206b Circular ring installed at the end of net

Fig. 206c Happa cum collection chamber installed at the end of shooting net

Fig. 206a-c Use of shooting net during spawn collection

Collection seasonand measurement of fish spawn

Though the procedure is only meant for operation during extensive monsoon period (July to August), the fishers laying the nets in different locations of the river do not follow any specific date to commence. As observed during the present investigation, the engagement of the shooting nets virtually starts during the mid-months of July because river water velocity gradually attains its peak during this period. The operation generally as a whole concludes in mid-August to September, preferably during 15th to 17th of the month when the level of the river water gradually gets lowered. Flood has a positive impact in spawn availability (CIFRI Bulletin no. 07, 1966 and CIFRI Bulletin no. 16,1971). It was observed that the numbers of spawn production reach maximum when the river water appears a reddish tinge (turbid/red) in colour owing to the addition of water from adjacent tributaries like Son and Ajay. Due to very tiny size, spawn cannot be measured in actual number. For selling of these spawnsan old field technique is being used in whichthe spawn sprouts are measured by metal or glass cups (locally termed as '*Bati*'). The size of the cups varies widely and is region specific (45- 120 ml).It has been assessed that spawn measuring cups has been estimated to contain an average count of 5,160 numbers and 30,000- 50,000 numbers per bati from Uttar Pradesh Bihar, Jharkhand and West Bengal region of collection sites.

Fig. 207 Series of Shooting net in operation

Fig. 208a

Fig. 208b

Fig. 208c

Fig. 208d

Fig. 208 a-d Different fish spawn measuring devices utilized in river Ganga during the collection period

Fish seed production in river Ganga

Previous reports on fish spawn availability from the river have indicated decreasing trend of wild IMC spawn (10%) in the period 2005-2009 in percent contribution compared to other fish stocks (90%) (Das et al., 2013). On the other hand, considerable decline in fish seed availability have also been noticed from 78.82% (1960's) to 34.48% (2004) (Vass et.al, 2009). The number of fish spawn (approx.) varies greatly depending upon the time of commencement of monsoon. Generally, the entire Ganga River basin receives heavy rainfall (80%) during the period from June to September with average of about 1200 mm (Nandargi et. al 2018). However, recent studies have indicated decrease of rainfall by 56 % over 133 districts along entire Ganga basin largely due to climate change (Bera, 2017). As a result, the river experiences several floods during the collection period i.e., extending over a period of 30 days. The bulk appearance of the spawn is observed only during first two floods during the peak season, while the remaining yield only traces of spawn. The first flood which contribute maximum of the spawn commences very late nowadays owing to delayed monsoon. However, on the other side, the operation also reaches its peak when the river water appears a reddish tinge in colour owing to the addition of water of river Son from north. It appears generally by last week of July and retains till 1st week of August. This is the reason behind the shorter span of collection time. The appearances of new and full moon also play a vital role in the huge availability of spawn as recorded from few places. The collection reaches up to 10 bati /day/ net from 4 bati /day/ net.

Fig. 209a

Fig. 209b

Fig. 209c

Fig. 209 a-c spawn collection from river

STORAGE OF SPAWN

For storage of spawn, various types of spawn storagetechniques are being traditionally used.

Short term storage

For short term storage, 3 types of storage techniques are being used by the fishers

❖ ***Happa installed in the river***

For short term and initial storage of spawn, Happa is being used for storage of spawn from the river in which the collected spawn is immediately placed in the happa installed in the river. This type of happa provides the optimum and favorable condition for survival of spawns and also provides maximum chances of their survival, with the regular exchange of riverine water. But, the maximum time span for their storage is 24-72 hrs. With in this period, the collected spawns were either soldinthe local market or are taken to the culture pond for their growth. The catch usually contains mixed catch of all the fish species which breed during the season.

Fig. 210 Storage happa installed on the river for short term storage of spawn.

❖ ***Storage in Earthen Pit***

For short term storage of spawn, apart from happa the technique used is earthen pit storage, in which the pits are made on the banks of the river and spawn collection site with the depth of 2-3 ft in which water from river is filled and collected spawn from the shooting net is transferred. Which further on taken to the rearing pond. The most probable reason behind the storage is temperature regulation as the earthen base provides the adequate temperature and favorable condition to the stored spawn samples and the slow collection rate encourages the fishers for collection of spawn for consecutive days, up to which the spawn samples were kept in the earthen pit.

Fig. 211 Storage in Earthen Pit

❖ ***Storage in Earthen Utensils***

Storage is also made in earthen utensils, in which the earthen pots were kept in the banks of the river and river water is filled in the earthen utensils which is helpful in temperature regulation and short-term storage of spawn i.e., generally for 24 to 72 hrs.

Fig. 212a

Fig. 212b

Fig. 212 a-b Earthen Utensils used for storage of spawn samples

SPAWN TRANSPORTATION

The spawns are collected from the river and are initially stored in the banks of the river. But to culture the spawn, these were transported to the different localities, distance of which determines the method of transportation to be adopted. The different transportation methods were accommodated to transport spawn from river to nursery ponds such as open tank transportation, polythene bag filled with oxygen and Aluminium *handi* (Based on the distance). In some cases, specialized red soil and Ganga river water were used for transportation to increase the survivality of the spawn.

❖ ***Long transportation***

For long distance transportation, the motorized vehicles are used with spawn samples filled in oxygen packet.

Fig. 213a

Fig. 213b

Fig. 213c

Fig. 213 a-c Long distance transportation

❖ ***Short Transportation***

Spawn samples are transported by using motorized/ non-motorized movable vansfor short distance transportation. Riverine water wereoftenused to increase the rate of survivability during transportation of spawn.

Fig. 214a

Fig. 214b

Fig. 214c

Fig. 214 a-c Short distance open transportation of spawn

REARING OF SPAWN

The collected spawn samples from different study sites were reared at different sites for further identification as mentioned below

- ❖ Cemented tanks at ICAR-CIFRI, Barrackpore.
- ❖ FRP tanks at different study sites of ICAR-CIFRI and Farraka.

Preparation of pond for spawn rearing

Prior to stocking of the collected riverine spawn, the nursery rearing ponds were prepared. The pond preparation process initiated 60 days prior to stocking. In the process, weed fishes were cleared with the help of Mahua oil cake. After the gap of 2 weeks, liming was done in the ponds after determining the soil pH value. Insecticides were used to eradicate the insects present in the pond. A fermented mixture of Ground nut oil cake, Rice bran, Molasses, and yeast powder were used as manure in the pond to develop planktonic organism in the pond.

Fig. 215a Rearing of spawn at CIFRI fry rearing unit

Fig. 215b Rearing of fish spawn in pond

Fig. 215c Rearing of spawn in Cemented Tank

Fig. 215d Rearing of fish spawn in FRP tanks

Fig. 215 a-d Preparation of pond for spawn rearing

Feeding of spawn

Feed were selected on the basis of food and feeding habits of spawn as the collected riverine spawn were unidentified. Different type of feed. i.e., Glucose powder, Mixture of milk and egg yolk, Infusoria and mixed plankton were used for rearing of riverine spawns and were fed up to their satiation level.

Fig. 216 a Commercial powdered feed

Fig. 216 b Culture of Artemia naupli

Fig. 216 c Milk powder and egg yolk mixture

Fig. 216 d Tubifex

Fig. 216 a- d Feeding of spawn

Identification of fish species

Spawns were identified with the help of microscopeatearly stage. After rearing the samples, identification was done with the help of various taxonomical keys such as Talwar and Jhingran, 1991 and websites such as Fishbase.org.

Quantitative and Qualitative evaluation of fish spawn

The studies carried out during the present survey focused upon both qualitative and quantitative production of natural fish seed from the river. The average fish spawn production has been estimated to be only 21 ml (435 million) from middle and lower stretch of River Ganga. Qualitative investigation was undertaken from the lower stretch of the river viz. Farakka, Lalgola and Guptipara in West Bengal indicated a total of 46 species belonging to 36 genera 19 families and 8 orders during the period of 2018-19. The species identification has been carried out solely from a representative sample from three different spots of the river. (Table 52). The site Guptipara has been confronted with maximum availability of fish species (0.38%) followed by Farakka (0.36%) and Lalgola (0.25%) respectively. Contribution from the economically important catfishes was merely 4.33 % signifying less abundance of the species during the sampling period. In the fish samples which was reared in ponds, only 30 % of the sample was of Indian Major carps and among the cyprinides the contribution of Indian Major Carps was only 43 %.

Table 52. Fish spawn species collected from different sites of river Ganga

Sl no.	Species	Family	Farakka	Lalgola	Guptipara
1.	*Amblypharyngodon mola* (Hamilton, 1822)	Cyprinidae	-	-	+
2.	*Aplocheiluspancax* (Hamilton, 1822)	Cyprinidae	-	-	+
3.	*Bagarius bagarius* (Hamilton, 1822)	Sisoridae	+	-	-
4.	*Batasio batasio* (Hamilton, 1822)	Bagridae	-	-	+
5.	*Chanda nama* (Hamilton, 1822)	Ambassidae	+	+	-
6.	*Channa punctata* (Bloch, 1793)	Channidae	-	-	+
7.	*Channa striata* (Bloch, 1793)	Channidae	-	-	+
8.	*Chitala chitala* (Hamilton, 1822)	Notopteridae	+	+	+
9.	*Cirrhinus mrigala* (Hamilton, 1822)	Cyprinidae	+	+	+
10.	*Cirrhinus reba* (Hamilton, 1822)	Cyprinidae	+	+	+
11.	*Crossochielus latius* (Hamilton, 1822)	Cyprinidae	+	+	+
12.	*Rasbora daniconius* (Hamilton, 1822)	Cyprinidae	+	-	+
13.	*Danio devario* (Hamilton, 1822)	Cyprinidae	-	-	+
14.	*Danio rerio* (Hamilton, 1822)	Cyprinidae	-	-	+
15.	*Eutropiichthys vacha* (Hamilton, 1822)	Schilbidae	+	+	-
16.	*Labeo catla* (Hamilton, 1822)	Cyprinidae	+	+	+
17.	*Glossogobius giuris* (Hamilton, 1822)	Gobiidae	+	+	-
18.	*Gudusia chapra* (Hamilton, 1822)	Clupeidae	+	-	-
19.	*Heteropneustes fossilis* (Bloch, 1794)	Heteropneustidae	-	-	+
20.	*Labeo bata* (Hamilton, 1822)	Cyprinidae	+	+	+
21.	*Labeo calbasu* (Hamilton, 1822)	Cyprinidae	+	+	+
22.	*Labeo rohita* (Hamilton, 1822)	Cyprinidae	+	+	+
23.	*Leiodon cutcutia* (Hamilton, 1822)	Tetraodontidae	+	-	-
24.	*Macrognathus aral* (Bloch & Schneider, 1801)	Mastacembelidae	+	-	-
25.	*Macrognathus pancalus* (Hamilton, 1822)	Mastacembelidae	+	+	-
26.	*Mastacembelus armatus* (Hamilton, 1822)	Mastacembelidae	+	+	+
27.	*Mystus bleekeri* (Day, 1877)	Bagridae	-	-	+

28.	*Mystus cavasiu s*(Hamilton, 1822)	Bagridae	+	-	+
29.	*Mystus tengra* (Hamilton, 1822)	Bagridae	-	-	+
30.	*Notopterus notopterus* (Pallas, 1769)	Notopteridae	-	-	+
31.	*Pachypterus atherinoides* (Bloch, 1794)	Schilbidae	+	+	+
32.	*Parambassis baculis* (Hamilton, 1822)	Ambassidae	+	-	-
33.	*Pisodonophis boro* (Hamilton, 1822)	Ophichthidae	-	-	+
34.	*Pethia conchonius* (Hamilton, 1822)	Cyprinidae	+	+	+
35.	*Pethia ticto* (Hamilton, 1822)	Cyprinidae	+	+	+
36.	*Puntius sophore* (Hamilton, 1822)	Cyprinidae	+	+	+
37.	*Rhinomugil corsula* (Hamilton, 1822)	Mugilidae	+	-	-
38.	*Salmostoma bacaila* (Hamilton, 1822)	Cyprinidae	+	-	+
39.	*Salmostoma phulo* (Hamilton, 1822)	Cyprinidae	-	-	+
40.	*Sperata aor* (Hamilton, 1822)	Bagridae	-	-	+
41.	*Systomus sarana* (Hamilton, 1822)	Cyprinidae	+	-	+
42.	*Trichogaster fasciata* (Bloch & Schneider, 1801)	Osphronemidae	-	-	+
43.	*Trichogaster lalius* (Hamilton, 1822)	Osphronemidae	-	-	+
44.	*Wallago attu* (Bloch & Schneider, 1801)	Siluridae	-	-	+
45.	*Xenentodon cancila* (Hamilton, 1822)	Belonidae	+	+	+
46.	*Hyporhamphus limbatus* (Valenciennes, 1847)	Belonidae	+	-	-

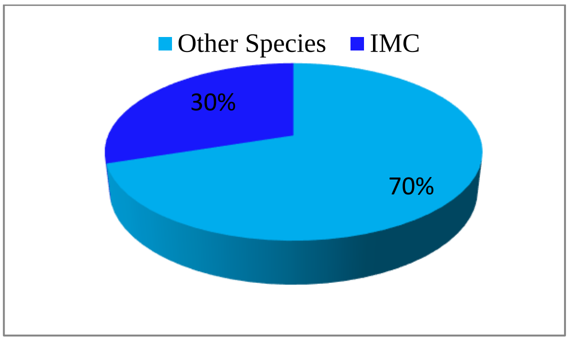


Fig. 217 Percentage of IMC and Other fish species among fish spawn

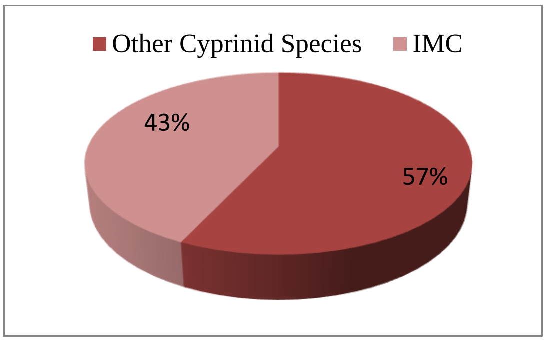


Fig. 218 Percentage of IMC and Other Cyprinid species among fish spawn

Cluster analysis of spawn prospecting sites

Bray- Curtis Cluster analysis was performed to know the hierarchical similarity between the different spawn production sampling stations (Fig. 219). The hierarchical dendrogram with Cophen correlation value of 0.92 showed that Rajmahal and Varanasi showed the similar pattern of spawn production with 96% of similarity. While the Patna and Farraka showed the similar pattern with the similarity of 98%. Bhagalpur shows the different pattern among all the stations.

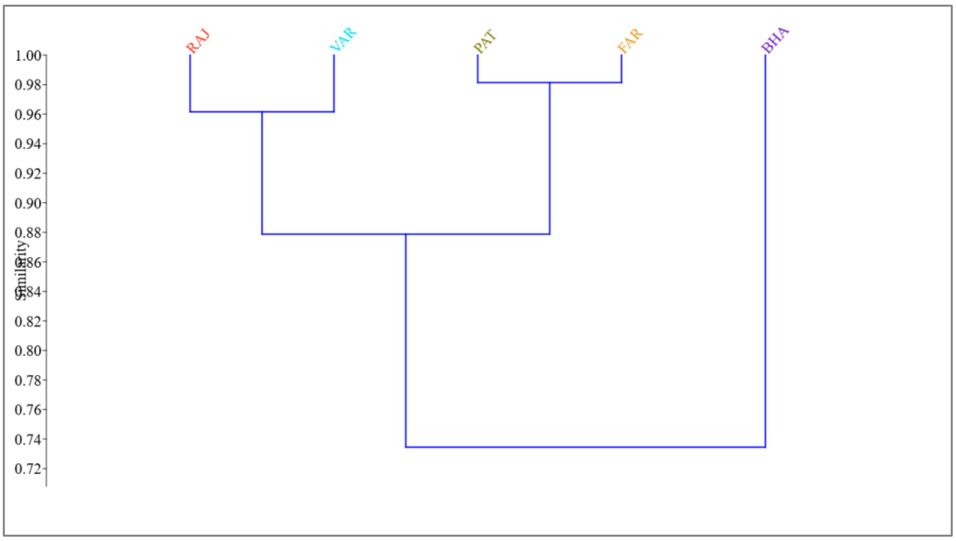


Fig. 219 Bray- Curtis Cluster analysis of spawn prospecting sites

Juvenile availability along Ganga river stretch

Ganga River along with its tributaries supports extensive aquatic biodiversity including fish fauna. Thirty-five commercially important fish species and their juvenile status were studied along the Ganga river stretch during 2017 to 2019. The various selective and non-selective gears like multi meshed gill nets, various seine nets, trap nets, barrier and falling nets, cast nets, drag nets, bag nets etc. were utilized for collection of the fish samples.Twelve sampling stations like Bijnor, Narora, Farrukhabad, Kanpur, Prayagraj, Varanasi, Buxar, Patna, Bhagalpur, Farakka, Berhampore and Balagarh from middle to lower stretches of river Ganga were found more productive area for fish juveniles of commercially inportant fishes. Very few numbers of juvenile fish species were reported from Harshil, Tehri and Haridwar stretch followed by Godakhali, Diamond Harbour and Fraserganj stretch.Thejuvenile composition obtained from river Ganga was mainly divided into seven major groups as carps included major, medium and minor fish representatives; the catfish included large and small sized catfish groups; the miscellaneous which included fish species of lesser economic importance, growth rate and opportunistic ones and lastly the exotics and their catch percentage have been calculated at each station in the entire river stretch.The dominant stretch was reported as Farakka (23), followed by Buxar (21) and Patna (19) according to the availability of juvenile fishes.

Bijnor: An exploration study revealed that juveniles of 8 commercially important fish species viz. *Labeo rohita*, *Labeo catla, Cirrhinus mrigala, Labeo calbasu*, *Bangana dero, Sperata aor, Tariqilabeo latius* and *Channa punctata* were available in monsoon and post monsoon season during the period of 2017 to 2019. IMC juvenile was reported plenty during 2018 and 2019.

Narora: Juvenile of 8 commercially important fish species viz. *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu, Bangana dero, Sperata aor, Tariqilabeo latius* and *Channa marulius* were reported from Narora in monsoon and post monsoon season. However, juvenile of *Channa punctata* was not found.

Farukhabad: A total of 5 fish species at juvenile stage as *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu* and *Channa marulius* were recorded from Farukhabad during the period under report.

Kanpur: A total of 7 commercially important fish species at juvenile stage as *Labeo rohita, Labeo catla*, *Cirrhinus mrigala*, *Labeo calbasu, Sperata aor, Systomus sarana,* and *Channa marulius* were found at Kanpur stretch of river Ganga. The species availability of juveniles was found more in monsoon as well as post monsoon season in 2017 to 2019.

Prayagraj: Study revealed that juveniles of 8 commercially important fish species i.e. *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu, Sperata aor, Systomus sarana, Channa punctata* and *Channa marulius* were recorded at Prayagraj sampling site. The occurances of *Labeo catla*, *Cirrhinus mrigala*, *Labeo calbasu* were dominant in monsoon and post monsoon whereas, *Labeo rohita* were found dominant in premonsoon season. Other juvenile fish species were recorded moderated to high range in monsoon as well as post monsoon season.

Varanasi: Commerciallyimportant fish species like *Labeo rohita, Labeo catla, Labeo calbasu*, *Anabas testudineus, Sperata aor, Systomus sarana, Channa punctata* and *Channa marulius* at juvenile stage were recorded from Varanasi stretch of river Ganga. Dominance of IMC juveniles were found monsoon and post monsoon season except *Cirrhinus mrigala*. *Anabas testudineus* is another important fish, has high market value with nutritive and medicinal quality. Juveniles of *Anabas testudineus* were found at less than 4 cm size and availability was more in 2017 and 2019 at Varanasi which indicates the probable breeding ground of *A. testudineus* along with other fish species.

Buxar: A total of 21 commercially important fish species including IMC, Catfishes and other miscellaneous group at juvenile stage were recorded at Buxar site during the study. Juvenile species like *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu,Ailia coila,* *Clupisoma garua, Eutropiicthys vacha, Rita rita, Mystus cavassius, Wallago attu, Sperata aor, Amblypharyngodon mola, Systomus sarana, Salmostoma bacaila, Setipinna phasa, Anabas testudineus, Channa punctata, Channa marulius, Johnius coitor* and *Mastacembelus armatus* having higher economic value were found at Buxar during monsoon to post monsoon period of entire study period. However, juvenile of *Cirrhinus reba* was recorded only in 2019.

Patna: Juveniles of *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu, Cirrhinus reba, Ailia coila, Clupisoma garua, Eutropiicthys vacha, Rita rita, Mystus cavassius, Sperata aor, Amblypharyngodon mola, Systomus sarana, Salmostoma bacaila, Setipinna phasa, Anabas testudineus, Channa punctata, Johnius coitor* and *Mastacembelus armatus* were found at Patna stretch of river Ganga. Occurance of economically valuable fish speciesfound dominant in monsoon and post monsoon season.

Bhagalpur: A total of 16 commercially important fish species juveniles viz. *Labeo rohita, Labeo catla, Ailia coila, Clupisoma garua, Eutropiicthys vacha, Mystus cavassius, Sperata aor, Amblypharyngodon mola, Systomus sarana, Salmostoma bacaila, Setipinna phasa, Anabas testudineus, Channa punctata, Johnius coitor* and *Mastacembelus armatus* were found dominated at Bhagalpur site. *Ompok bimaculatus* is designated to be in Near Threatened category under IUCN red list was recorded in pre monsoon and monsoon season.

Farakka: The exploration study revealed that a total of 23 fish species viz. were *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu, Cirrhinus reba,Labeo gonius, Ailia coila, Clupisoma garua, Eutropiicthys vacha, Rita rita, Mystus cavassius, Wallago attu, Sperata aor, Heteropneustes fossilis, Ompok bimaculatus, Amblypharyngodon mola, Systomus sarana, Tenualosa ilisha, Setipinna phasa, Anabas testudineus, Johnius coitor,* and *Mastacembelus armatus* were recorded at juveniles stage in Farakka stretch of river Ganga. The stretch is considered as most productive area and probable breeding ground of maximum number of commercially important fish species due to availability of juvenile fishes. Occurance of IMC, Catfishes and other fish group found dominant in monsoon and post monsoon season whereas, *Tenualosa ilisha* was available in pre monsoon and monsoon season.

Berhampore: A total of 11 commercially important fish species juveniles like *Labeo rohita, Labeo catla, Cirrhinus mrigala, Labeo calbasu, Cirrhinus reba, Rita rita, Heteropneustes fossilis, Ompok bimaculatus, Amblypharyngodon mola, Systomus sarana* and *Johnius coitor* were recorded in Berhampore stretch.

Balagarh: The study revealed that a total of 16 fish species juvenile as *Labeo rohita*, *Labeo catla, Cirrhinus mrigala, Labeo calbasu,Cirrhinus reba, Ailia coila, Clupisoma garua, Eutropiicthys vacha, Rita rita, Sperata aor, Heteropneustes fossilis, Ompok bimaculatus*, *Amblypharyngodon mola*, *Systomus sarana, Salmostoma bacaila* and *Tenualosa ilisha* were found dominated in monsoon and post monsoon season during 2017 to 2019.

At estuarine stretch (Godakhali to Fraserganj) brackishwate fish species juvenile like *P. paradesius, O. pama, H. nehereus, A. chacunda* and migratory fish species like *T. ilisha* were reported at monsoon period during the study.

The abundance of Hilsa catch occurs mainly during winter months in the estuarine part of the river.In Ganga, juveniles of hilsawere mostly available during March to October with average size length of 7.1 cm (TL) and recorded highest from Diamond harbour (46.41%), Godakhali (28.32%) followed by Tribeni (14.72 %), Farakka (5.62 %) and Berhampore (4.68%). In the present study, Diamond Harbour (55%) and Fraserganj (70%) are the key area of juvenile availability of *M. gulio* mostly during post monsoon months. Highest availability of *P. paradiseus* juveniles (89%) were recorded from Diamond Harbour in 2019 followed by Fraserganj (87%). Indiscriminate explotation of *P. paradiseus* juveniles (51-70 mm) were also noticed from the Hooghly estuary using fine meshed bag nets leading to declining of fish stock as well as the loss of fisher community.

The juvenile availability in monsoon period is quite obvious as June to september is considered as peak spawning season of maximum fish species of Ganga River. The middle and lower stretch of river Ganga is ideal place for developing conservation and management plan as availability of commercially important juvenile fishes were found in huge number. Pollution and modification ofriverine ecosystem often affect the recruitment pattern of fish thus, identification of juvenile ground as well as spawning ground is necessary for establishment of the proper management guidelines to protect the declining indigenous stock.

Fig. 220a

Fig. 220b

Fig. 220c

Fig. 220d

Fig. 220e

Fig. 220f

Fig. 220 a-f Juvenile fish species

Table 53. Juvenile availability of Important fish species along Ganga river stretch

Species Name	Season	Harsil	Tehri	Haridwar	Bijnor	Narora	Farukhabad	Kanpur	Prayagraj	Varanasi	Buxar	Patna	Bhagalpur	Farakka	Berhampore	Balagarh	Godakhali	Diamond Harbour	Fraserganj
Labeo rohita	Pre-2017				0	66.67	60	60	50	50	44.56	42.71	0	29	0	0			
	Mon-2017				78	40	37.5	62.5	40	60	50	51.93	58	60	0	0			
	Post-2017				30	42.86	60	40	75	25	60	45.95	47	0	0	0			
	Pre-2018				0	25	50	28.57	80	20	40	40.19	42	0	0	0			
	Mon-2018				60	0	34	42.86	0	0	66	65.69	62	60	69	0			
	Post-2018				0	66.66	0	0	66	34	34	34.31	41	0	78	60			
	Pre-2019				49	40	60	50	72	28	42.5	42.57	21	0	0	0			
	Mon-2019				33.33	60	75	0	66	34	58	57.84	60	45	45	0			
	Post-2019				70	63.64	0	0	50	50	47	47.05	44	50	60	50			
Labeo catla	Pre-2017				12	0	0	25	0	7.69	12	22	10	35	0	49			
	Mon-2017				0	0	0	50	0	50	15	65	65	25	0	0			
	Post-2017				60	66.67	66.667	66.667	50	93	50	45	65	80	30	16			
	Pre-2018				28.57	0	0	50	0	11.11	20	29	30	16	0	0			
	Mon-2018				0	0	50	0	66.67	90	56	65	54	15	0	0			
	Post-2018				0	50	19	94.73	22	18	66	25	15	49	20	0			
	Pre-2019				0	0	0	40	0	33	32	49	50	15	0	77			
	Mon-2019				55	0	60	84	0	64	52	55	54	50	0	50			
	Post-2019				50	42.86	19	0	0	16	44	67	79	20	16	11			
	Pre-2017				40	40	50	34	60	50	36	46		46	55	75.86			
	Mon-2017				50	70	60	50	83	60	66	76		66	60	50			
	Post-2017				66.67	50	25	34	50	25	40	44.55		10	34	30.1			

Labeo calbasu	Pre-2018				66.666666667	16	50	50	50	20	47.11	26.08		44.44	50.63	77.55			
	Mon-2018				70	0	50	50	0	0	43.24	28.2		64.28	66.02	37.83			
	Post-2018				0	66.67	50	50	0	34	47.36	64.38		36.78	33.96	68.62			
	Pre-2019				60	38	40	40	80	28	40.54	21.12		47.91	41.33	62.16			
	Mon-2019				84	70	64	66	0	34	34.54	25.58		25.58	39.69	52.83			
	Post-2019				45.45	40	60	60	62.5	50	61.11	52.88		43.58	66	64.28			
Cirrhinus mrigala	Pre-2017				38	30.76923077	40	50	89		56	25		20		55			
	Mon-2017				8.33333333	37.5	33.33333333	25	0		14	30		0		50			
	Post-2017				26.666666667	60	0	42.85714286	15		6	13		25		0			
	Pre-2018				37.5	25	50	20	0		0	54		0		46			
	Mon-2018				0	42.85714286	33.33333333	28.57142857	0		20	50		56		50			
	Post-2018				75	37.5	40	30	25.80645161		56	0		0		56			
	Pre-2019				60	27.27272727	0	42.85714286	52.38095238		0	0		26		0			
	Mon-2019				38.46153846	70	0	33.33333333	36		67	46		0		15			
	Post-2019				40	41.66666667	42.85714286	40	86.95652174		9	54		50		66			
Cirrhinus reba	Pre-2017																		
	Mon-2017																		
	Post-2017																		
	Pre-2018																		
	Mon-2018																		
	Post-2018																		
	Pre-										20.58	83.3		86.66	22.47	21			

	2019											3							
	Mon-2019										80	80		85	79.07	86.81			
	Post-2019										62.63	62.64		60	68.23	79.71			
Labeo gonius	Pre-2017													24					
	Mon-2017													80					
	Post-2017													31					
	Pre-2018													29					
	Mon-2018													86					
	Post-2018													49					
	Pre-2019													25.85					
	Mon-2019													84					
	Post-2019													34					
Bangana dero	Pre-2017			0	0	0													
	Mon-2017			0	0	0													
	Post-2017			0	0	0													
	Pre-2018			0	0	0													
	Mon-2018			0	75.24	0													
	Post-2018			0	84.77	0													
	Pre-2019			0	30.48	0													
	Mon-2019			88.89	73.33	77.78													
	Post-2019			79	83.33	69.15													
Ailia coila	Pre-2017										0	0	0	0		0			
	Mon-2017										84.62	86.95	89.16	91.88		91.91			
	Post-2017										32.14	59.82	57.5	59.78		63.01			

	Pre-2018										68.54	65.93	73.05	72.23		79.91			
	Mon-2018										89.29	87.73	90.64	87.92		92.4			
	Post-2018										68.81	58.19	56.51	57.91		77.89			
	Pre-2019										0	0	0	0		0			
	Mon-2019										86.95	87.21	88.68	89.45		83.56			
	Post-2019										50.27	56.51	57.16	58.1		63			
Clupisoma garua	Pre-2017										0	0	0	0		0			
	Mon-2017										70.49	0	0	0		0			
	Post-2017										80.97	0	0	0		70.83			
	Pre-2018										36.58	48.78	0	0		0			
	Mon-2018										76.4	0	77.89	80.61		77.36			
	Post-2018										57.01	73.18	58.16	47.36		65.39			
	Pre-2019										0	0	0	0		0			
	Mon-2019										71.05	72.09	74.41	79.41		77.5			
	Post-2019										50	75.7	68.75	48.84		69.44			
Eutropiicths vacha	Pre-2017										0	0	0	0		0			
	Mon-2017										0	0	0	0		0			
	Post-2017										0	0	0	24.52		0			
	Pre-2018										0	0	0	0		16.84			
	Mon-2018										67.03	59.79	57	83.16		80			
	Post-2018										38.54	55	36.17	30.98		0			
	Pre-2019										0	0		0		36.84			
	Mon-2019										0	55.91	85.86	84		78			
	Post-										49.49	48	46.93	22.5		0			

	2019																		
	Post-2019										54.54	62.74	58.16	76.13					
Rita rita	Pre-2017										0	0		0	0	0			
	Mon-2017										0	0		0	0	0			
	Post-2017										0	0		0	0	0			
	Pre-2018										7.45	7.291		0	0	0			
	Mon-2018										80	88.89		85.71	0	0			
	Post-2018										40.47	59.25		36.45	0	0			
	Pre-2019										13.13	14.14		24.7	13.09	24.7			
	Mon-2019										76	87.77		70.11	70	70.11			
	Post-2019										24	41.75		33.7	38.77	33.7			
Mystus cavassius	Pre-2017										10	0	0	0					
	Mon-2017										29	45	38	0					
	Post-2017										36	31	50	0					
	Pre-2018										0	0	0	14					
	Mon-2018										47	47	27	58					
	Post-2018										60	40	24	39					
	Pre-2019										0	0	0	0					
	Mon-2019										67	0	67	55					
	Post-2019										25	20	22	38					
Mystus gulio	Pre-2017																	0	0
	Mon-2017																	0	0
	Post-2017																	0	0
	Pre-2018																	0	0

	Mon-2018																	70	62.26
	Post-2018																	55.55	52
	Pre-2019																	0	0
	Mon-2019																	68	68
	Post-2019																	55	53.53
Wallago attu	Pre-2017										0			0					
	Mon-2017										0			0					
	Post-2017										16.67			0					
	Pre-2018										0			0					
	Mon-2018										12.5			0					
	Post-2018										0			10					
	Pre-2019										0			0					
	Mon-2019										0			100					
	Post-2019										8.33			0					
Sperata aor	Pre-2017				0	0		0	0	0	38.33	0	0	0		25			
	Mon-2017				20	64		12	19	17.49	71.67	63.33	70.73	57		0			
	Post-2017				33.33	40		23.53	40	36.36	53.33	30.76	82.6	21		0			
	Pre-2018				0	48		12	13	16	44.55	0	0	0		0			
	Mon-2018				50	87.5		33.33	20	5	74	46	23.8	50		20			
	Post-2018				50	87.5		72.72	29.41	40	0	66	33.33	52.5		0			
	Pre-2019				50	62.5		77.77	9.09	20	0	54	0	32		0			
	Mon-2019				50	87.5		55.55	25	38.89	46	0	64.1	0		50			
	Post-2019				100	100		100	100	100	71	31	20	37.5		40			
Heteropneu	Pre-													0	0	0			

stes fossilis	2017																		
	Mon-2017													14.28	40	71.42			
	Post-2017													50	32.5	0			
	Pre-2018													25	0	0			
	Mon-2018													50	45	0			
	Post-2018													0	28	0			
	Pre-2019													0	0	0			
	Mon-2019													18.18	40	0			
	Post-2019													0	32.5	85.71			
Ompok bimaculatus	Pre-2017												50	0	0	0			
	Mon-2017												66.66	16.67	42.85	25			
	Post-2017												0	0	0	0			
	Pre-2018												0	0	0	30			
	Mon-2018												45	0	26	15			
	Post-2018												0	20	0	0			
	Pre-2019												25	0	0	0			
	Mon-2019												55	30	0	0			
	Post-2019												0	0	35	15			
Nemapteryx caelata	Pre-2017																0	0	
	Mon-2017																43.18	95.23	
	Post-2017																75	80	
	Pre-2018																0	0	
	Mon-2018																0	88.23	
	Post-2018																66.67	68.96	

	Pre-2019																0	0	
	Mon-2019																76	56.75	
	Post-2019																80	0	
Amblypharyngodon mola	Pre-2017										0	0	0	11.44067797	6.162011173	3.44			
	Mon-2017										0	0	0	3.389830508	4.469273743	2.49			
	Post-2017										8.91	0	26.33	16.94915254	19.67597765	10.99			
	Pre-2018										18.81	0	0	11.86440678	11.18435754	6.24			
	Mon-2018										11.88	21.75	0	5.084745763	4.245810056	2.37			
	Post-2018										0	0	29.66	17.79661017	11.73184358	6.55			
	Pre-2019										17.32	54.29	18.33	11.44067797	12.45251397	6.95			
	Mon-2019										0	0	0	4.661016949	9.184357542	5.13			
	Post-2019										43.06	0	25.66	17.79661017	20.67039106	11.54			
Tariqilabeo latius	Pre-2017			61.9	70	0													
	Mon-2017			57.89	50	0													
	Post-2017			43.48	25	0													
	Pre-2018			45	25	57.14													
	Mon-2018			39.13	50	60													
	Post-2018			34.78	20	42.86													
	Pre-2019			52.17	33.33	0													
	Mon-2019			45	50	50													
	Post-2019			43.75	40	50													
Systomus sarana	Pre-2017							0	0	0	0	0	0	0	0	0			
	Mon-2017							27.16	34	11.14	0	0	0	0	0	0			
	Post-							35.79	11.2	24	75	67.5	94.74	60	64	67			

	2017																		
	Pre-2018							48.73	26.49	16.45	0	0	0	0	0	0			
	Mon-2018							56.07	74.84	17.8	0	0	0	0	0	0			
	Post-2018							42.42	20	19.45	60	62	84	80	36.36	75			
	Pre-2019							0	8.33	6.8	0	0	0	0	0	0			
	Mon-2019							76.08	83.16	11.4	20	50	59	30.499	75	10			
	Post-2019							39.04	12	21.4	64	64	50	48.18	16	40			
	Pre-2017										0	5.88	0			28.57			
	Mon-2017										0	0	47.5			0			
	Post-2017										5.88	0	40			0			
	Pre-2018										26	0	0			32.14			
Salmostoma bacaila	Mon-2018										0	0	50			0			
	Post-2018										6.55	11.65	0			40			
	Pre-2019										19.02	0	14			0			
	Mon-2019										0	0	0			12			
	Post-2019										0	0	0			0			
	Pre-2017													67.74		71.42	59.375	57.89	70.83
	Mon-2017													28.2		79.73	66	85.71	56.81
	Post-2017													52.38		16	0	0	32.65
Tenualosa ilisha	Pre-2018													0		33.33	0	40	0
	Mon-2018													55		42.85	74.07	14	53.92
	Post-2018													27		0	75	66	0
	Pre-2019													31		52.38	28.57	48.94	35.41
	Mon-2019													81		61.29	70.03	62.85	55.36

	Post-2019													39.69		8	37.5	33	32.6
Anodontostoma chacunda	Pre-2017																		0
	Mon-2017																		4.22
	Post-2017																		54.12
	Pre-2018																		0
	Mon-2018																		40
	Post-2018																		31.4
	Pre-2019																		25
	Mon-2019																		27
	Post-2019																		9
Polynemus paradiseus	Pre-2017																	0	0
	Mon-2017																	0	0
	Post-2017																	0	0
	Pre-2018																	69.05	75.55
	Mon-2018																	87.13	83.5
	Post-2018																	65.11	68.37
	Pre-2019																	74.07	75.29
	Mon-2019																	89	87
	Post-2019																	56.17	56.19
Setipinna phasa	Pre-2017										0	0	0	0			0		
	Mon-2017										63.3	72	66.67	0			0		
	Post-2017										22	22	33	0			0		
	Pre-2018										0	0	0	68			46		
	Mon-										66	55	0	12			0		

	2018																		
	Post-2018										68	60	36	0			63.81		
	Pre-2019										12	0	55	0			0		
	Mon-2019										63.81	69	60	0			0		
	Post-2019										47.37	33	0	64.22			0		
Setipinna tenuifilis	Pre-2017																	0	0
	Mon-2017																	78.57	0
	Post-2017																	0	13.33
	Pre-2018																	0	0
	Mon-2018																	92.31	33.33
	Post-2018																	0	0
	Pre-2019																	0	0
	Mon-2019																	16.67	0
	Post-2019																	0	20
Anabas testudineus	Pre-2017									52.16	26.1	86.44	0	15.4					
	Mon-2017									20.16	11.6	87.15	0	11.14					
	Post-2017									24.79	38.9	85.79	11.2	24					
	Pre-2018									29.78	47.9	81.48	26.49	16.45					
	Mon-2018									24.97	16.4	86.07	74.84	17.8					
	Post-2018									22.45	35.8	42.42	20	19.45					
	Pre-2019									10.53	0	0	8.33	6.8					
	Mon-2019									70.21	47.47	80.77	83.16	11.4					
	Post-2019									17.78	33.33	39.04	12	21.4					
Otolithoides pama	Pre-2017																0	0	0

	Mon-2017																0	0	0
	Post-2017																0	0	0
	Pre-2018																38.63	78.64	84.04
	Mon-2018																79	90	87.23
	Post-2018																25	30.21	31.86
	Pre-2019																72.06	80.21	86.25
	Mon-2019																84	89	90.72
	Post-2019																22.68	28.26	28.26
	Pre-2017				0				0	0	0	0	0						
	Mon-2017				0				0	0	0	0	0						
	Post-2017				61.36				17.86	0	75.24	0	55.05						
	Pre-2018				0				0	0	0	0	13.86						
Channa punctata	Mon-2018				0				0	0	0	0	0						
	Post-2018				82.98				78.78	0	84.76	0	42.72						
	Pre-2019				0				0	0	30.47	0	0						
	Mon-2019				0				0	0	0	0	0						
	Post-2019				87				79.56	79	83.33	69.15	0						
	Pre-2017					0	0	0	0	0	0								
	Mon-2017					20	64	12	19	17.49	11.01								
Channa marulius	Post-2017					33.33	40	23.53	40	36.36	88.7								
	Pre-2018					0	0	0	0	0	0								
	Mon-2018					50	87.5	33.33	20	5	42.72								
	Post-2018					50	87.5	72.72	29.41	40	0								
	Pre-					50	62.5	77.78	9.09	20	60								

	2019																		
	Mon-2019					50	87.5	55.56	25	38.89	0								
	Post-2019					100	100	100	100	100	100								
Johnius coitor	Pre-2017										0	0	0	0	0				
	Mon-2017										0	0	0	0	0				
	Post-2017										0	0	0	0	0				
	Pre-2018										0	0	0	31.31	13.86				
	Mon-2018										84.94	78.22	0	55.96	55.04				
	Post-2018										30.24	43.68	0	40.4	42.72				
	Pre-2019										0	0	0	0	0				
	Mon-2019										71.875	75.52	82.22	59.46	60				
	Post-2019										24.42	40	32.99	40.66	0				
Mastacembelus armatus	Pre-2017										36	46	41	43.43					
	Mon-2017										67	56	61	56					
	Post-2017										19	34	27	53					
	Pre-2018										48	0	0	44.44					
	Mon-2018										24	68	0	58					
	Post-2018										21	51	25	44					
	Pre-2019										49	0	56	45					
	Mon-2019										31	45	59	36					
	Post-2019										20	26	14	26					
Harpadon nehereus	Pre-2017																	44.44	41
	Mon-2017																	80	30
	Post-2017																	0	45

	Pre-2018																	65	0
	Mon-2018																	65.22	28.57
	Post-2018																	0	44.64
	Pre-2019																	36	37.12
	Mon-2019																	28.57	40
	Post-2019																	0	0

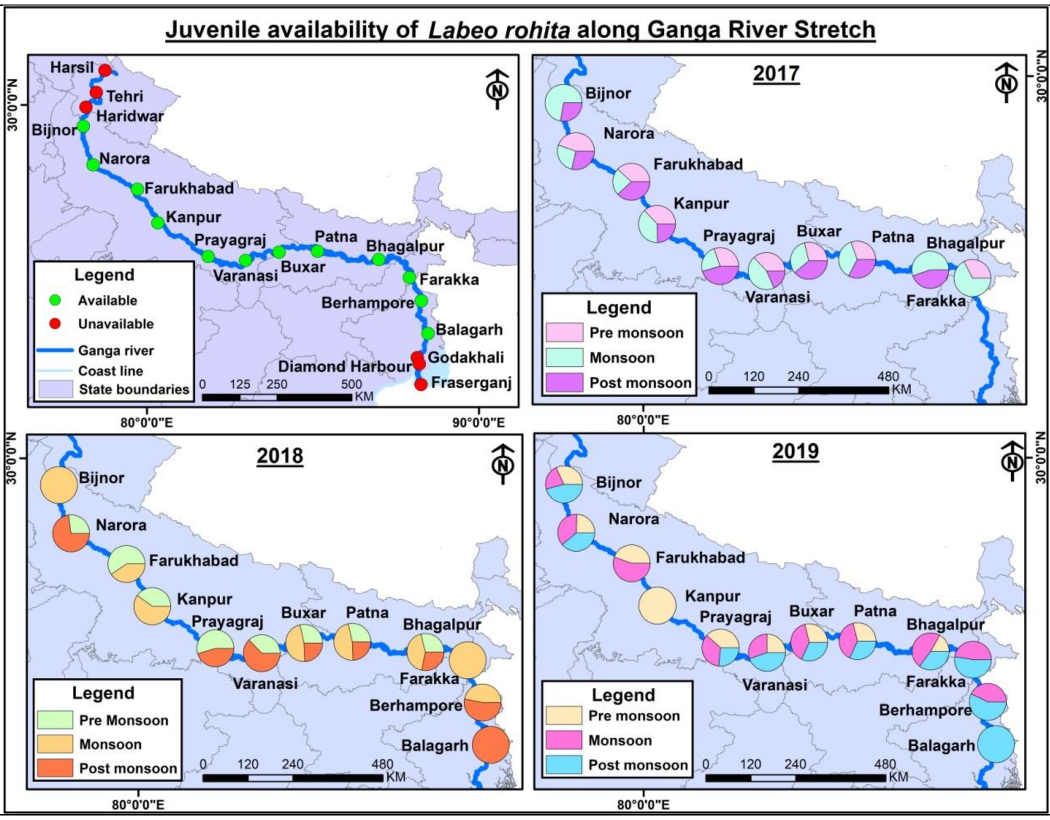


Fig.221a

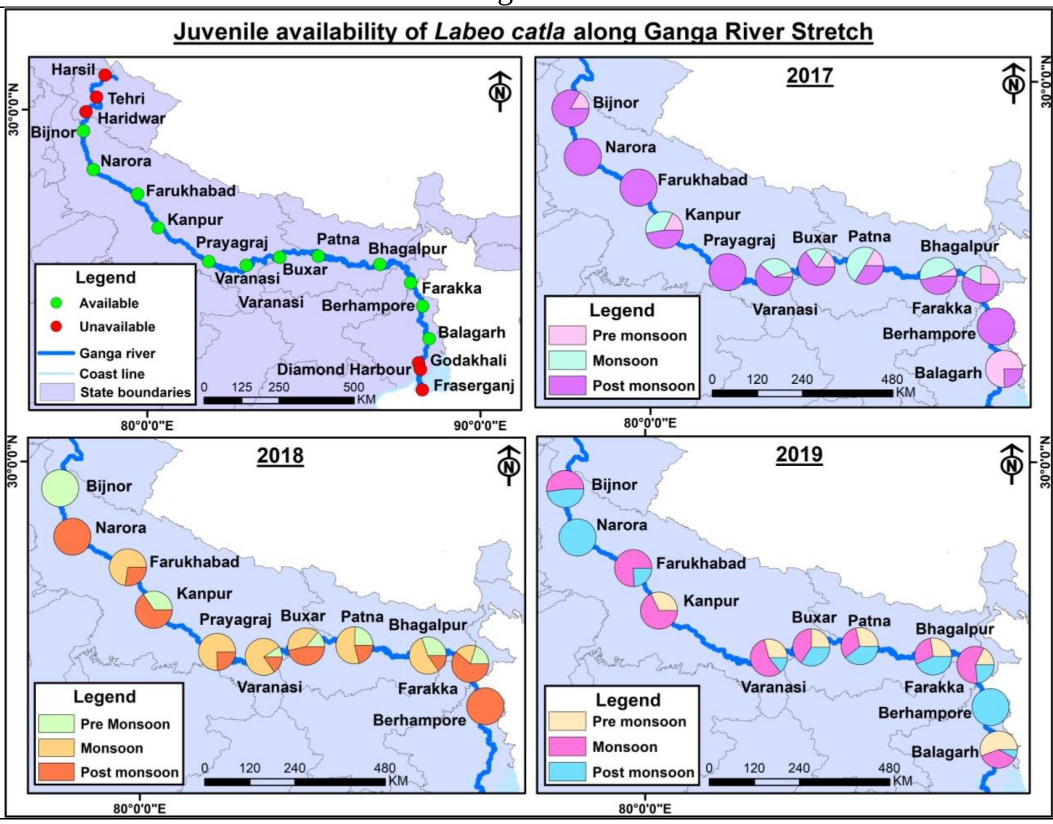


Fig.221b

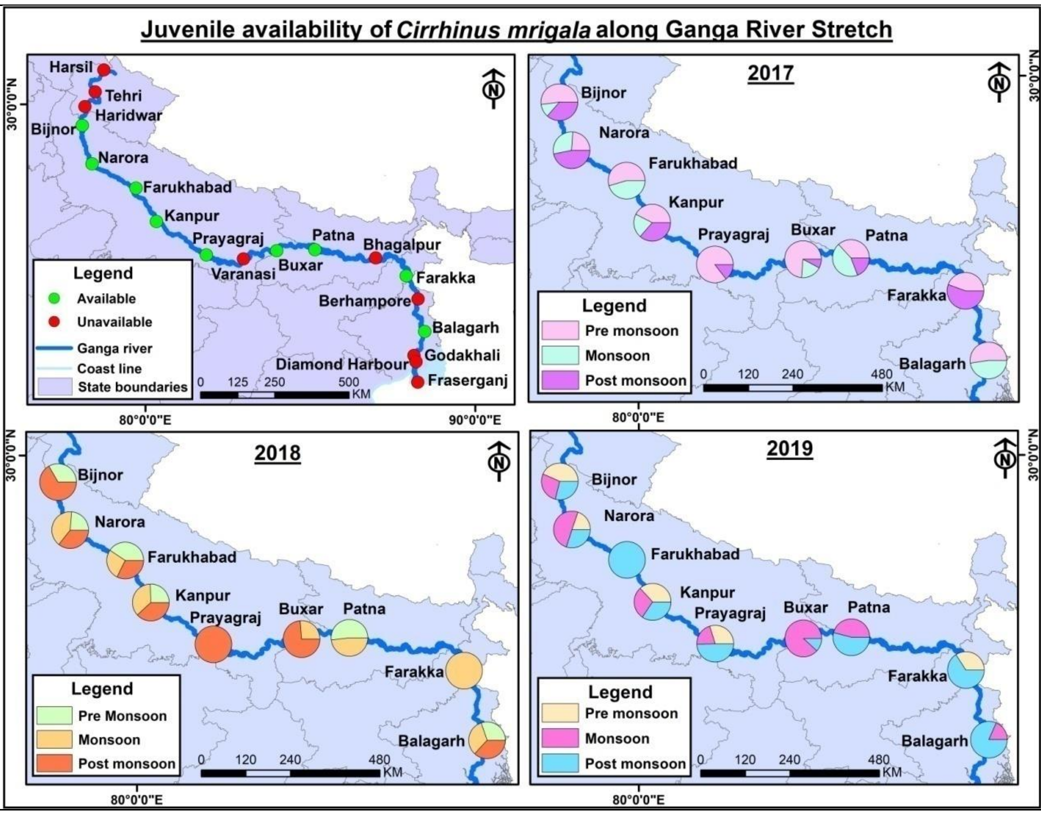


Fig.221c

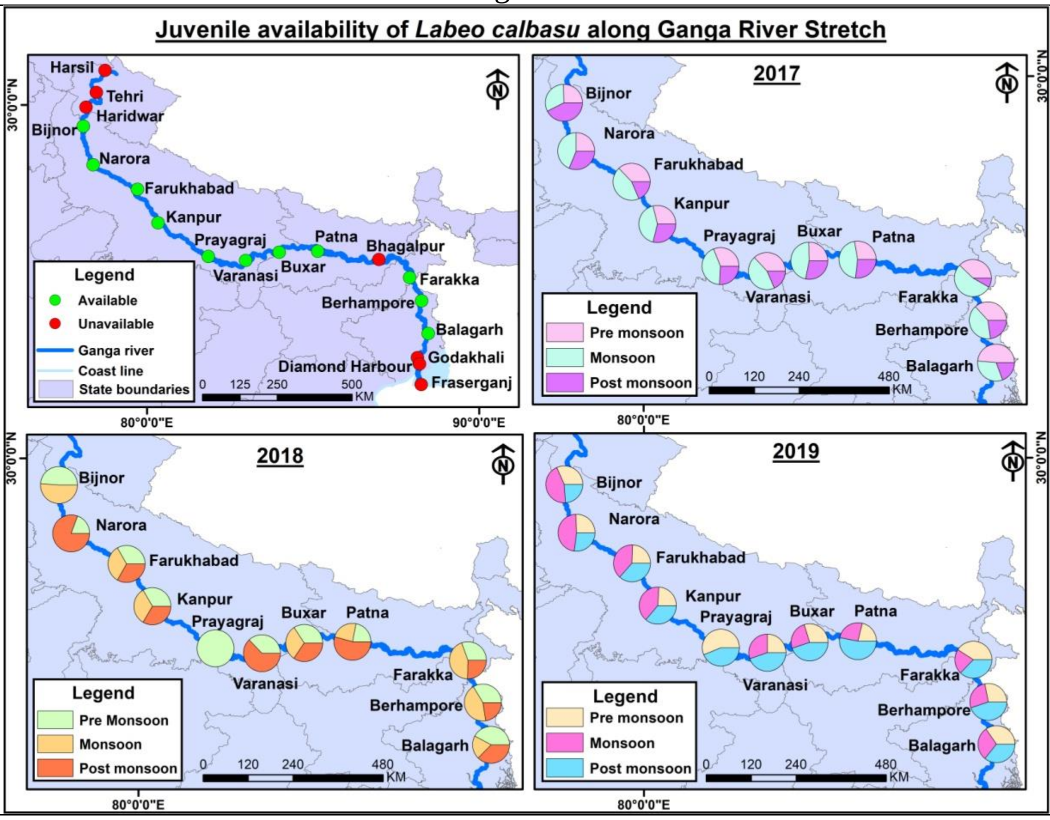


Fig.221d

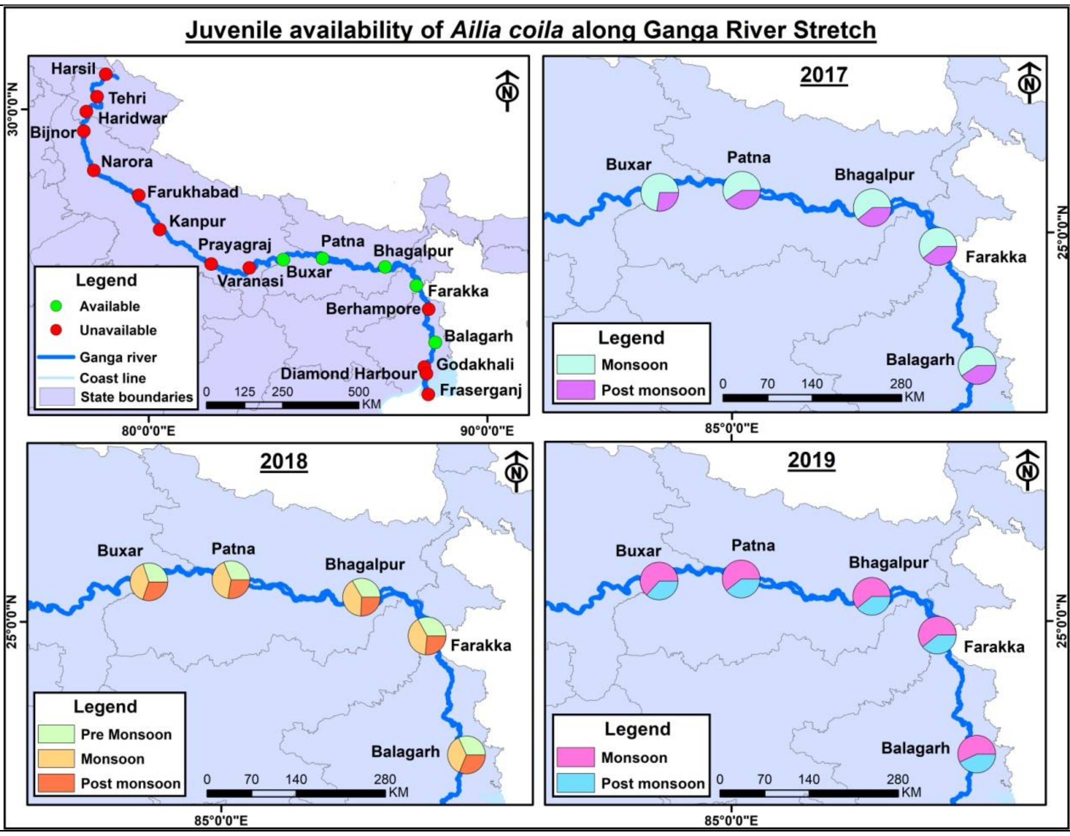


Fig.221e

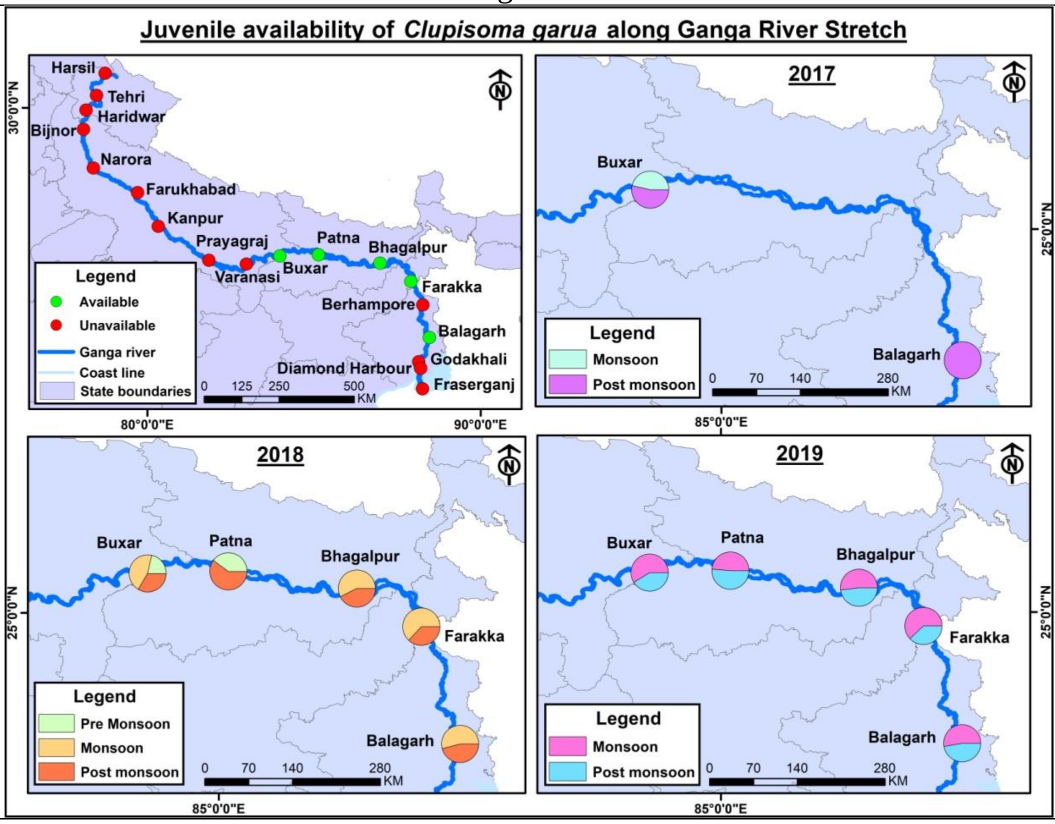


Fig.221f

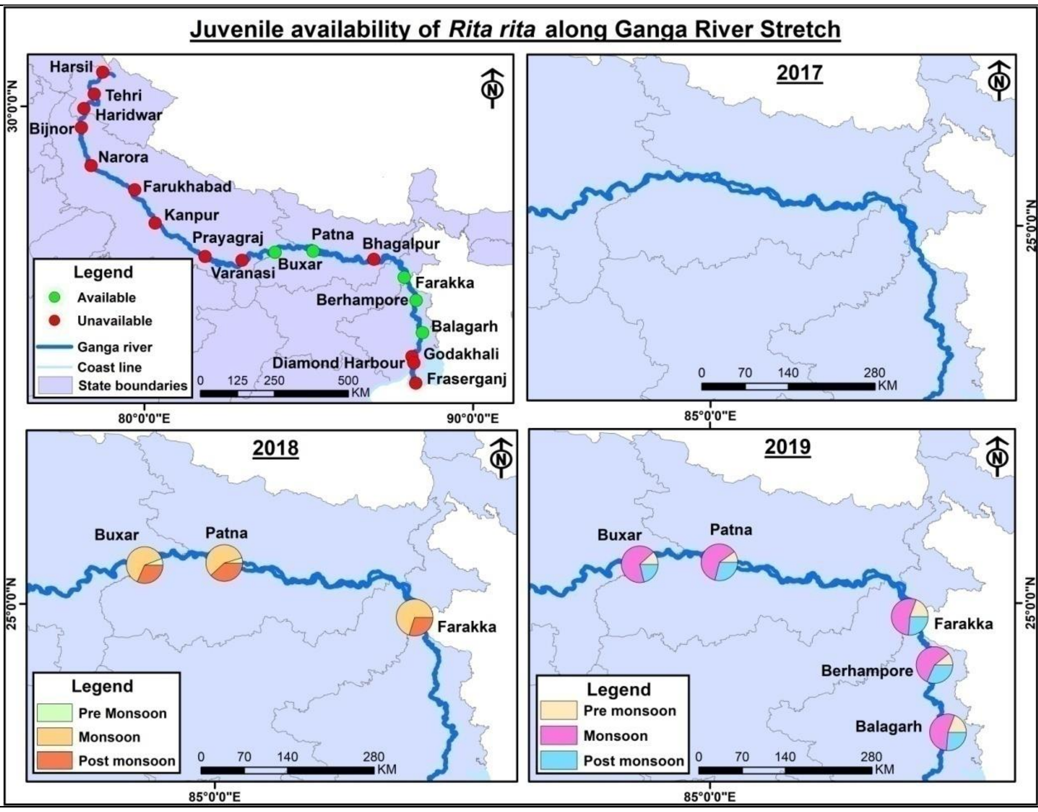


Fig.221g

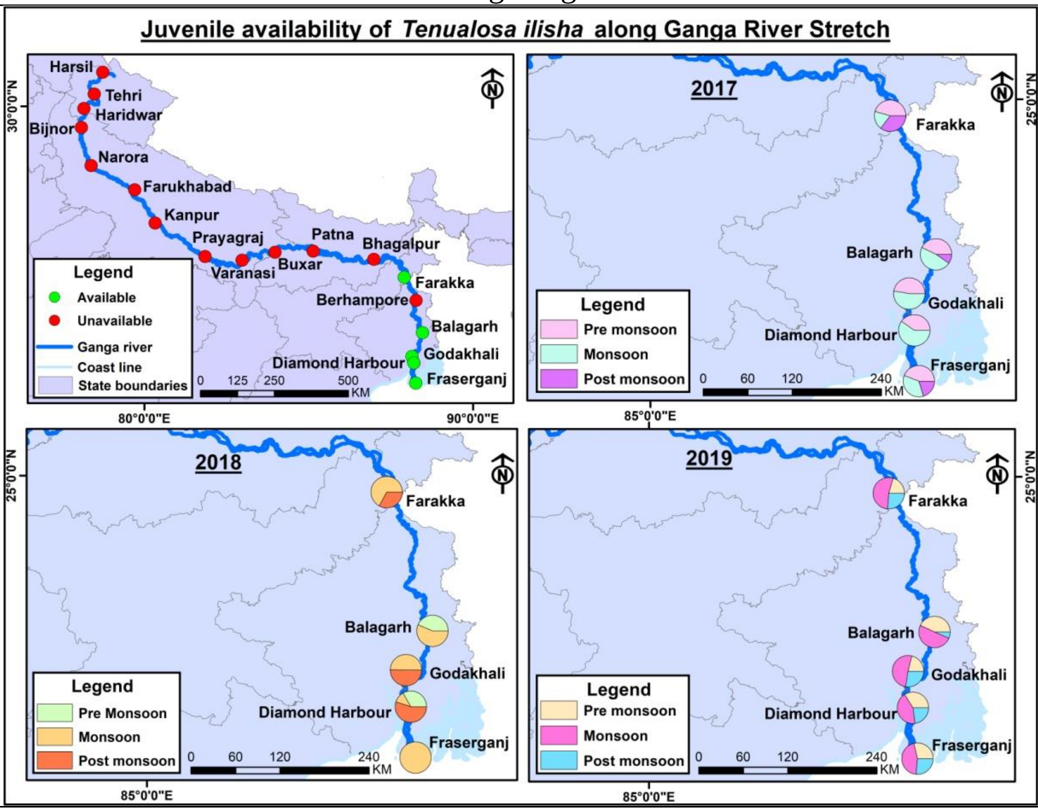


Fig.221h

Fig.221 a-h Juvenile availability of Important fish species along Ganga river stretch on GIS platform

OBJECTIVE–VII

AWARENESS CAMPAIGN ON SUSTAINABLE FISHERIES AND CONSERVATION FOR CONTROLLING OF DESTRUCTIVE FISHING METHODS, MESH SIZE REGULATION, BAN PERIOD IMPLEMENTATION WITH COMMUNITY MOBILIZATION

Several mass awareness programmes were organised along with fish ranching programmes to create awareness among local fishers and other stakeholders for conservation and susrtainable fisheries in different depleted stretches of river Ganga. Under this activity, ICAR-CIFRI conducted 46 awareness programmes during the project period. A total of 3890 numbers of fishers were sensitized through the awareness campaign at 4 states as Uttarakhand, Uttar Pradesh, Bihar and West Bengal on the detrimental effects of destructive methods of fishing like to ban the operation of zero mess size net and other destructive fishing method likeuse of toxic chemicalsor poisoning for fishing and were advised not to catch the juveniles and brooders especially in the breeding seasons (June-August) for their sustainable fisheries inriver Ganga.CIFRI's initiation with the aim to restore the prized fishes of river Ganga under the project has created an impact among the local fishers.The awareness prgramme were conducted successfully with the active participation of fishernmen communities and they were also advised to attain sustainable development goals for improving the fish stocks of river Ganga which in turn could augment the fisheries production in future.

GIS Mapping of Awareness Campaign on Sustainable Fisheries and Conservation along Ganga River Stretch

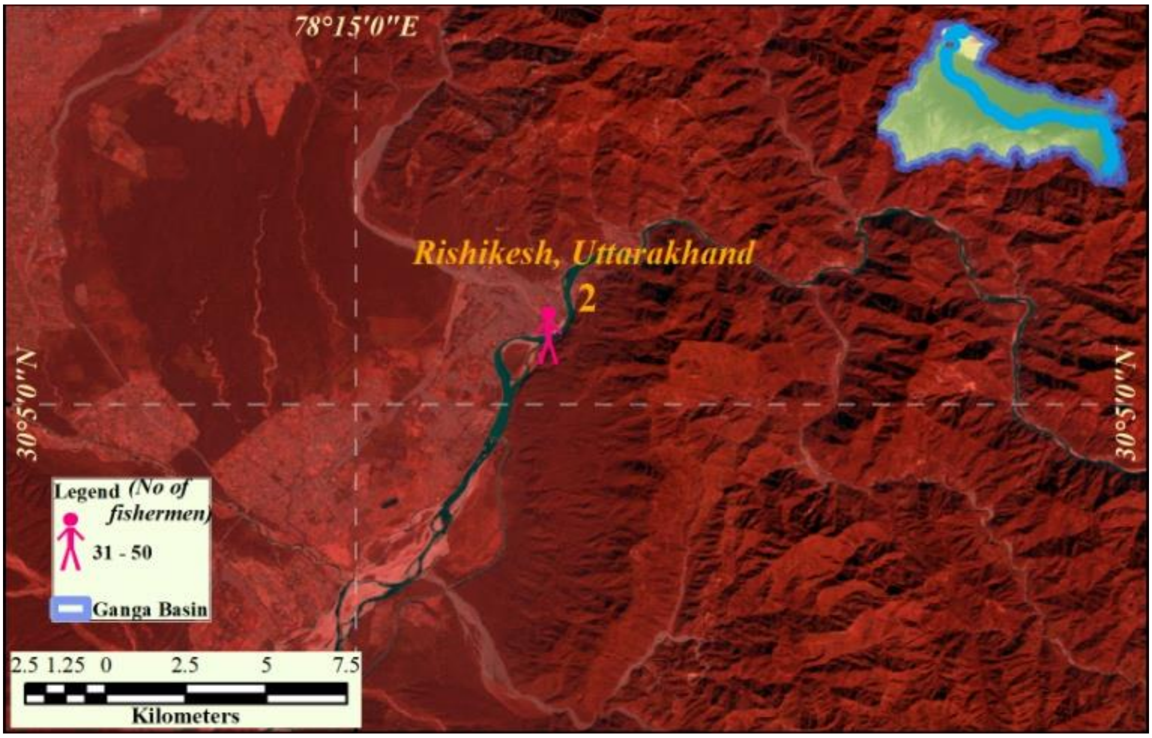


Fig. 222a

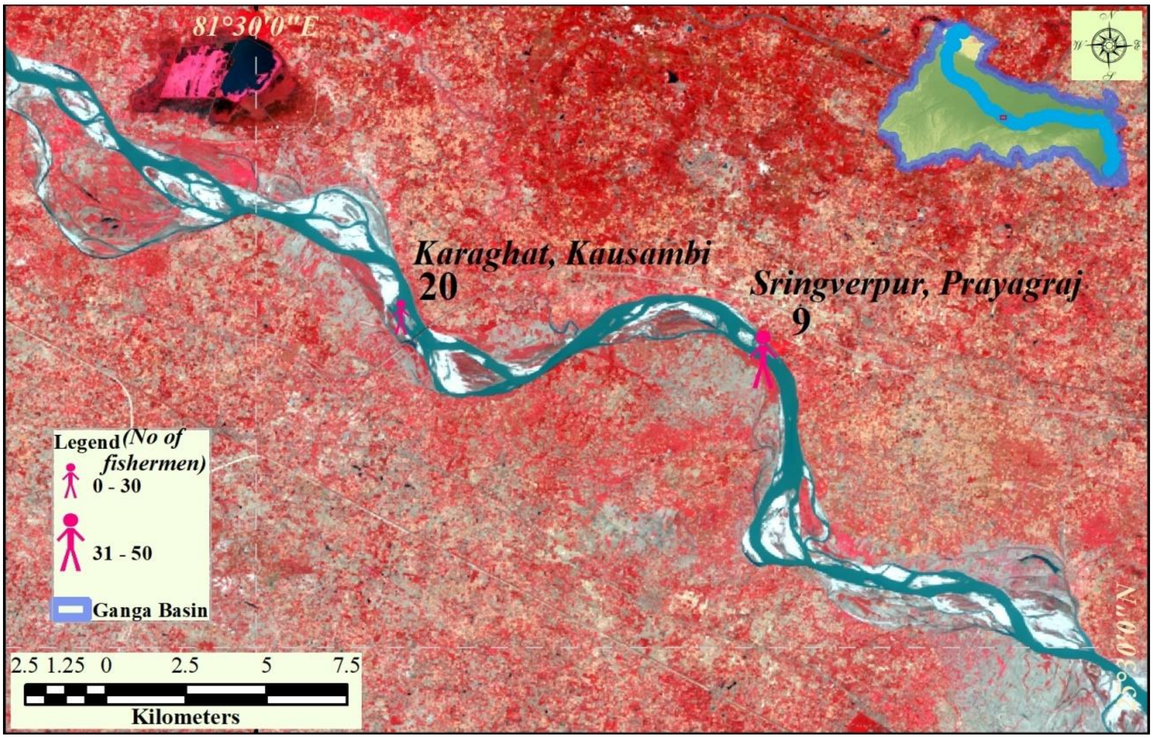


Fig. 222b

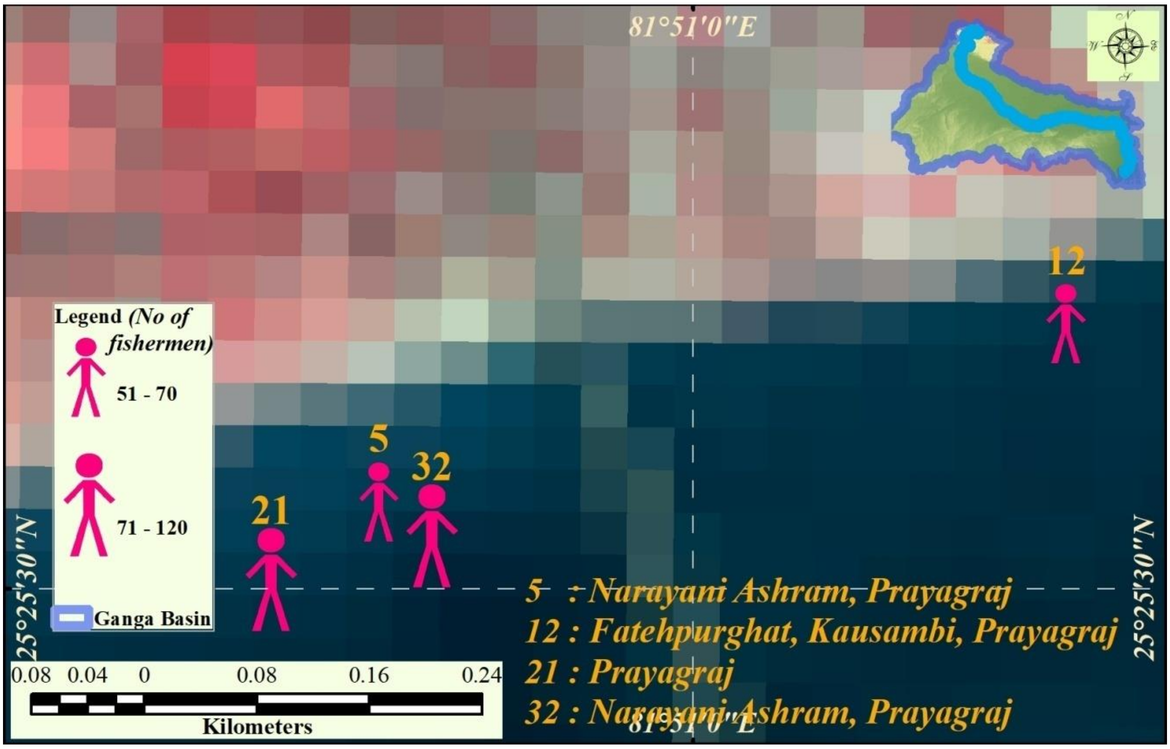


Fig. 222c

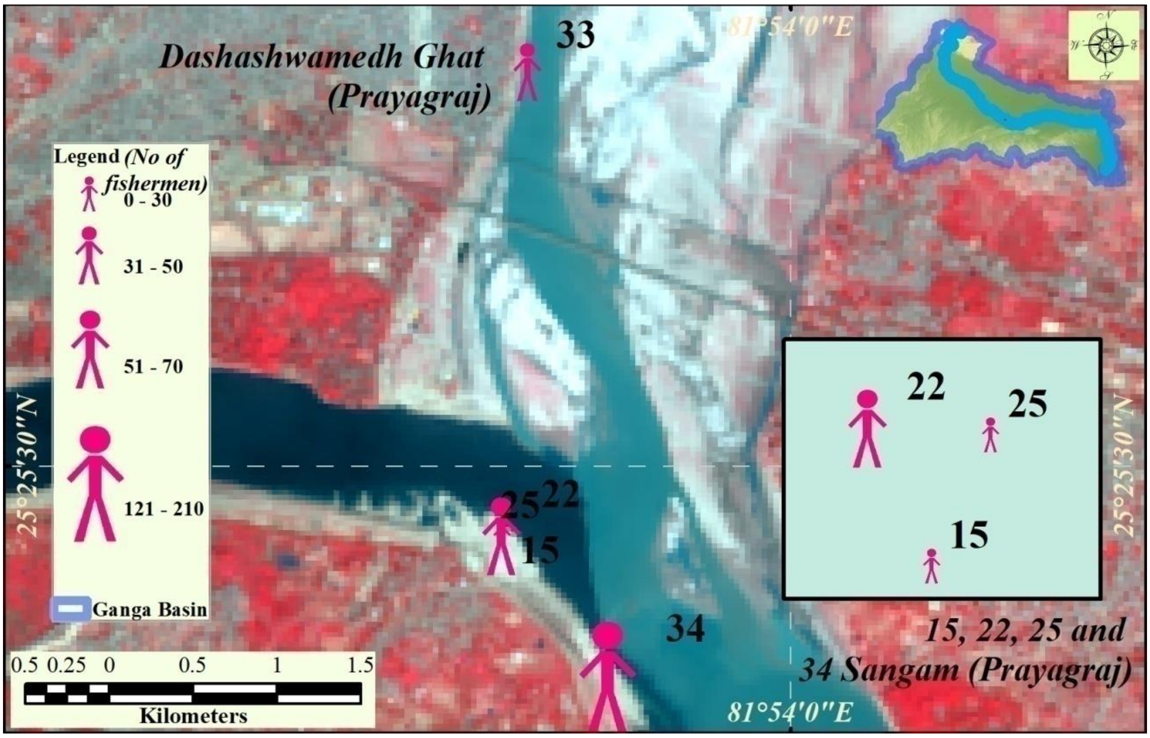


Fig. 222d

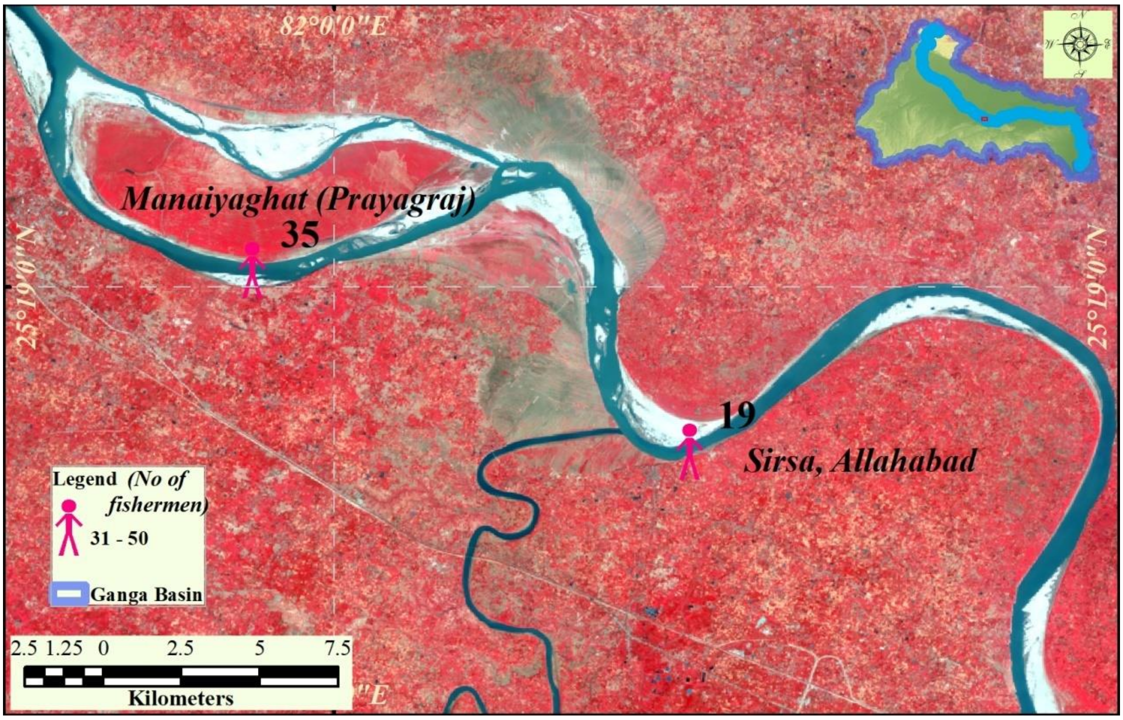


Fig. 222e

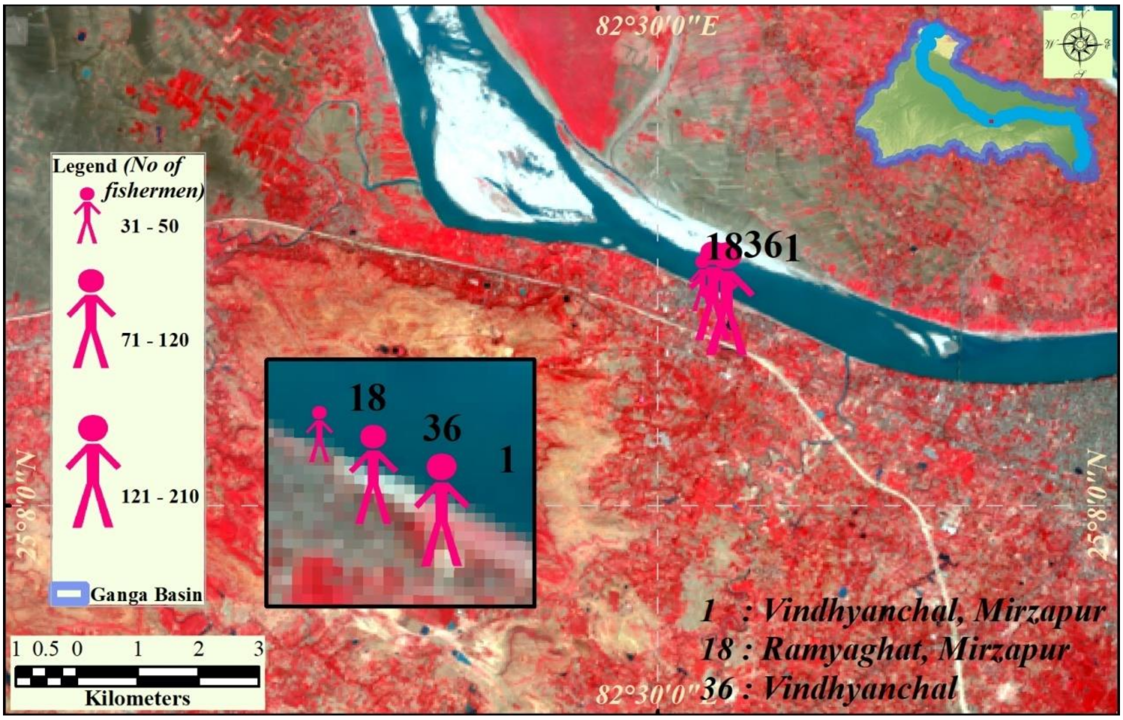


Fig. 222f

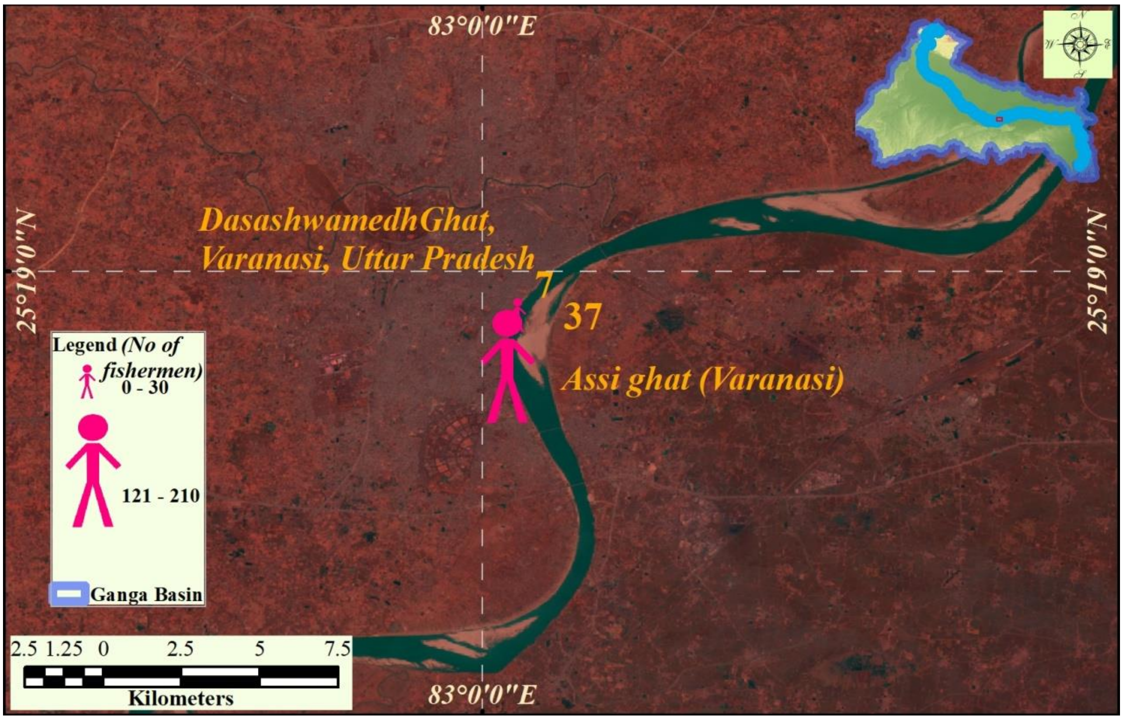


Fig. 222g

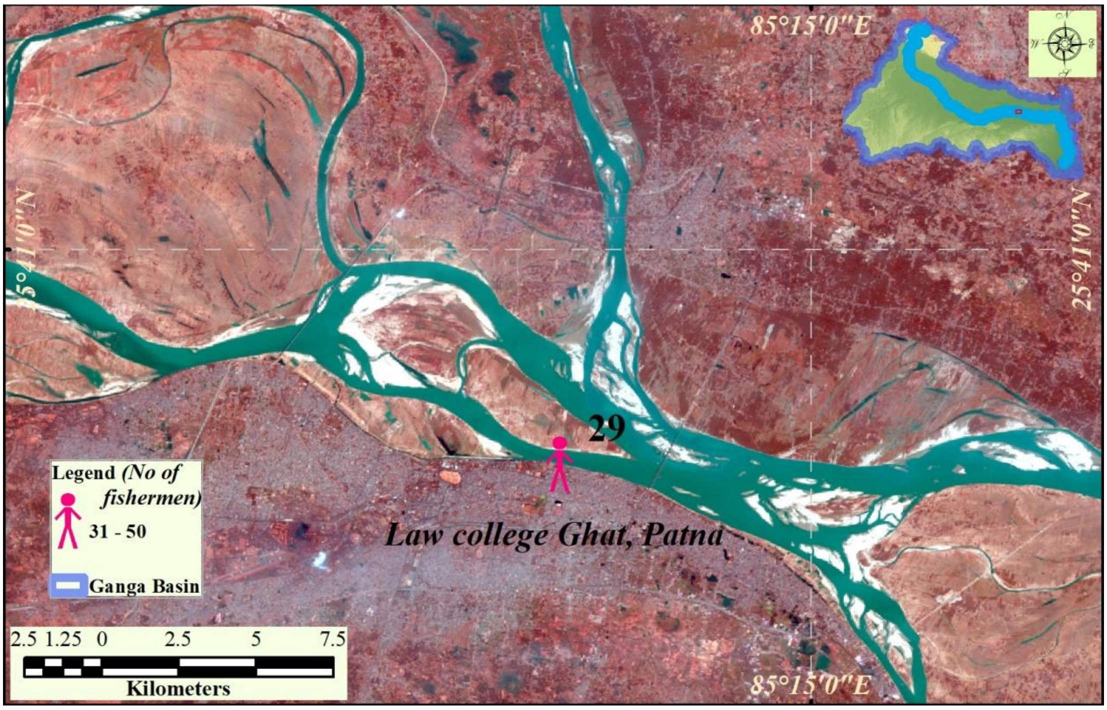


Fig. 222h

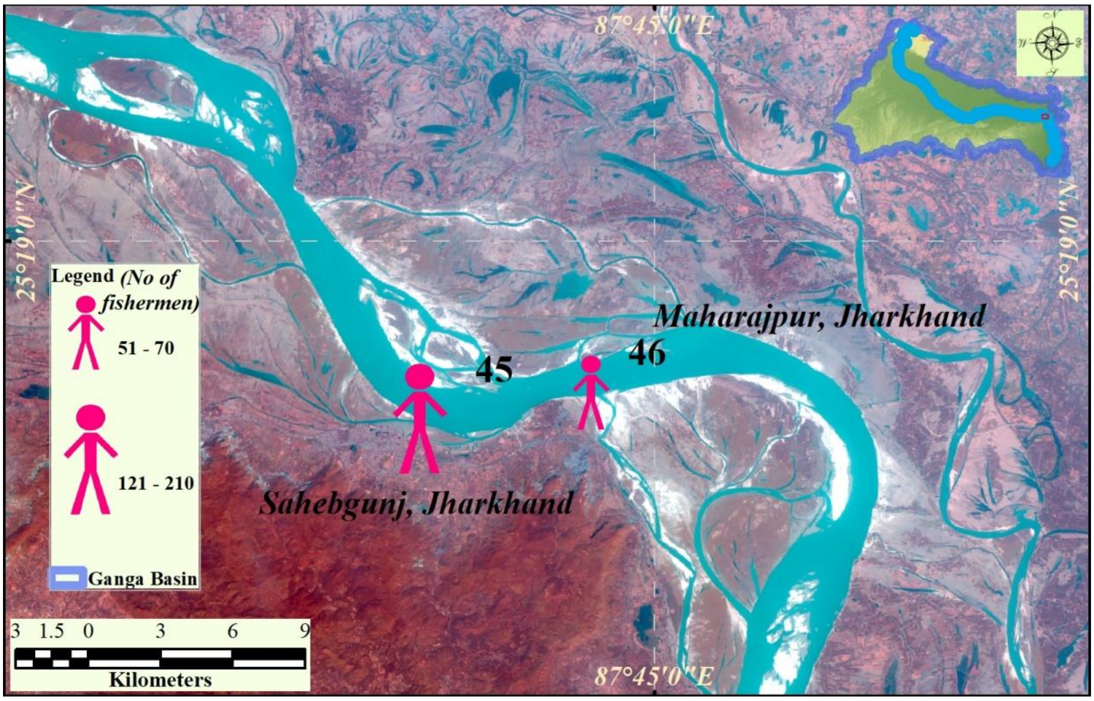


Fig. 222i

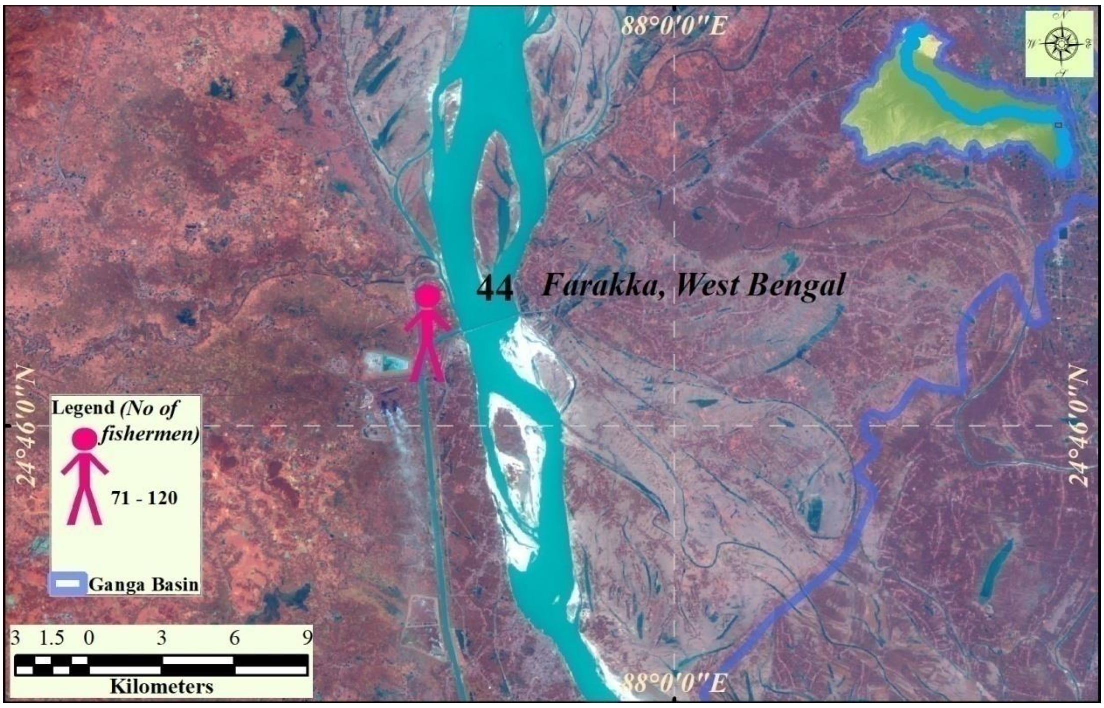


Fig. 222j

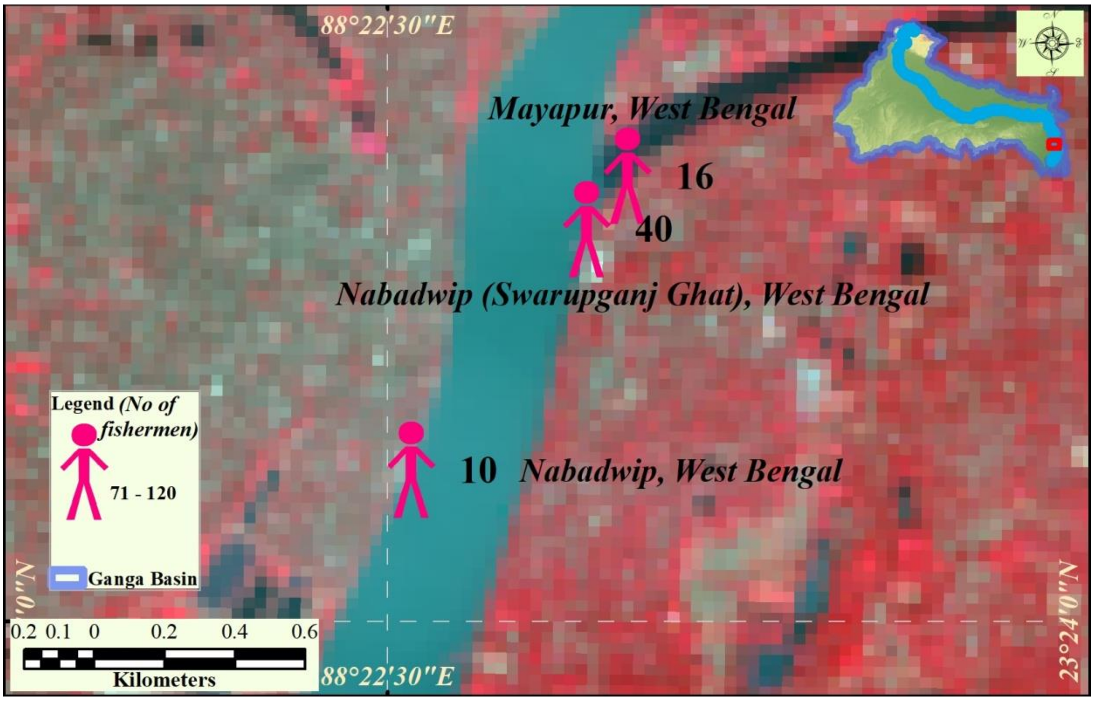


Fig. 222k

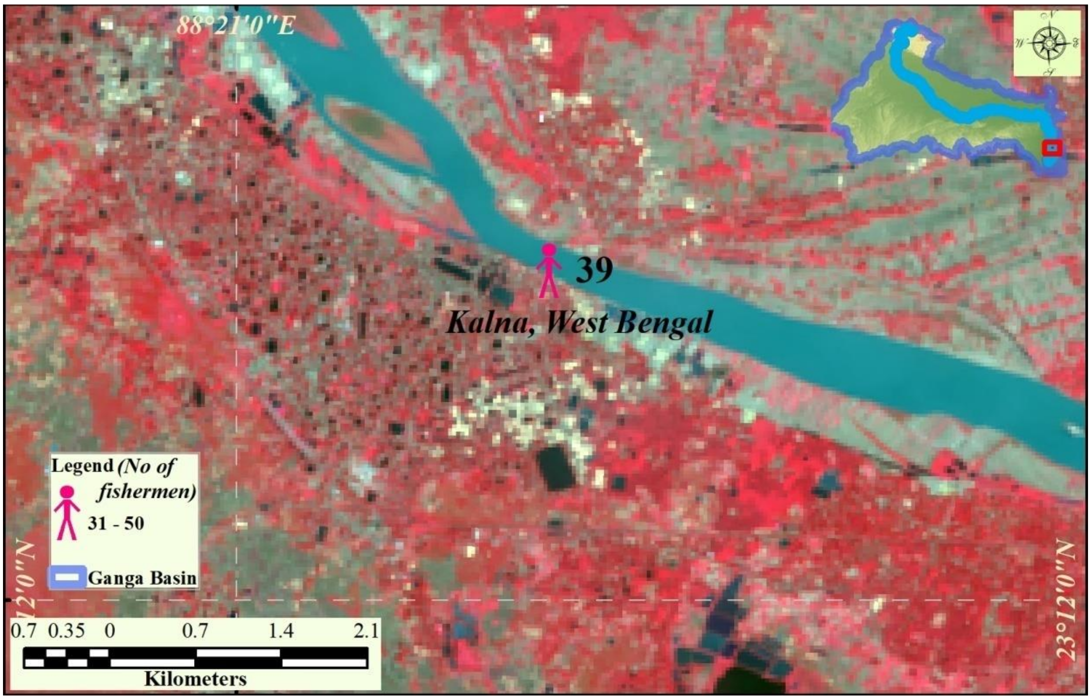


Fig. 222l

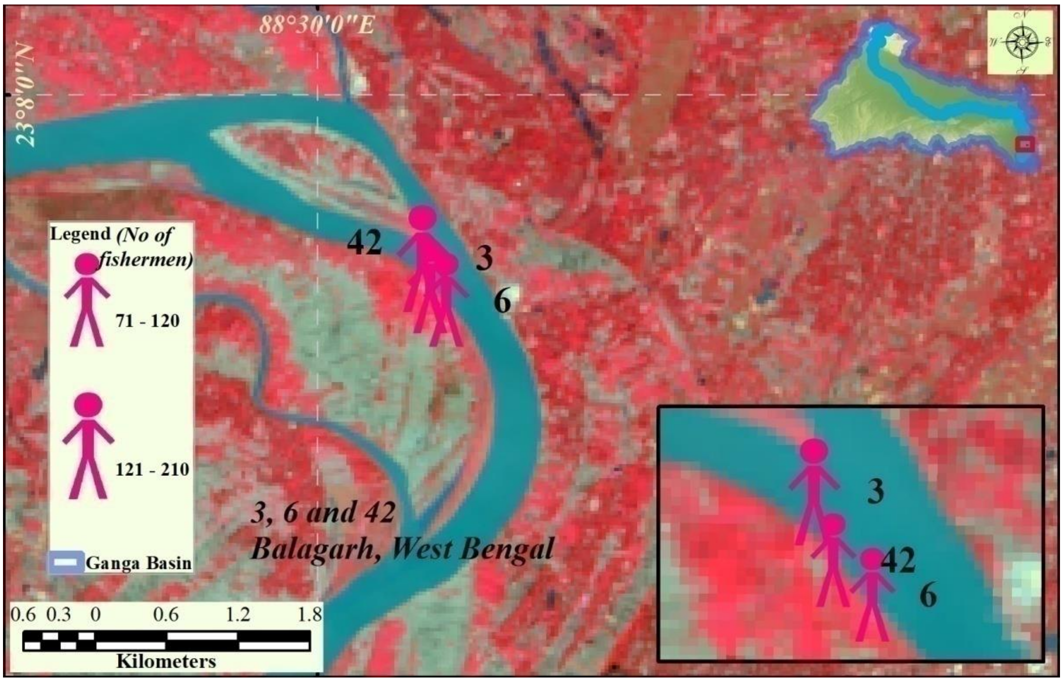


Fig. 222m

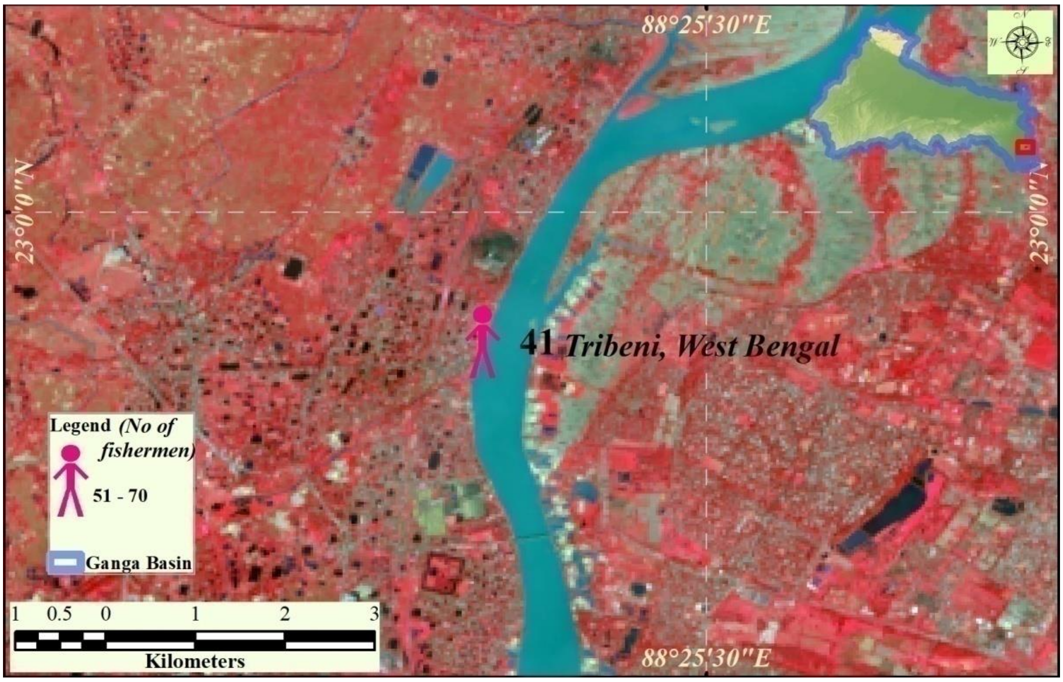


Fig. 222n

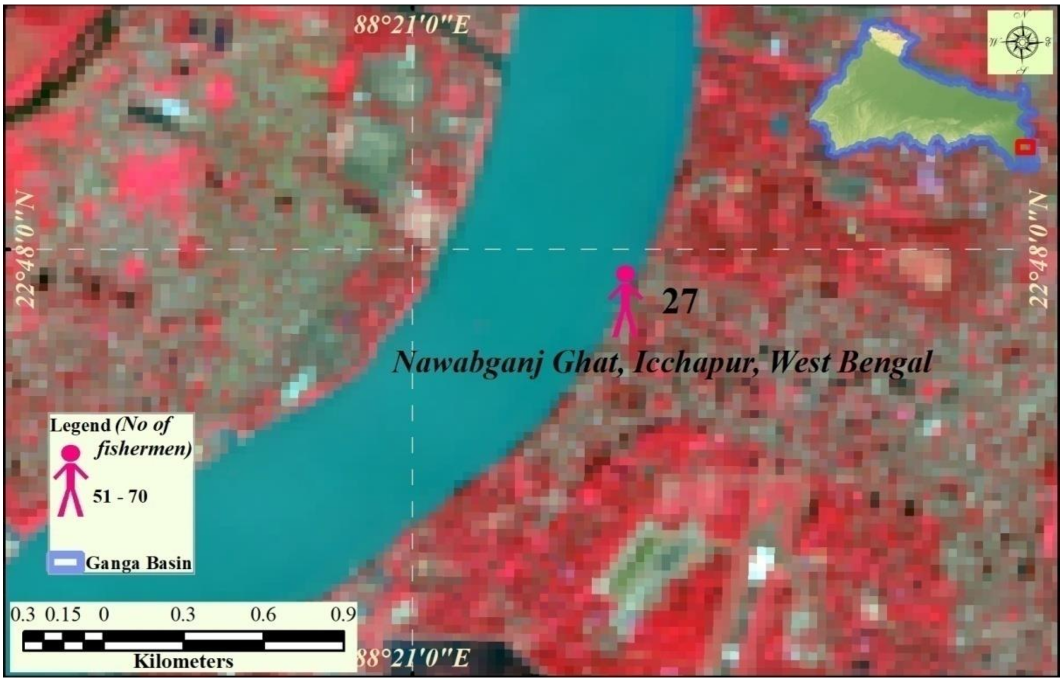


Fig. 222o

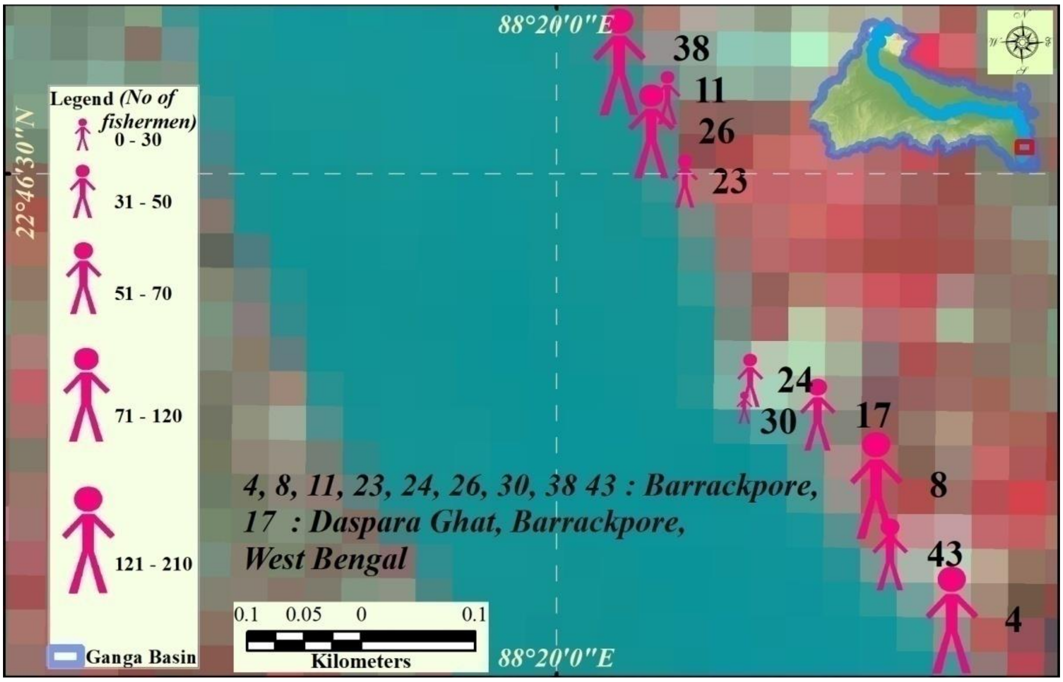


Fig. 222p

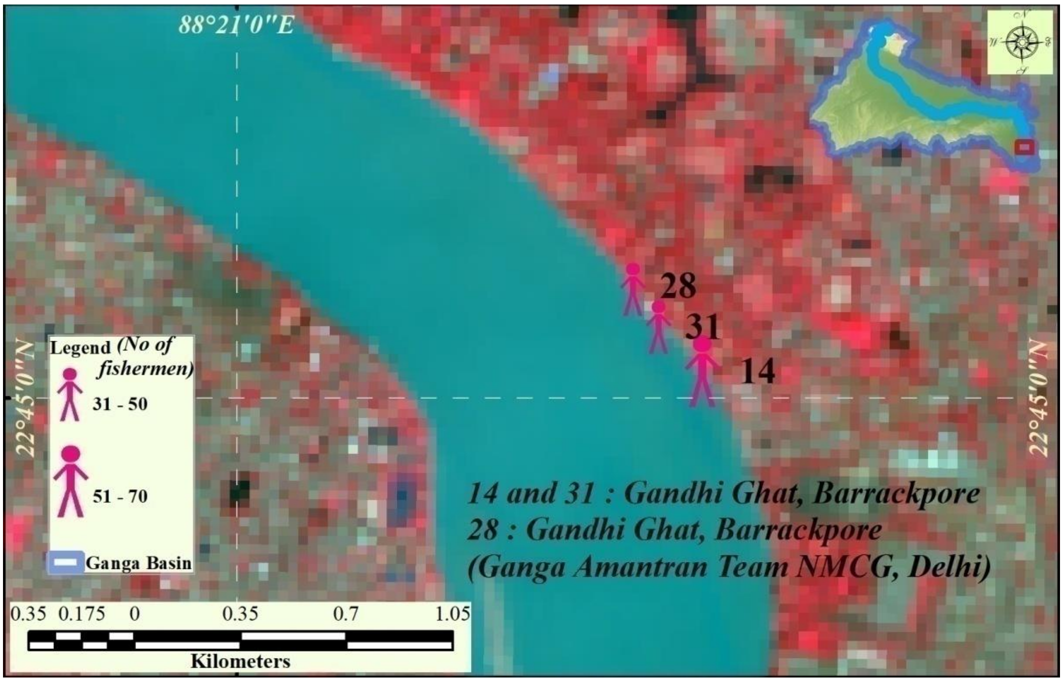


Fig. 222q

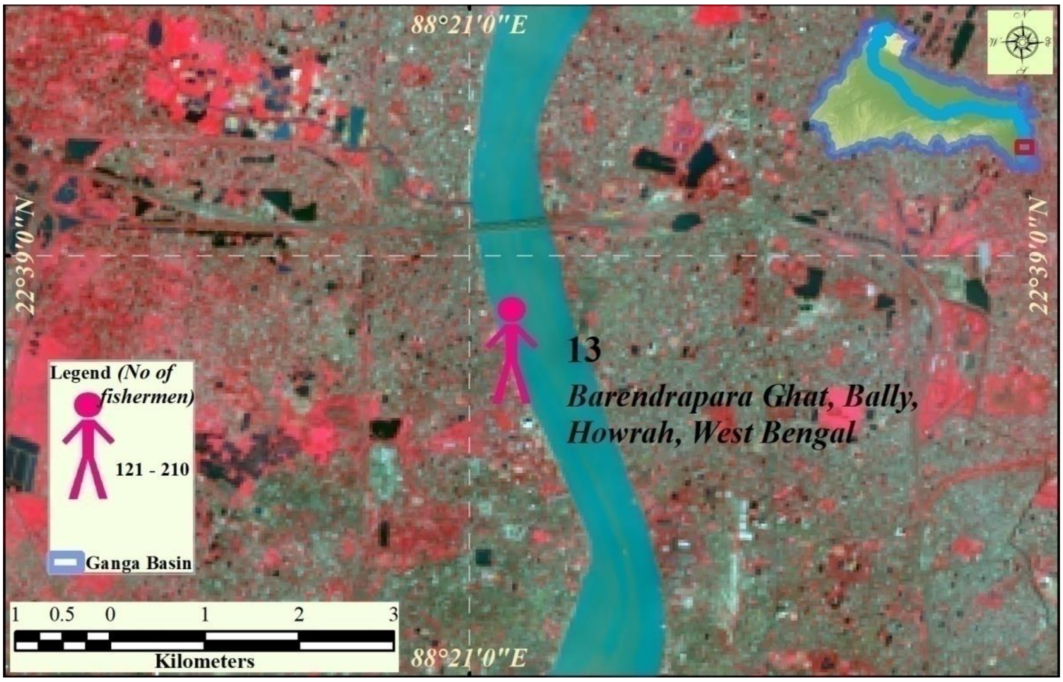


Fig. 222r

Fig. 222 a-r GIS Mapping of Awareness Campaign on Sustainable Fisheries and Conservation along Ganga River Stretch

Vindhyanchal, Mirzapur, Uttar Pradesh (21st March, 2016)

An awareness campaign was organized involving around 200 fishermen community at Malguda village, Vindhyanchal, Mirzapur district of Uttar Pradesh on 21stMarch, 2016. Interacted and suggested about controlling destructive fishing, choice of mesh size, fishing ban period to the fisher community. Campaign about cleanliness, Ganga pollution and fisheries enhancement involving poor fisher communities.

Awareness programme at Vindhyanchal, Mirzapur, Uttar Pradesh

Rishikesh; Uttarakhand (23rd May, 2017)

Awareness programme was organized at at Rishikesh along with ranching programmeand its likely implications on restoration and conservation of biodiversity in river Ganga focusing Mahseer and Trouts in hilly stretch was briefly described during the programme. Several non-governmental organizations, students from different universities, fishers of nearby areas and local fish traders attended the programme.

Rishikesh, Uttarakhand, 23rd May, 2017

Balagarh,West Bengal (22nd April, 2017)

Awareness programme was organized by ICAR-CIFRI, NMCG team at Milan dwip, Balagarh, West Bengal on 22nd April, 2017. An all of total 210 fishers were participated in the programme.

Balagarh,West Bengal, 22nd April, 2017

Barrackpore, West Bengal (26th May, 2017)

Honourable Union Minister of Water Resources, River development and Ganga Rejuvenation Sushri Uma Bharti ji visited ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, Kolkata on 26th May, 2017.

Barrackpore, West Bengal (26th May, 2017)

Prayagraj; Uttar Pradesh (1st August, 2017)

The event was attended by the students of from nearby University, fishers of nearby villages, fish traders of Sadiapur, Daraganj & Mehdauri and local people living on the bank of the Ganga and Yamuna. The event was graced by Hon. Minister of State (Dept. of Animal Husbandry and Fisheries) Shri Jai Prakash Nishad. Dr. B.K. Das, PI of the project, expressed his concern of recruitment over fishing of brooder stock during the breeding season and growth over fishing of the child of the fishes (fingerling) during raining season which in turn hampers biodiversity finally affecting the livelihood of fishermen community.Expressing their views, representatives from GangaVicharManch and several other NGOs suggested measures to reduce pollution and to increase the fishes in the river. During this process pamphlets known as “Ganga Ko Aviral Bahne Do” as a guiding principle to restore Ganga and livelihood of fishermen community was released by the Minister during programme.

Prayagraj; Uttar Pradesh (1st August, 2017)

Balagarh; West Bengal (03rd November 2017)

ICAR- Central Inland Fisheries Research Institute, Barrackpore under its mega project '*Namami Gange'* and under cooperation with SripurBalagarhMatsyajibi Cooperative Society (Balagarh, West Bengal) organized a mass awareness programme. Participation of more than 100 local fishermen for the sustainable development of aquatic life was the reflection. Besides stressing upon self-reliance of the fishers, Dr. Basanta Kumar Das (Principal Investigator) urged to utilize the invaluable resource of river Ganga by just adopting the conservation practices. He demanded more pro-activism and mentioned that Ganga fishery can only be restored through 'Community participation' where Govt. organizations and fishermen have to work together to achieve the goal. Local Member of Legislative Assembly (M.L.A) Mr. Ashim Majhi requested to avoid littering activities in river Ganga and highlighted that traditional practices should not be overpowered by prejudice.

Balagarh; West Bengal (03rd November 2017)

Varanasi; Uttar Pradesh (11th November, 2017)

ICAR-CIFRI organizedamass awareness camp at Dasaswamedh Ghat, Varanasi, Uttar Pradesh. Fishers were also awaked about the rising concerns of river pollution and their impacts on the ecosystem. Event was attended by large numbers of students and local people.

Varanasi; Uttar Pradesh (11th November, 2017)

Barrackpore; West Bengal (21st November, 2017)

ICAR-CIFRI has celebrated **'**World Fisheries Day'at Barrackpore on 21.11.2017. In this occasiona mass awareness programme has been organised at Daspara Ghat, Barrackpore under *Namami Gange* Project. Dr. D. K. De, renowned expert in Hilsa (*Tenualosa ilisha*) fisheries highlighted about construction of huge number of barrages/ dams causing water abstraction and thereby hindering migration of fishes. Director CIFRI mentioned about the importance of ranching which can increase fishers' income from rivers that can yield 'Green fish in Blue economy' and thereby improved livelihood of very poor fisher folks.

Barrackpore; West Bengal, 21st November, 2017

Sringverpur, Prayagraj (05th December, 2017)

Fish ranching and awareness programme organized by ICAR- CIFRI, Prayagraj Centre on 05.12.2017. 10000 nos. of IMC fingerlings were released in river Ganga. Mr. P. S. Pandey, Ex-MLA, U. P. graced the occasion and give his comments to the fishers who were present there.More than 50 fishermen community and six news papers including UNI, PTI, ANI participated in program.

Nabadwip; West Bengal (21st January, 2018)

The institute has performed ranching of 50,000 (Fifty thousand) seed of Indian Major Carp in river Ganga at Nabadwip, West Bengal. The entire event took place in the holy place at

Prachin Mayapur, Nidaya Ghat. Mr. Nibasi Ch. Das, Assistant Fishery Officer, Govt. of West Bengal requested fishers not to use zero mesh drag net and described about different Government schemes which may improve the livelihood of fishers who have to come forward to take advantages of those schemes. Mr. Pundarikakhya Saha, MLA, Nabadwip who visited the meeting site and extended his full support to the program. On his behalf, Mr. Sukumar Rajbanshi, local councilor, Nabadwip Municipality requeste the State and Central Govt. officials to take immediate measures to stop severe river bank erosion in the area. He requested fishers not to kill the released fishes immediately but allow them to growand breed so that, the fish stock can be restored.

Nabadwip; West Bengal (21stJanuary, 2018)

Barrackpore; West Bengal (15th March, 2018)

ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata celebrates its Platinum Jubilee for having completed its Glorious Presence. On this grand occasion, and to restore prized Major Carp fisheries of river Ganga, a total of 50,000 (fifty thousand) Rohu, Catla, Mrigal fingerlings have been released in the river at Barrackpore. The event was graced by number of eminent scientists and officials including Deputy Director General (Fy. Science) Dr. J. K. Jena, Padmashree Awardee & Dolphin man of India Prof. R. K. Sinha, Dr. Sandeep Behera, Consultant, Biodiversity, NMCG, New Delhiemphasized the need for ranching, conservation of wetlands in Ganga basin and conducting awareness programmes to sensitize the community living in the vicinity.

Barrackpore; West Bengal (15th March, 2018)

Prayagraj; Uttar Pradesh (27th March, 2018)

ICAR-CIFRI, Prayagraj conducted a mass awareness programme cum ranching of IMC seed in Ganga river at Fatepurghat on 27th March, 2018 under NMCG (National Mission for Clean Ganga) to restore and conserve the depleting fish stock in the river Ganga. A total of 20,000 (twenty thousand) advanced fingerling of IMC seed were ranched in the river. Dr. R. S. Shrivastava, Head of the division, ICAR-CIFRI, Prayagraj enlightened the different causes for the depleting of fish diversity of the river Ganga to the different fishers of the region. The fishers were informed about the ranching programme which is an important component of NamamiGangeprogramme. Scientist–fishers interaction was held in the event. More than 60 fishers participated in the programme.

Prayagraj; Uttar Pradesh (27th March, 2018)

Bally; West Bengal (05th September, 2018)

Ranching cum awareness campaign was organized on 5th September, 2018 at Barendrapara Ghat, Bally, Howrah, West Bengal. A total of 5 lakh fry of species like Rohu, Catla, Mrigal and Calbasu were ranched in the event.Dr. B. K. Das, Director of the Institute and Principal Investigator, CIFRI-NMCG project highlighted about the progress made by the institute under the project covering habitat data, biotic communities, fish diversity, stock assessment etc. He highlighted the need of ranching in river Ganga which in turn will ensure unremitting livelihood for the fishers encompassing the biodiversity and ecological integrity. On the occasion, Swami Atmapriyananda ji Maharaj, Vice Chancellor, Ramakrishna Mission Vivekananda Educational and Research Institute, Belur addressed the gathering. He stated that the preaching's of Swami Vivekananda regarding the purity of our Holy River Ganga. He said purity of the river will sustain only if we can make a coordinated approach. Swami Girashananda ji Maharaj, Manager, Ramkrishna Matha and Ramkrishna Mission, Belur Math, delivered the presidential address on the event. Giving credit to the efforts of Central Inland Fisheries Research Institute, Swami ji reckoned about the ongoing degrading situation of the holy river and urged the local people to initiate active coordination.

Ranching at Bally Ghat, West Bengal

Barrackpore; West Bengal (02nd October, 2018)

To commemorate 150th Birth anniversary of Mahatma Gandhi, and as a part of NamamiGange initiative ICAR-CIFRI created a fish ranching programme on 2nd October, 2018 at three consecutive Ganga ghats (Seoraphully, Mangal pandey and Gandhi ghat) at Barrackpore, Kolkata, West Bengal. On the occasion, Shri Nabin Naik, Director,NeheruYuva Kendra Sangathangraced the event as a guest. As a part of the event, total of 2.8 Lakhs of fingerling of Rohu, Catla, Mrigal were released in river Ganga in different adjacent ghats. Bilingual pamphlets were distributed among the local fishermen & were awared regarding the rising concern.

Ranching cum awareness programmeat Bally Ghat, West Bengal.

Sangam, Prayagraj(02nd October, 2018)

Ranching cum awareness campaign was organized on 02nd October, 2018. Five thousand of IMC (Rohu, Catla and Mrigal) seed were ranched in river Ganga on this programme.

Mayapur, West Bengal (06thNovember, 2018)

ICAR-Central Inland Fisheries Research Instituteorganized a river ranching cum fishermen awareness programme on 6th November, 2018 at Swarupganj Ghat, Nabadwip, Nadia,West

Bengal under the ‘NamamiGange’ programme.As a part of the programme, 03 lakhs seed offishes like Calbasu, Mrigal&Rohuwere released in the river Bhagirathi (Ganga) in front of the holy ISKCON temple, Mayapur.Theprogrammewas attended by more than 150local active fishermen and their family members. The event was well covered by several local print media and electronic media. As a part of the programme, 03 lakhs seed of fishes like Calbasu, Mrigal & Rohu were released in the river Bhagirathi (Ganga) in front of the holy ISKCON temple, Mayapur.

Mayapur, West Bengal (06th November, 2018)

Barrackpore, West Bengal (20th November,2018)

A ranching cum awareness programme was organized on the occasion of **World Fisheries Day** at Daspara Ghat, Barrackpore, West Bengal on 20th November, 2018. As a part of this programme 02 lakh IMC fingerling were released in river Ganga. Shri Nabin Naik, Director, Neheru Yuva Kendra Sangathan was expressed his view in fisheries of river Ganga to the fishers.

Ranching at Barrackpore, West Bengal

Ramayaghat, Mirzapur (26th November,2018)

Another fish ranching programme at Ramayaghat, Mirzapur was conducted on 26th November 2018. 10000 IMC (Rohu, Catla, Mrigal) were released in river Ganga. Dr.Varshi, DDF, Govt. of U.P. was preset in this occasion and aware the fishers about the fish & fisheries of river Ganga.

Sirsa, Prayagraj (04thDecember, 2018) &Karaghat, Kousambi, Prayagraj (05th December, 2018)

Concurrence ranching cum mass awareness program at Sirsaghat (Prayagraj) and Kade dham ghat (Kaushambi), Uttar Pradesh was organized on 4th and 5th December, 2018 respectively. A total of 30000 advance Indian Major Carp (Rohu, Catla& Mrigal) fingerlings were ranched in the river Ganga with wide mass media coverage. Mr. M. N. Pathak, Ret. Principal, Sirsa Inter College delivered his valuable comments on fish and fisheries of river Ganga at Sirsaghat.

Sirsa, Prayagraj, 04th December, 2018

Awareness Programmeon the occasion of Kumbh mela-2019 in Prayagaraj (26.02.2019)

Honourable Member of Parliament and chairperson of Parliamentary committee on Official Language, Shri Prashanna Kumar Patshaniji released high quality wild stock fish seed of IMC into the river Ganga. While his visit to Kumbh mela-2019 in Prayagaraj on special invitation to grace the occasion of ranching cum mass awareness programme on 26th February, 2019 organized by ICAR-Central Inland Fisheries Research Institute, Prayagraj addressed the wide spectrum of audience and stakeholders devoted to cause of Mission NamamiGange and rejuvenation of river Ganga.

Awareness Programme at Kumbh Mela, Prayagraj (15th January to 4th March 2019)

In the presence of Honourable Minister Mr. Nitin Gadkari (Ministry of Water Resources, River development and Ganga Rejuvenation, Govt. of India) ranching cum awareness progrmme was conducted in the event of Kumbh Mela, 2019 at Prayagraj.

Kumbh Mela, Prayagraj, 15th January to 4th March 2019

Barrackpore, West Bengal (15.03.2019)

A total of 10,000 juveniles of Indian Major Carp were ranched in river Ganga at Barrackpore, West Bengal on 15.03.2019.

Barrackpore, West Bengal, 15.03.2019

Awareness campaign on the occasion of Matsya Samriddhi Mela & CIFRI Foundation Day celebration at Barrackpore, West Bengal (17.03.2019)

17th March, 2019 marked the 73rd Foundation Day of the Institute. On this occasion a total of 50000 IMC seeds were released in River Ganga at Ghatak para Ghat, Barrackpore, West Bengal on 17.03.2019.

Barrackpore, West Bengal, 17.03.2019

Awareness Programme at Sangam, Prayagraj (29.03.2019)

Ranching cum mass awareness program was organized at Sangam (Prayagraj) on 29th March, 2019. A total of 15000 advance IMCs fingerlings were ranched in the river Ganga.

Sangam, Prayagraj, 29.03.2019

Barrackpore, West Bengal (10.07.2019)

A river ranching programme and mass awareness campaning was organised by ICAR-CIFRI, Barrackpore on the occassion of National Fish Farmers Day at Daspara Ghat, Barrackpore.More than 100 fishers, entraprenures participated from West Bengal, Bihar , Jharkhand & Madhya Pradesh.

Nawabganj Ghat, Icchapur, West Bengal (27.07.2019)

A ranching cum awareness programme was organized at Nawabgunj Ghat, Ichapur, West Bengal on 27th July, 2019. Dr. C. Vasudevappa,Vice Chancellor, NIFTEM, Haryana and other dignitaries, were expressed their views in fisheries of river Ganga to the fishers.

Nawabganj Ghat, Icchapur, West Bengal 27.07.2019

Gandhi Ghat, Barrackpore (Team NMCG, Delhi) (10.11.2019)

ICAR-CIFRI along with NMCG expedition team, *'Ganga Amantran'* performed a river ranching programme at Gandhi Ghat, Barrackpore.

Gandhi Ghat, Barrackpore (Team NMCG, Delhi) (10.11.2019)

Law college Ghat, Patna (20.11.2019)

ICAR-CIFRI , Barrackpore with the support from Department of Fisheries, Govt. of Bihar performed a river ranching programme at Law College Ghat, Patna, Bihar. The programme was attended by several officials from state fisheries department including Mr. V. S. Gunjiyal, Director of Fisheries, Bihar. The event was attended by more than 50no. Of local fishermen.

Law college Ghat, Patna (20.11.2019)

Barrackpore, West Bengal (12.12.2019)

A ranching cum awareness programme was organized at Daspara Ghat, Barrackpore, West Bengal on 12th December, 2019. Dr. Huang Jie, Director General, Network of Aquaculture Centres in Asia-Pacific and other dignitaries, were expressed their views in fisheries of river Ganga to the fishers.

Barrackpore, West Bengal (12.12.2019)

Gandhi Ghat, Barrackpore (26.01.2020)

On the occassion of 71st Republic Day, ICAR-CIFRI under NMCG project organised mass awareness campaign at Gandhi Ghat, Barrackpore, West Bengal on 26.01.2020.

Narayani Ashram, Prayagraj (28.01.2020)

A huge & productive mass awareness generation among local fishers was organised beside the Ganga river bank at Narayani Ashram, Prayagraj on 28.01.2020

Dashashwamedh Ghat (Prayagraj) (06.02.2020)

A Hindi leaflet on riverine ranching was released during the awareness programwith a huge and productive mass awareness generation with local fishers residing beside the Ganga river bank, students and several Magh Mela pilgrims on 06.02.2020.

Dashashwamedh Ghat (Prayagraj) (06.02.2020)

Sangam (Prayagraj) (11.02.2020)

A mass awareness campaign was organised at *Sangam Nose (Ganga river & Yamuna river confluence point),* Prayagrajon 11th February 2020.Mr. Atharv Raj, NMCG, Ministry of Jal Shakti, Govt. Of India was the chief guest of this program. Mr. Rajesh Sharma (Ganga VicharManch), Mr. Sanjay Mamgai (Zonal Ofiicer), Mr. K. P. Upadhaya, Dr. Nityanand Pandey & Delegates of Ganga Prahari, WWI, Dehradun, Uttrakhand were also participated in this program. Two Hindi leaflets on *Fish diversity* & *Contibution of women in fisheries and optional earning* was released during the programme.

Sangam (Prayagraj) (11.02.2020)

Manaiyaghat (Prayagraj) 25.02.2020

A mass awareness campaign was organised at *Manaiya Ghat*, Jhunsi, Prayagraj on 25th February 2020.Dr. S.C. Tiwari, Pro. Vice chancellor, Nehru Gram Bharti Deemed University (NGBU), was the chief guest of this program He released a Hindi leaflet on Golden Mahseer: An effort toward Conservation. During this occasion Prof. Ramkripal (Dean Science, NGBU), Dr. AsishShivam (Head Zoology Department, NGBU) were also present. Several Students of NGBU, Fishermen (residing along the Ganga River) were also participated in this programme.

Manaiyaghat (Prayagraj) 25.02.2020

Vindhyanchal 29.02.2020

A mass awareness campaign was organised at *Divan Ghat*, Jhunsi, Prayagraj on 29th February 2020. Dr. K.W. Warsi, Deputy Director, Fisheries Department, Uttar Pradesh was the chief guest of this program He released a Hindi leaflet on Phytoplankton - A Source of Oxygen in Riverine ecosystem. Fisheries inspector Mirzapur, Mr. Sarang was also present in this program. Several other staff of fisheries department, Fishers, Pilgrims, Priest &river bank side Shopkeepers were also participated in this program.

Vindhyanchal 29.02.2020

Assi ghat (Varanasi) 05.03.2020

A mass awareness campaign was organised at on 5th March 2020 at *Assi Ghat,*Varanasi. Mr Ravindra Prasad (C.E.O.) Department of fisheries Govt. of Uttar Pradesh, Varanasi, chief guest ofthe program was aware to fisherman for the conservation and restoration of the river Ganga through valuable speech.

Assi ghat (Varanasi) 05.03.2020

Barrackpore, West Bengal 17.03.2020

A mass awareness campaign was organised at Barrackpore, West Bengal on the occasion of 74th Foundation Day on 17th March, 2020. The occasion was graced by Dr. (Smt) Vijayalakshmi Saxena, General President (Elected) of Indian Science Congress and Dr. Ashok Kumar Saxena, Former President of Indian Science Congress Association. The program was over all guided by Dr. B. K. Das, Director, ICAR-CIFRI and PI, NMCG project.

Dolphin awareness Week (11.06.2020 -15.06.2020)

Nabadwip, Kalna, Balagarh, Tribeni and Barrackpore were covered within a period of 7 days for the campaign. Local fishermen and stakeholders present in the program were sensitized about the various factors behind declining fish biodiversity as well as total fish catch from river Ganga like indiscriminate destruction of brooders and juvenile fishes through use of zero mesh destructive fishing gears and also asking for their active cooperation towards success of river ranching program for restoration of fishery of Indian major carps in Barrackpore stretch of River Ganga. Dr. B. K. Das, Director, ICAR-CIFRI and PI, CIFRI-NMCG project highlighted the importance of celebration of the day as it calls for sustainable fishery of open waters, conservation of aquatic biodiversity, restoration of fish habitat, etc. Ranching can increase fishers' income from rivers that can yield 'Green fish in Blue economy' and thereby improved livelihood of very poor fisher folks, he added. The event was successful and the efforts made by CIFRI under its National Mission for Clean Ganga Project (NMCG) was highly appreciated by both local authorities and fisher communities residing along close proximity of the river.

Farakka, West Bengal 23.09.2020

A mass awareness campaign wasorganised at Farakka, West Bengalon 23rd September, 2020. Shri D.S.G.S.S. Babji, Executive Director, NTPC, Farakka, West Bengal; Dr. B.K. Das, Director, ICAR-CIFRI, Barrackpore, Kolkata; Shri R.K. Singh, Superintending Engineer, Farakka Barrage Authority and Shri Sanjeev Kumar, Assistant Director, IWAI were present as the Special Guests on the occasion.

Maharajpur & Sahebgunj (Jharkhand) 24.09.2020

A mass awareness campaign was organised at Maharajpur & Sahebgunj, Jharkhand was conducted in presence of local fishers and fishermen Co- operative societies.

Maharajpur & Sahebgunj (Jharkhand) 24.09.2020

Table 54. List of Awareness programme

Sl No.	Date	Place	No of fishermen particicipated
01	21.03.2016	Vindhyanchal, Mirzapur, Uttar Pradesh	200
02	23.05.2017	Rishikesh, Uttarakhand	50
03	22.07.2017	Balagarh, West Bengal	210
04	26.05.2017	Barrackpore, West Bengal	150
05	01.08.2017	Narayani Ashram, Prayagraj	70
06	03.11.2017	Balagarh, West Bengal	100
07	11.11.2017	Dasashwamedh Ghat, Varanasi, Uttar Pradesh	30
08	21.11.2017	Barrackpore, West Bengal	150
09	05.12.2017	Sringverpur, Prayagraj	50
10	21.01.2018	Nabadwip, West Bengal	100
11	15.03.2018	Barrackpore, West Bengal	50
12	27.03.2018	Fatehpurghat, Kausambi Prayagraj, U.P.	60
13	05.09.2018	Barendrapara Ghat, Bally, Howrah, W.Bengal	150
14	02.10.2018	Barrackpore, West Bengal	60
15	02.10.2018	Sangam, Prayagraj	30
16	06.11.2018	Mayapur, West Bengal	100
17	20.11.2018	Daspara Ghat, Barrackpore, West Bengal	60
18	26.11.2018	Ramyaghat, Mirzapur	50
19	04.12.2018	Sirsa, Prayagraj	50
20	05.12.2018	Karaghat, Kausambi	30
21	08.02.2019	Prayagraj	100
22	26.02.2019	Sangam, Prayagraj	70
23	15.03.2019	Barrackpore	50
24	17.03.2019	Barrackpore	50
25	29.03.2019	Sangam, Prayagraj	20
26	10.07.2019	Barrackpore, West Bengal	100

27	27.07.2019	Nawabganj Ghat, Icchapur, West Bengal	70
28	10.11.2019	Gandhi Ghat, Barrackpore (Ganga Amantran Team NMCG, Delhi)	50
29	20.11.2019	Law college Ghat, Patna	50
30	12.12.2019	Barrackpore, West Bengal	50
31	26.01.2020	Gandhi Ghat, Barrackpore	50
32	28.01.2020	Narayani Ashram, Prayagraj	100
33	06.02.2020	Dashashwamedh Ghat (Prayagraj)	50
34	11.02.2020	Sangam (Prayagraj)	150
35	25.02.2020	Manaiyaghat (Prayagraj)	50
36	29.02.2020	Vindhyanchal	100
37	05.03.2020	Assi ghat (Varanasi)	150
38	17.03.2020	Barrackpore, West Bengal	200
39	11.06.2020	Kalna, West Bengal	50
40	12.06.2020	Nabadwip (Swarupganj Ghat), West Bengal	120
41	13.06.2020	Tribeni, West Bengal	70
42	15.06.2020	Balagarh, West Bengal	100
43	16.06.2020	Barrackpore, West Bengal	70
44	23.09.2020	Farakka, west Bengal	100
45	24.09.2020	Sahebgunj, Jharkhand	150
46	24.09.2020	Maharajpur, Jharkhand	70

WORKSHOPS, EXHIBITIONS, AND OTHER CELEBRATIONS

Interction Meeting of NMCG at ICAR-CIFRI

An interaction meeting of NMCG Project was organized at ICAR-CIFRI, Barrackpore from 26-27th May 2016. All the project team members from CIFRI (Regional Centre), Prayagraj participated in this meeting. Objective wise discussion was made to formulate technical activities along with detailed methodology. A five year activity schedule format was also developed encompassing the major components.

CIFRI-NMCG Project Launching Workshops

Shri Shyama Charan Gupta, Member of Parliament (M.P.), Prayagraj formally launched the programme and inaugurated the NMCG Research Centre and Laboratory set up under the project on 07.07.2016. The distinguished guest present on the occasion were Prof. U. C. Srivastava, General Secretary, National Academy of Sciences, Prayagraj; Dr. B. K. Dwivedi, Director, Bioved Institute, Prayagraj; Dr. S. P. Singh, Retired Head of Prayagraj Regional Centre of CIFRI. More than 95 participants including fishers, fish traders, serving and retired scientists of CIFRI, researchers, representatives of local institutions and students participated in the programme.

Prof. R. K. Kole, Head, Department of Agricultural Chemicals, Bidhan Chandra Krishi Viswavidyalaya and a renowned researcher on ecology and pollution of River Ganga was the Chief Guest in the program at CIFRI, Barrackpore. Dr. M. K. Das, Former Head, FREM Division, CIFRI and a noted scientist with significant contribution on Ganga fisheries research was present in the program as Guest of Honour. More than 80 participants including Ganga researchers, scientists, technical officers, students, etc. were present in the workshop. A laboratory was inaugurated as "Namami Gange Fish Research Centre' at the ground floor of the main building of CIFRI HQ during the occasion. Local print media gave adequate coverage to the activities of the programme.

Launching workshop of NMCG project at CIFRI, Prayagraj Centre

Inauguration of 'Namami Gange Fish Research Centre' at Prayagraj

Launching program at ICAR-CIFRI HQ, Barrackpore

Workshop on '*Biodiversity of river Ganga and its Conservation for Sustainable Fisheries*'

ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata celebrates its Platinum Jubilee for having completed its Glorious Presence. On this momentous milestone of the institute a workshop on '*Biodiversity of river Ganga and its Conservation for Sustainable Fisheries*' was organized on 15th March at CIFRI, Monirampore, Barrackpore under the 'Namami Gange' programme, for holistic fisheries development of river Ganga. As a comprehensive approach to restore prized Major Carp fisheries of river Ganga, a total of 50,000 Rohu, Catla, Mrigal fingerlings have been released in the river at Barrackpore. The event was presided over by Hon. Deputy Director General of Fishery Science (ICAR) Dr. J. K. Jena. Many renowned experts including Padmashri awardee Professor (Dr.) R. K. Sinha and Biodiversity expert (NMCG) Dr. Sandeep Behera have exchanged their views for sustainable biodiversity including fisheries of river Ganga. The event was attended by number of eminent scientists, students and research scholars.

Dignitaries on the dais

Prof. Dr. R.K. Sinha delivering on diversity of river Ganga

Dr. J. K. Jena, DDG (Fy.) ICAR delivering on present health of River Ganga

Dr. B. K. Das, Director &PI,CIFRI-NMCG project delivering on ongoing project activitiesat the event

Participants in the Workshop

CIFRI-NMCG Project in Exhibitions

Several exhibitional campaigns have been perormed by ICAR-CIFRI under the present Namami Gange project. A total of9exhibitions have been successfully completed so far with details as mentioned below.

Table 55. Exhibition details conducted under CIFRI NMCG project

Sl no.	Place	Exhibition	Year
01.	Science City, Kolkata, West Bengal	International Conference on Aquatic Resource and Sustainable Management	2016
02.	ICAR- CIFRI, Barrackpore, West Bengal	Visit of Sushree Uma Bharati ji, Minister	2017
03.	ICAR- CIFRI, Barrackpore, West Bengal	29th All India Congress of Zoology (AICZ)	2017
04.	Sunderban, West Bengal	Sunderban Kristi Mela	2018
05.	Prayagraj, Uttar Pradesh	Kumbh Mela	2019
06.	ICAR- CIFRI, Barrackpore, West Bengal	MatsyaSamridhi Mela & 73rd Foundation Day of ICAR-CIFRI	2019
07.	New Delhi	Ganga Utsav 2019	2019
08.	ICAR- CIFRI, Barrackpore, West Bengal	**Visit of ‘Ganga Amantran’, NMCG Expedition team**	2019
09.	Sunderban, West Bengal	Sunderban Kristi Mela	2019

Details of the exhibitions are given below

1. **CIFRI-NMCG pavilion in International Conference on Aquatic Resource and Sustainable Management held at Science City, Kolkata**

   ICAR-CIFRI, Barrackpore displayed posters related to different aspects of river Ganga with an emphasis of fish and fisheries in the pavilion allotted to NMCG in International Conference on Aquatic Resource and Sustainable Management held at Science City, Kolkata during 17-19th February, 2016. The displayed posters included (i) The Ganga river: water quality and fisheries; (ii) Riverine ecology and fisheries; (iii) Invasion of exotic fishes in the river Ganga; (iv) Fishes of river Ganga; (v) River Ganga at a glance; (vi) NMCG project on restoration of Ganga fisheries (vii) Existing fishes of the Hooghly estuary; (viii) Fish and Fishery of river Ganga; (ix) Management of Hilsa fisheries; (x) Temporal changes in fish landing of river Ganga at Prayagraj. CIFRI publications (books, bulletins, leaflets etc) on river Ganga and its tributaries like Yamuna including estuarine zone of river Ganga *i.e.* Hooghly-Matlah estuary and Sundarban were also displayed in the stall. The pavillion was visited by almost all the participants of the conference. Visitors included Mr. Rabiranjan Chattopadhyay, Minister for the departments of Technical Education and Training, Science and Technology and Biotechnology, Government of West Bengal; Dr. J. K. Jena, Deputy Director General (Fisheries), ICAR, New Delhi; Dr. Saptarshi Biswas, Deputy Director, Dept. of Fisheries, Govt. of West Bengal; Prof. Rakesh K. Bhagat, Tribhuvan University, Nepal; Prof. Wing-Keong Ng, University Saina, Pennang, Malaysia, Dr. Krishna Das, University of Liege, Belgium; Dr. Binoy K. Chakraborty, Bangladesh etc. Distinguished professors, researchers, scholars of different Indian Universities, Institutes, colleges, etc also visited the NMCG pavilion and acknowledged the values of posters / publications describing different aspects of river Ganga. There is very high demand of several posters and books by the visitors who have placed their indent for those publications related to Ganga. Books /posters describing fish diversity with fish photo were having more demand by the visitors. Most of the visitors expressed their satisfaction after going through ‘highly informative’ posters and publications related to River Ganga.

Mr. Rabiranjan Chattopadhyay,
Minister, Government of West Bengal, India
visiting NMCG stall

Dr. J. K. Jena, DDG (Fy) with Dr. V. R. Suresh, Director, CIFRI; Dr. B. K. Mahapatra, In-charge, CIFE Reg. centre, Kolkata; Dr. P. P. Chakraborty, CIFA Reg. Centre, Rahara and other dignitaries in NMCG pavilion

Prof. N. C Dutta, noted educationist and Retd. Prof., University of Calcutta discussing some points in the poster

Smt. Kalyani Dutta, sister of Late Prof. Hiralal Chaudhuri, father of induced breeding in the NMCG stall

Visitors going through publications related to river Ganga and placing their requisitions

Displayed materials attracted large number of visitors to the NMCG stall

Dr. R. K. Manna, NMCG project team member describing the present status of river Ganga to the visitor

visitors of the NMCG stall is getting clarified about different aspect of fisheries of river Ganga

Mr. Raju Baitha, NMCG project team member answering to the queries of the visitors

Visitors placing their valuable comment and requisition for the displayed publications on Ganga

2. Exhibition on the occasion of visit of Sushri Uma Bharti ji to ICAR-CIFRI, Barrackpore

Former Honourable Union Minister of Water Resources, River development and Ganga Rejuvenation Sushri Uma Bharti ji visited ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, Kolkata on 26th May, 2017. She took part in river Ranching programme at Barrackpore and was briefed about the project activities. During her visit, she along with other NMCG offcials were enlightened about CIFRI-NMCG project activities through an exhibition.

Release of IMC fish seed by Hon'ble Minister, Sushri Uma Bharti ji in river Ganga at Barrackpore

Address by Hon'ble Minister, Sushri Uma Bharti ji to the Fishers of river Ganga during ranching program

Dr. B. K. Das, Director, ICAR-CIFRI showing exhibits related to river Ganga to the Hon'ble Minister

Address by Hon'ble Minister, Sushri Uma Bharti ji in the Auditorium of ICAR-CIFRI, Barrackpore

3. Exhuibition on the occasion of 29th All India Congress of Zoology (AICZ)

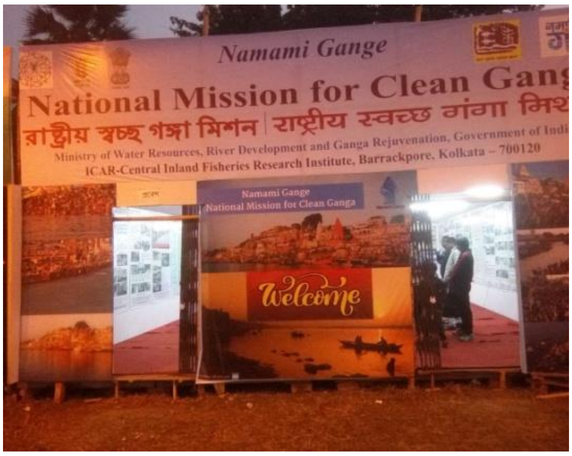
As a part of 29th All India Congress of Zoology (AICZ) held at ICAR- CIFRI, Barrackpore during 9th to 11th June 2017, NMCG project team had installed exhibition stall in the premises. The main purpose of the stall was to inform participants from different parts of India as well as abroad about the present condition of river Ganga and different activities carried by NMCG team in order to conserve and rejuvenate this river. Banners and posters describing the type of hook and line operating in Ganga, unique fishing practices like "Tuka-Feka", sustainability issues due to use of destructive gears like seine and bag net, invasion of exotics fishes and their adverse impact on indigenous fishes were displayed. A poster illustrating "Fish diversity of river Ganga" with their respective images of fish species draws attention of the viewers. Formalin preserved fish species, recorded from entire stretch of river Ganga provided value addition to our exhibition. Curiosity of the visitors on collaborative work of CIFRI and NMCG along with their positive feedback made our show a great success.

Dr. J. K. Jena, DDG (Fisheries), ICAR visiting NMCG Stall

CIFRI-NMCG project stall 'Namami Gange' in AICZ

4. **Exhibition at Sundarban Krishti Mela O Lokosanskriti Utsav from 20th Dec to 29th Dec 2018 at Kultoli, Sunderban (West Bengal)**

As a comprehensive part of the CIFRI-NMCG project entitled 'Assessment of fish and fisheries of the Ganga River System for Developing Suitable conservation and restoration plan', ICAR-CIFRI, Barrackpore has participated in the Exhibition at SundarbanKrishti Mela O Lokosanskriti Utsav from 20th Dec to 29th Dec 2018 at Kultoli, Sunderban (West Bengal) and displayed the exhibits in the 'National Mission for Clean Ganga' pavilion showcasingvarious ongoing activities of the institute under the project 'NAMAMI GANGE'.



NMCG CIFRI Pavillion at Sunderban Mela, 2018

Shri. Badaruddoza Khan at NMCG pavillion

Pavilion included various publication of NMCG describing overall activities by NMCG to make the river Ganga clean. The CIFRI NMCG pavilion was inaugurated by Honorable Member of Parliament (Lok Sabha) Shri. Badaruddoza Khan on 20th December, 2018. Further, the exhibition pavilion was also visited by Hon. Member of Parliament Smt. Shatabdi Roy on 22nd December, 2018. Giving credits to the efforts of ICAR-CIFRI, she interacted with the team regarding the ongoing activities. The exhibition witnessed the participation of several local dignitaries, school students and local people including fishermen communities. The pavilion has acquired **4th position** among the several other Governmental pavilions in the event.

Gathering at the pavillion

NMCG oath taking platform

Local fishermen at CIFRI-NMCG the stall

5. **CIFRI- NMCG project has participated in KUMBH MELA 2019 at Prayagraj, Uttar Pradesh**

   CIFRI- NMCG project personnel have participated in KUMBH MELA 2019 at Prayagraj, Uttar Pradesh. Pavilion represents the publication of NMCG and CIFRI activities to make the river Ganga clean. Mr. Nitin Gadkari, Hon. MIC, Ministry of Water Resources, River Development and Ganga Rejuvenation visited CIFRI pavilion in Kumbh MelaandofficiallyinauguratedGanga river ranching programme on this occasion. The pavilion was also visited by Hon. Health Minister of U.P., Mr. Sidharth Nath Singh, Mrs. Kanchan Gadkari and various other dignitaries.

Hon. MIC, Ministry of Water Resources, River Development and Ganga Rejuvenation at CIFRI pavilion in Kumbh Mela

Fish Ranching at Prayagraj in Kumbh Mela


Hon. Health minister (Govt. of U.P.) Mr. Sidharth Nath Singh at CIFRI pavilion in Kumbh Mela

CIFRI NMCG team at Kumbh Mela, 2019

6. Exhibition on the occasion ofMatsyaSamridhi Mela & 73rd Foundation Day of ICAR-CIFRI on 17th March 2019

CIFRI-NMCG project members displayed various project activities in NMCG pavilion during Matsya Samridhi Mela & 73rd Foundation Day of ICAR-CIFRI on 17th March 2019. The pavilion was visited by Prof. A. K. Saxena, Prof. Vijay Lakshmi Saxena, Prof. Amit Krishna De of Indian Science Congress and many other dignitaries. Numerous participants including fishers, students, common people also visited the pavilion and got enlightened about different conservation measures for restoration of fish and fishery of river Ganga.

NMCG Stall in Matsya Samridhi Mela

7. **CIFRI-NMCG project activities showcase in “Ganga Utsav 2019” at New Delhi**

‘Ganga Utsav’ is organized by NMCG to commemorate the declaration of river Ganga as “National River” and increase public awareness about peoples’ role in protecting the environment and rivers. In this occasion, “Ganga Utsav 2019” was celebrated on 04.11.2019 at New Delhi. The CIFRI exhibition stall portrayed different exhibits regarding Ganga fish and fisheries, fishing gears, books, pamphlets, posters etc. Visitors like school students, academicians, researchers were enlightened about the present threats to fish diversity and ways of sustainable management.

CIFRI pavilion in ‘Ganga Utsav 2019’

CIFRI pavilion in ‘Ganga Utsav 2019’

8. **Exhibition made at ICAR-CIFRI, Barrackpore during the visit of 'Ganga Amantran', the NMCG Expedition team**

An exhibition was displayredat ICAR-CIFRI, Barrackpore during the visit of 'Ganga Amantran' on 10.11.2019 to enlighten the NMCG Expedition team about CIFRI-NMCG project activities. A powerpoint presentation and a video was also shown to the honoured guests. During this occasion, a fish ranching programme was conducted at Gandhi Ghat, Barrackpore. Scholars and Scientists associated with the CIFRI-NMCG project and also Head of Divsions, ICAR-CIFRI have significantly contributed in the program.

Member of the 'Ganga Amantran' team in CIFRI were enlightened about CIFRI-NMCG project activities

9. **Participation in 24th Sunderban Kristi Mela o LokoSanskriti Utsav, 2019**

ICAR-CIFRI participated in 24th Sunderban Kristi Mela o Loko Sanskriti Utsav, 2019 from 20th to 29th December at Kultoli, Basanti, Dist.- South 24 parganas, West Bengal and displayed its present ongoing activities under NMCG project. The pavilion exhibits various publications, posters and models showcasing the activities. The exhibition witnessed participation from local dignitaries, school students and large numbers of local communities including fishermen. The CIFRI-NMCG project pavilion acquired 1st position among other exhibition stalls of the exhibition.

Children were being educated in CIFRI-NMCG pavilion at 24th Sundarban Kristi Mela-O-LokoSanskritiUtsab, 2019

CIFRI-NMCG project pavilion acquired **1st position** among 47 exhibition stalls in 24th Sundarban Kristi Mela-O-LokoSanskritiUtsab

Table 56. List of Workshop/Exhibition participated

Sl. No.	Year	Workshop/Exhibition	Approximate number of participants sensitized
01.	17.02.2016to 19.02.2016	Pavilion in International Conferenceon Aquatic Resource and Sustainable Management held at Science City, Kolkata	230
02.	07.07.2016	CIFRI-NMCG Project Launching Workshops	80
03.	26.05.2017	Exhibition at ICAR-CIFRI, Barrackpore	50
04.	9.06.2017 to 11.06. 2017	Exhibition on the occasion of 29th All India Congress of Zoology (AICZ)	200
05.	15.03.2018	Workshop on 'Biodiversity of river Ganga and its Conservation for Sustainable Fisheries'	150
06.	20.12.2018 to 29.12.2018	Exhibition at 23rd Sundarban Krishti Mela O Lokosanskriti Utsav	5000
07.	26.02.2019	Exhibition at KUMBH MELA 2019 at Prayagraj	1000
08	17.03.2019	Exhibition at MatsyaSamridhi Mela	500
09.	04.11.2019	Exhibition at Ganga Utsav 2019 at New Delhi	250
10.	10.11.2019	Exhibition at ICAR-CIFRI, Barrackpore	50
11.	20.12.2019 to 29.12.2019	24th Sundarban Kristi Mela o Loko Sanskriti Utsav, 2019	7000

Celebration of "*Ganga Vriksharopan Saptah*" on 31st July, 2017

The "*Ganga Vriksharopan Saptah*" was celebrated during 31st July, 2017 by ICAR-Central Inland Fisheries Research Institute, Barrackpore, West Bengal under NMCG project entitled '*Assessment of fish and fisheries of the Ganga River System for Developing Suitable conservation and restoration plan"* with main objective of restoration, rejuvenation and conservation of the Ganga River basin. The programme was inaugurated by Dr. B. K. Das, Director, ICAR-CIFRI and PI, CIFRI-NMCG project with planting sapling of a mango tree on the bank of river Ganga at Barrackpore. All the staffs of the institute participated in the programme and planted more than 300 saplings of Jack fruit, Java Plum (Jamun) and Mango tree on the river bank. The purpose of planting such tree saplings were to prevent soil erosion of river bank and contribute to the future benefits of the local people of Barrackpore by making environment healthy and prosper.

Planting of tree saplings near Ganga river bank

World Environment Day Celebration under NMCG Project

NMCG team of ICAR-Central Inland Fisheries Research Institute, Barrackpore celebrated World Environment Day on 5th June, 2017. In recent advances, various environmental problems like climate change, biodiversity loss, water scarcity, pollution etc. are posing major threat to our environment. The main aim of the celebration was to create awareness regarding importance of environment in our lives. The theme for world Environment Day 2017 was "Connecting people to nature". Theme based Rangoli was made depicting the role of organisms and their interaction in the ecosystem.

NMCG Team contributed to World Environment Day by creating awareness through onboard campaign on Hooghly River. The campaign was led by Dr. B. K. Das, PI-NMCG project. Different playcards and banners in Hindi, English and Bengali were made in accordance to reveal the importance of River cleanliness to the present and future generations. Playcards depicted with slogans which emphasize to keep water clean and healthy were displayed. Through mike and sound system people along the bank of river were advised to avoid garbages discharge into the river, to stop day to day habits like washing clothes, taking bath etc in river water and at the same time awared about the negative impacts of such habits or activities which is going to create serious health issues. The campaign was concluded by final remarks of PI of NMCG project who call upon to protect environment and explained that ecosystems are essential to human life as it provides goods and services upon which human welfare depends, which includes everything from clean air and water to food and fuel. All CIFRI staff participated in the campaign.

Awareness program in river Ganga at Barrackpore

Dr. B. K. Das, Director, CIFRI calls for peoples' participation for 'Clean Ganga'

PROJECT PUBLICATIONS AND MEDIA COVERAGE

Research Articles (in Journals)

1. Hari Om Verma, Sandeep Kumar Mishra, AbsarAlam, Shyamal Chandra Sukla Das, Venkatesh Thakur, Jeetendra Kumar, Dharma Nath Jha, Rama Shankar Srivastava, Basant Kumar Das. 2018.Length–weight relationships of *Johnius coitor* (Hamilton, 1822), *Osteobrama cotio* (Hamilton, 1822), and *Gonialosa manmina* (Hamilton, 1822), from the River Ganga. India. Journal of Applied Ichthyology, 34 (6): 1361-1363.
2. Kalpana Srivastava, D. N.Jha., Sandeep Mishra, Vijay Kumar, S. C. S.Das,AbsarAlam, R. S.SrivastavaandBasanta Kumar Das. 2020.Impact of Prayagraj Kumbh-2019 on water quality and plankton communities of the river Ganga. *Journal of Fisheries and Life Sciences*, 5(1):44-48.
3. Kalpana Srivastava, Sandeep Mishra,Hari Om Verma, Venkatesh R. Thakur, D. N. Jha, AbsarAlam and Basanta Kumar Das. 2020. Time scale changes of plankton in the river Ganga at Kanpur. *Journal of Entomology and Zoology Studies*, 8(5):1414-1419.
4. Absar Alam, Dharm Nath Jha, Sushil Kumar Verma, Hari Om Verma, Sandeep Kumar Mishra, Shyamal Chandra Sukla Das, Jeetendra Kumar, VenkateshRamaRao Thakur, Monika Gupta, Basanta Kumar Das.2020. Length–weight relationships of four small indigenous freshwater fishes from the subtropical Ganga River, India. Lake and Reservoirs: Science, Policy and management for sustainable use, 00:1–4.https://doi.org/10.1111/ lre. 12337.
5. DharmNath Jha, AbsarAlam, Shyamal Chandra Sukla Das, VenkateshRamarao Thakur, Jeetendra Kumar, Monika Gupta, Rama Shankar Srivastava,Basant Kumar

Das.2020. Chronological variation in landing of Indian Major Carp (IMC) of Ganga River. World Water Policy. 2020; 6: 142– 151. https://doi.org/10.1002/wwp2.12027.

6. Baitha, R., Karna, S. K., Ray, A., Chanu, T. N., Swain, H. S., Ramteke, M. H., & Das, B. K. (2018). Length–weight and length–length relationships of eight fish species from river Ganga, India. *Journal of applied ichthyology, 34*(4), 1052-1054.
7. Karna, S. K., Baitha, R., Ray, A., Mondal, A., Swain, H. S., Chanu, T. N. & Das, B. K. (2018). Length–weight relationships for *Eutropiichthys murius* (Hamilton, 1822), *Coilia reynaldi* Valenciennes, 1848 and *Johnius gangeticus* Talwar, 1991 from lower stretch of the River Ganga, India. *Journal of Applied Ichthyology*, *34*(5), 1251-1252.
8. Baitha, R., Ray, A., Karna, S. K., Chanu, T. N., Swain, H. S., Ramteke, M. H., & Das, B. K. (2018). Length–weight relationships for four fish species from lower stretch of River Ganga, India. *Journal of Applied Ichthyology*, *34*(5), 1195-1197.
9. Verma, H. O., Verma, S. K., Mishra, S. K., Alam, A., Das, S. C. S., Thakur, V., & Das, B. K. (2018). Length–weight relationships of *Johniuscoitor* (Hamilton, 1822), *Osteobramacotio* (Hamilton, 1822), and *Gonialosamanmina* (Hamilton, 1822), from the River Ganga, India. *Journal of Applied Ichthyology, 34(6),* 1361-1363.
10. Ray, A., Karna, S. K., Mohanty, T. R., Swain, H. S., & Das, B. K. (2019).Length–weight relationships of some fish from the Ganga River, India. Journal ofApplied Ichthyology, 35(4), 1050-1052.
11. Baitha R., Karna S. K., Ray A., Chanu T. N., Swain H. S., Ramteke M. H., Bayen S., Manna R. K. and Das B. K. (2018).Length–weight and Length–length relationships of eight fish species from river Ganga, India. Journal of Applied Ichthyology, 34(4): 1052-1054. DOI: 10.1111/jai.13698.
12. Kalpana Srivastava , Vijay Kumar, Venkatesh R Thakur, Sandeep Mishra, Susheel Kumar, D.N. Jha and R. S. Srivastava. 2019.Eco-status of Ramganga, Kali, Karmnasa, Yamuna, Ghagra and Gomti tributaries in middle stretch of river Ganga.*Journal of Fisheries and Life Sciences,* 4 (2): 17-21.
13. Ranjan Kumar Manna, Archisman Ray, Puspendu Samanta, Aprajita, Tuhin Subhro Bhowmik, Raju Baitha, Samir Kumar Paul, Sandeep Kumar Behera Basanta Kumar Das. *Baits pecificity in Hook and line fishery of River Ganga and associated conservation issues*. Indian Journal of Traditional Knowledge Vol 19(1), January 2020, pp 61-72
14. R. K. Manna, Archisman Ray, Puspendu Samanta, T. S. Bhowmik, Aprajita Singh, M. H. Munivenkatappa, M. H. Ramteke, Subhendu Mandal, S. K. Behera and B. K. Das

(2020) 'Tuka -Feka' Fishery-An Indigenous Fishing Practice to catch Indian Major Carps in Buxar-Balia Stretch of River Ganga, India. Fishery Technology 57: 221 – 223.

15. Basanta Kumar Das, Archisman Ray, Ranjan Kumar Manna, C. M. Roshith, Raju Baitha, Subodha Kumar Karna, Subhadeep Das Gupta and Manisha Bhor (2020). Occurrence of exotic vermiculated sailfin catfish Pterygoplichthys disjunctivus from the lower stretch of River Ganga, West Bengal, India. *Current Science,* Vol. 119, No. 12.

Popular article

1. R K Manna, Archisman Ray and Basanta Kumar Das 2019. Fishing gear of Hilsa in esturine stretch of river Ganga and associated conservation issues. Sanlap.

Published Book

Das B. K., Manna R. K., Bhor M., Srivastava R. S., Mohanty T. R., Swain H. S., Baitha R., Ray A. and Bayen S. 2020. Fish mapping of River Ganga: A GIS Perspective, ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata and National Mission for Clean Ganga, New Delhi,448p

Book chapters

1. बाएंन सुप्रीति, थांगजाम निरुपोदा चानू , दास बसंत कुमार, मन्ना रंजन कुमार, रे अर्चिष्मान, भोर मनीषा,दास गुप्ता सुभोदीप, तिवारी नितीश कुमार, मोहंती त्रुप्ती रानी, चक्रबोर्ती लोकनाथ और रामटेके मितेश हीरादा स.छारागंगा बील में मछलियों की बिबिधता और संरक्षण का अध्ययन . Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 140 Pp.

2. दास बी के, भोर मनीषा, मन्ना आर के, रे अर्चिष्मान, बाएंन सुप्रीति, तिवारी नितीश कुमार, दास गुप्ता सुभोदीप, पाल समीर कुमार, बैठा राजू आर जॉनसन कान्सिअल . गंगा नदी में मछली प्रजातियो की उपलब्धता और बितरण पर आधारित जी आई एस. Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 26 Pp.

3. रामटेके हिरदास हीरादास, स्वैन एच एस, बैठा राजू, साहू ए के, मीणा डी के, मन्ना रंजन कुमार, जॉनसन कान्सिअल, बेरा टी, चानू टी एन, दास गुप्ता ऐस, रे ए, बाएंन ऐस आर दास बी केगंगा नदी की जैब . संस्थान द्वारा एक पहल :बिबिधता और सतत मात्स्यिकी पालन के लिए संरक्षण . Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 180Pp.

4. रे अर्चिष्मान, दास गुप्ता सुभोदीप, मन्ना रंजन कुमार, बाएंन सुप्रीति, तिवारी नितीश कुमार,राय चौधुरी आशीष, स्वाइन हिमांशु शेखर और दास बसंत कुमारपातन जाल .' -हूगली मुहाने, पश्चिम बंगाल, के ताजा पानी की सीमा में एक अद्वितीय स्थापित अबरोधक थैला जाल .(सेट बैरियर बैग नेट) Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 197Pp.

5. मोहंती त्रुप्ती रानी, मन्ना रंजन कुमार, तिवारी नितीश कुमार, रे अर्चिष्मान, बाएंन सुप्रीति, दास गुप्ता सुभोदीप और दास बसंत कुमार गंगा नदी .,भारत के निचले हिस्से में एक बीशेष जेनेरा माइक्रोसिस्टिस समूह) के उल्ले (सयानोफैसि: Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 102 Pp.1.

6. बाएंनसुप्रीति, थांगजाम निरुपोदा चानू , दास बसंत कुमार, मन्ना रंजन कुमार, रे अर्चिष्मान, भोर मनीषा,दास गुप्ता सुभोदीप, तिवारी नितीश कुमार, मोहंती त्रुप्ती रानी, चक्रबोर्ती लोकनाथ और रामटेके मितेश हीरादास.छारागंगा बील में मछलियों की बिबिधता और संरक्षण का अध्ययन . Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 140 Pp.

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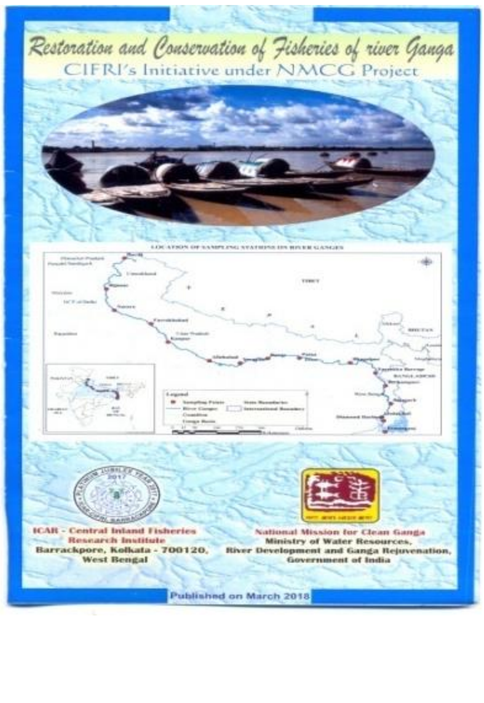
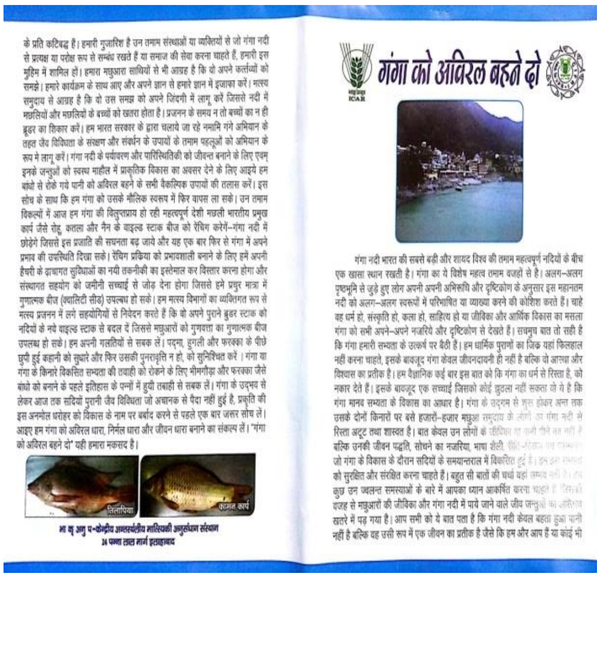
जेनेरा माइक्रोसिस्टिस .के उल्लेख (सयानोफैसि:समूह) Hindi workshop on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 102 Pp.

Pamphlet

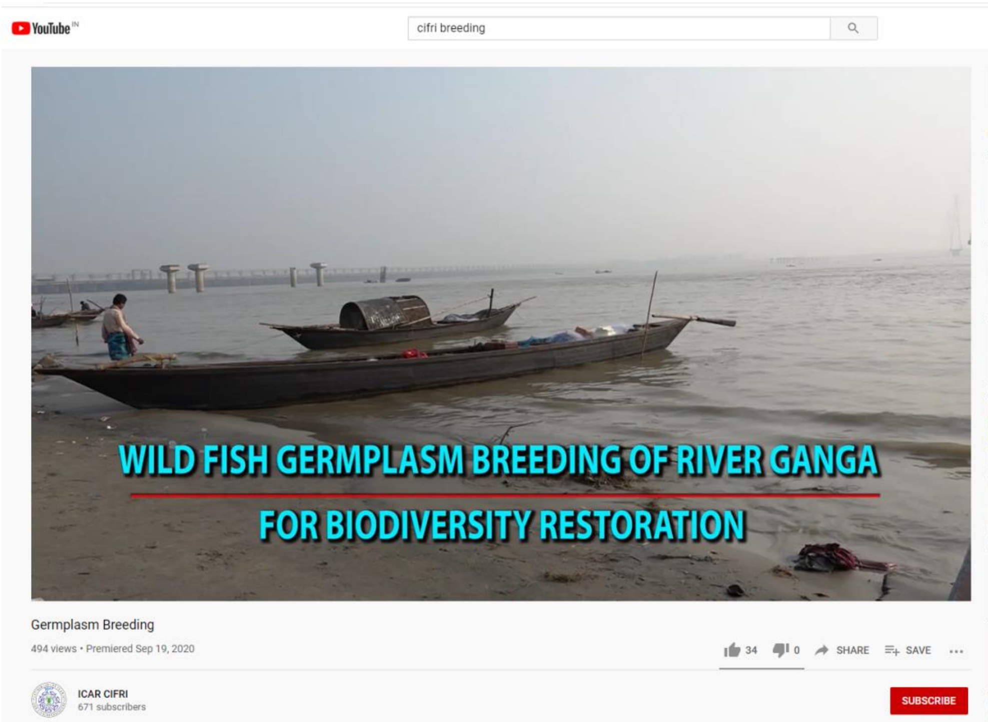
1. Das B. K., Swain H. S., Baitha R., Manna R. K., Chanu T. N., Ray A. and Verma H. O. 2020. Invasive fish species of River Ganga. Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.
2. Das B. K., Swain H. S., Ramteke M. H., Das Gupta S., Tiwari N. K., Bhor M., Bayen S., Mohanty T. R. and Roy S. 2020. Ex-situ conservation of Indian Major Carps germplasm of River Ganga. Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.
3. Das B. K., Swain H. S., Ramteke M. H.,Manna R. K.,Baitha R., Jha D. N., Alam A., Thakur V., Gupta M. and Das R. 2020. Ranching of IMC in river Ganga.Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.
4. Das B. K., Swain H. S., Ramteke M. H.,Tiwari N. K.,Das Gupta S., Ray A., Roy chowdhury A., Chakraborty L., Mondal S. and Mondal K. 2020. Spawn prospecting of river Ganga. Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.
5. Das B. K., Johnson C., Swain H. S., Alam A., Das S. C. S., Ray A. and Mishra S. 2020. Euryhaline fishes of river Ganga. Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.
6. Das B. K., Swain H. S., Baitha R., Johnson C., Kumar J., Bayen S. and Verma S. 2020. Threatened fishes of river Ganga. 2020. Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.
7. Das B. K., Manna R. K., Kumari S., Bera T., Swain H. S., Mohanty T. R. and Roy S. 2020. Common Planktons of River Ganga (Middle to Lower Stretch). 2020. Pamphlet. ICAR-Central Inland Fisheries Research Institute, Barrackpore.

Bilingual leaflets highlighting the project activities and NMCG initiatives towards Ganga biodiversity conservation

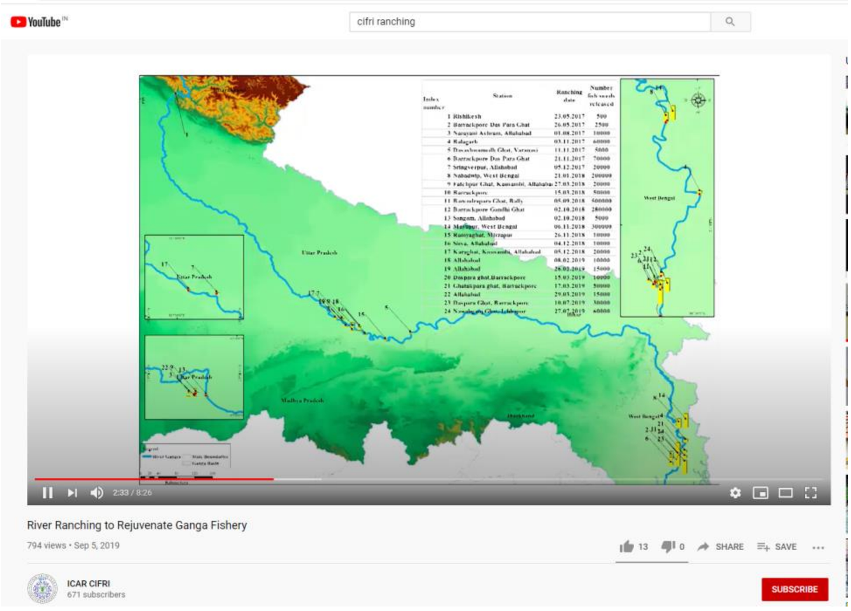




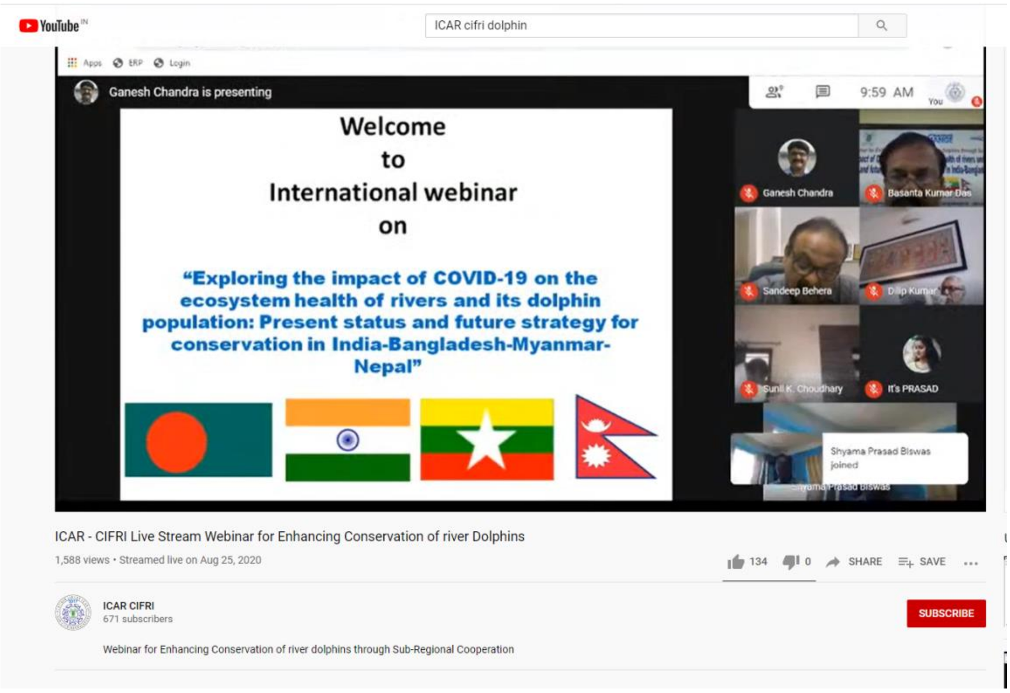
Online publication



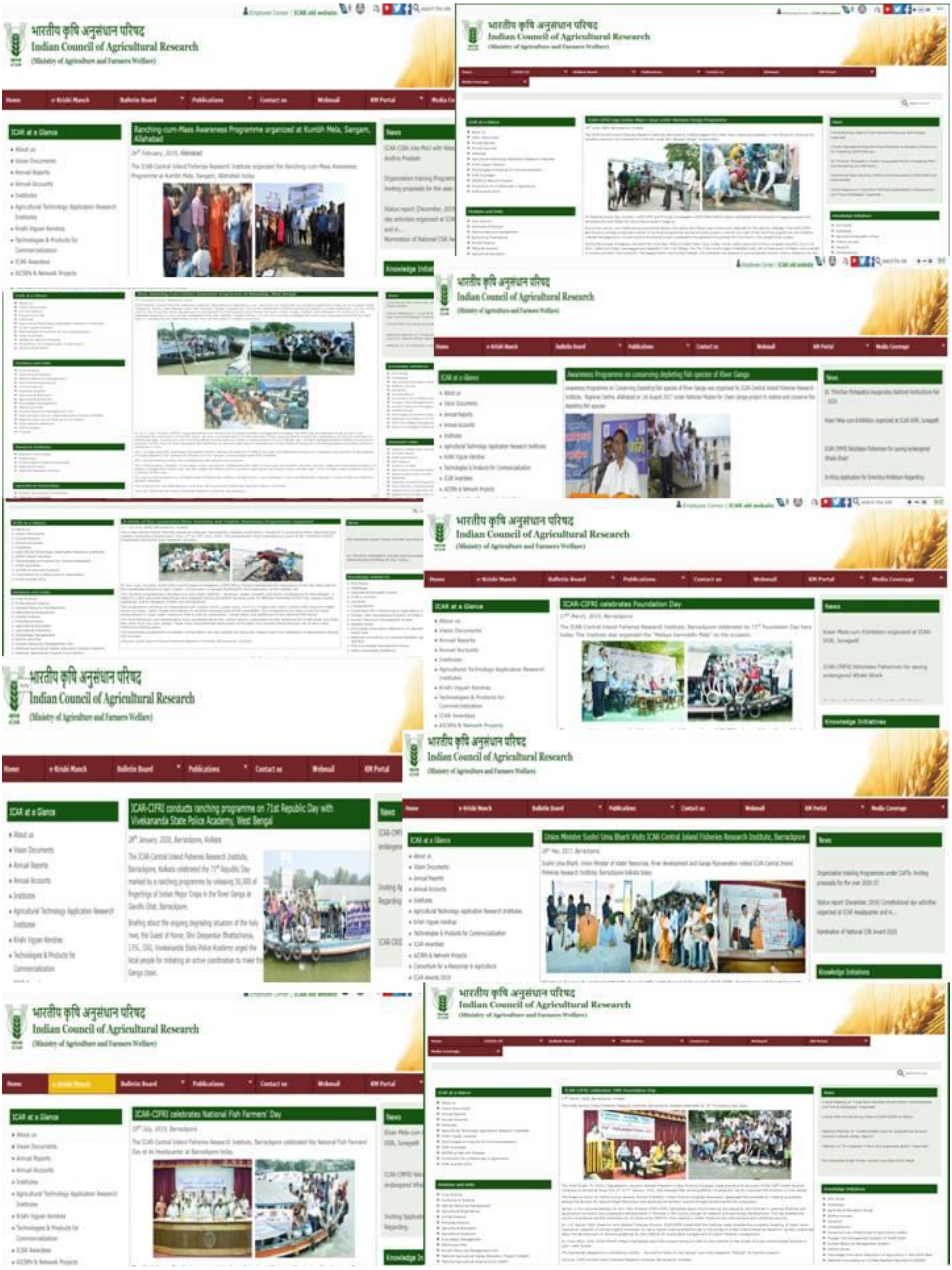
YouTube video on Ranching, Tagging and awareness



YouTube video on River ranching to Rejuvenate Ganga Fishery



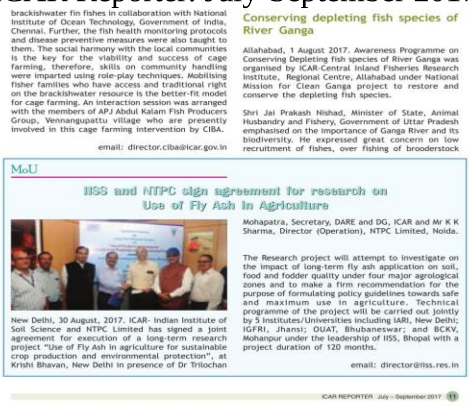
Work duly appreciated by Indian Council of Agricultural Research and published more than 10 times on its website/News



ICAR-CIFRI work published in social media platform by NMCG

Reports on NMCG activities in ICAR-Reporter

ICAR Reporter: July-September 2017



brackishwater fin fishes in collaboration with National Institute of Ocean Technology, Government of India, Chennai. Further, the fish health monitoring protocols and disease preventive measures were also taught to them. The social harmony with the local communities is the key for the viability and success of cage farming, therefore, skills on community handling were imparted using role-play techniques. Mobilising fisher families who have access and traditional right on the brackishwater resource is the better-fit model for cage farming. An interaction session was arranged with the members of APJ Abdul Kalam Fish Producers Group, Vennangupattu village who are presently involved in this cage farming intervention by CIBA.

email: director.ciba@icar.gov.in

Conserving depleting fish species of River Ganga

Allahabad, 1 August 2017. Awareness Programme on Conserving Depleting fish species of River Ganga was organised by ICAR-Central Inland Fisheries Research Institute, Regional Centre, Allahabad under National Mission for Clean Ganga project to restore and conserve the depleting fish species.

Shri Jai Prakash Nishad, Minister of State, Animal Husbandry and Fishery, Government of Uttar Pradesh emphasised on the importance of Ganga River and its biodiversity. He expressed great concern on low recruitment of fishes, over fishing of brooderstock

MoU

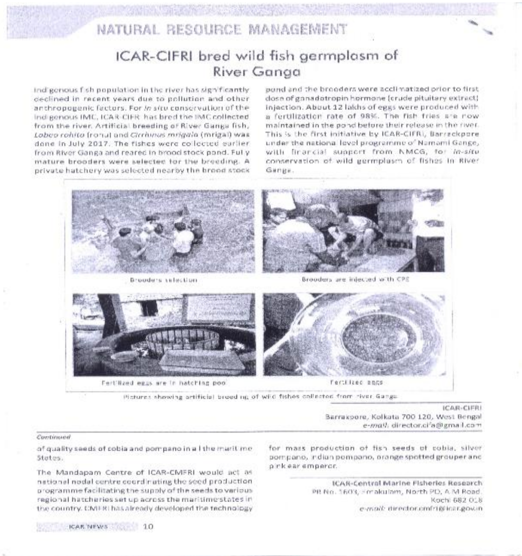
IISS and NTPC sign agreement for research on Use of Fly Ash in Agriculture

New Delhi, 30 August, 2017. ICAR- Indian Institute of Soil Science and NTPC Limited has signed a joint agreement for execution of a long-term research project "Use of Fly Ash in agriculture for sustainable crop production and environmental protection", at Krishi Bhavan, New Delhi in presence of Dr Trilochan Mohapatra, Secretary, DARE and DG, ICAR and Mr K K Sharma, Director (Operation), NTPC Limited, Noida.

The Research project will attempt to investigate on the impact of long-term fly ash application on soil, food and fodder quality under four major agrological zones and to make a firm recommendation for the purpose of formulating policy guidelines towards safe and maximum use in agriculture. Technical programme of the project will be carried out jointly by 5 Institutes/Universities including IARI, New Delhi; IGFRI, Jhansi; OUAT, Bhubaneswar; and BCKV, Mohanpur under the leadership of IISS, Bhopal with a project duration of 120 months.

email: director@iiss.res.in

ICAR REPORTER July – September 2017 11



NATURAL RESOURCE MANAGEMENT

ICAR-CIFRI bred wild fish germplasm of River Ganga

Indigenous fish population in the river has significantly declined in recent years due to pollution and other anthropogenic factors. For *in situ* conservation of the indigenous IMC, ICAR-CIFRI has bred the IMC collected from the river. Artificial breeding of River Ganga fish, *Labeo rohita* (rohu) and *Cirrhinus mrigala* (mrigal) was done in July 2017. The fishes were collected earlier from River Ganga and reared in brood stock pond. Fully mature brooders were selected for the breeding. A private hatchery was selected nearby the brood stock pond and the brooders were acclimatized prior to first dose of ganadotropin hormone (crude pituitary extract) injection. About 12 lakhs of eggs were produced with a fertilization rate of 98%. The fish fries are now maintained in the pond before their release in the river. This is the first initiative by ICAR-CIFRI, Barrackpore under the national level programme of Namami Gange, with financial support from NMCG, for *in-situ* conservation of wild germplasm of fishes in River Ganga.

Brooders selection

Brooders are injected with CPE

Fertilized eggs are in hatching pool

Fertilized eggs

Pictures showing artificial breeding of wild fishes collected from river Ganga

ICAR-CIFRI
Barrackpore, Kolkata 700 120, West Bengal
e-mail: director.cifa@gmail.com

Continued

of quality seeds of cobia and pompano in all the maritime States.

The Mandapam Centre of ICAR-CMFRI would act as national nodal centre coordinating the seed production programme facilitating the supply of the seeds to various regional hatcheries set up across the maritime states in the country. CMFRI has already developed the technology for mass production of fish seeds of cobia, silver pompano, Indian pompano, orange spotted grouper and pink ear emperor.

ICAR-Central Marine Fisheries Research
PB No. 1603, Ernakulam, North PO, A M Road,
Kochi 682 018
e-mail: director.cmfri@icar.gov.in

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PRINT MEDIA PUBLICATIONS

इलाहाबाद, 8 जुलाई 2016 दैनिक जागरण

मत्स्यिकी प्रबंधन केंद्र व लैब का उद्घाटन

इलाहाबाद : नमामि गंगे योजना के तहत मत्स्यिकी प्रबंधन केंद्र और प्रयोगशाला का उद्घाटन किया गया। गुरुवार को केंद्रीय अंतरस्थलीय मत्स्यिकी अनुसंधान संस्थान के क्षेत्रीय केंद्र में मत्स्यिकी प्रबंधन केंद्र व प्रयोगशाला योजना का उद्घाटन सांसद श्यामाचरण गुप्ता ने किया। इस लैब के जरिए गंगा से विलुप्त हो रही मछलियों को बचाने काम होगा। केंद्र के अध्यक्ष डा. केडी जोशी ने कहा कि गंगा में कतला, रोहू, मृगल व पर्वतीय क्षेत्र की महाशीर, स्नो ट्राउट मछलियां पाई जाती है। लेकिन प्रदूषण के चलते इनकी तादात कम हो रही है। इस लैब के जरिए उन मछलियों को बचाने में मदद मिलेगी। इस मौके पर प्रोफेसर यूसी श्रीवास्तव, डा. वीके द्विवेदी, डा. एसपी सिंह, डा. आरके स्वामी, जेपी मिश्रा, विश्वनाथ निषाद, जीतेंद्र कुमार आदि थे।

Prayagraj04th July, 2017

अमर उजाला मिर्जापुर

ग्रामीणों ने बीडीओ का किया घेराव

जल से ही जीवन की कल्पना संभव

एनएफएस के पात्रों का किया गया चयन

वसूला गया 17 लाख 30 हजार रुपये का बिल

Prayagraj 3rd March, 2017

গঙ্গা থেকে হারিয়ে যাচ্ছে রুই-কাতলা

Kolkata 02nd November, 2017

नमामि गंगे में मछलियां भी होंगी संरक्षित

केंद्रीय अंतस्थलीय मात्स्यिकी अनुसंधान संस्थान के क्षेत्रीय केंद्र से परियोजना का शुभारंभ

गंगोत्री से गंगासागर तक मछलियों की कई प्रजातियों को किया जाएगा संरक्षित

इलाहाबाद (ब्यूरो)। भारत सरकार की बहुचर्चित नमामि गंगे परियोजना के अंतर्गत मछलियों को भी संरक्षित किया जाएगा। बृहस्पतिवार को इसके अंतर्गत केंद्रीय अंतस्थलीय मात्स्यिकीय अनुसंधान संस्थान के क्षेत्रीय केंद्र पर इससे जुड़ी परियोजना का शुभारंभ सांसद श्यामा चरण गुप्ता ने किया। इस दौरान उन्होंने गंगा की एतिहासिकता पर प्रकाश डाला। कहा कि इसे निर्मल करना बहुत जरूरी है। उन्होंने इसमें मछलियों के संरक्षण और संवर्धन पर भी बल दिया। परियोजना के बारे में संस्थान के केंद्राध्यक्ष डॉ. केडी जोशी ने परियोजना की विस्तृत जानकारी दी। कहा कि गंगोत्री से गंगासागर तक गंगा नदी में पाई जाने वाली मछलियों को संरक्षित करना इसका मुख्य लक्ष्य है। उन्होंने कतला, रोहू, मृगल, स्नो ट्राउट समेत कई मछलियों का नाम लिया। कार्यक्रम के विशिष्ट अतिथि प्रो. यूसी श्रीवास्तव, आयुर्वेद के निदेशक डॉ. वीके द्विवेदी, डॉ. एसपी सिंह, डॉ. आरके स्वामी, जेपी मिश्रा, विश्वनाथ निषाद, जितेंद्र कुमार, डॉ. कल्पना श्रीवास्तव, एसके श्रीवास्तव, एसआर मीण आदि मौजूद रहे।

Prayagraj 8th July, 2018

गंगा में देशी प्रजाति की रोहू, मृगाल के दस हजार डाले गए मत्स्य बीज

Varanasi on 27th November, 2018

मत्स्य के संरक्षण के लिए गंगा में छोड़ीं 10 हजार मछलियां

विंध्याचल। शिवपुर स्थित रामगया घाट पर सोमवार को भारतीय कृषि अनुसंधान परिषद एवं केंद्रीय अंतस्थलीय मत्स्य अनुसंधान संस्थान इलाहाबाद की ओर से राष्ट्रीय स्वच्छ गंगा मिशन (एनएमसीजी) के तहत गंगा में 10 हजार देशी मछलियों को छोड़ा गया। विलुप्त हो रहे मत्स्य प्रजातियों के संरक्षण व संवर्धन को ध्यान में रखते हुए कार्प, कटला, रोहू, मृगाल मछलियों के बीज को गंगा नदी में रैंचिंग कार्यक्रम के तहत छोड़ा गया। कार्यक्रम का उद्घाटन मुख्य अतिथि डॉ. बरसाती उप मत्स्य निर्देशक ने किया। संस्थान के वैज्ञानिक डीएन झा ने अतिथियों का स्वागत एवं संस्थान के केंद्र अधीक्षक डॉ. आर्य श्रीवास्तव ने उपस्थित लोगों को विस्तार से नमामि गंगे के अंतर्गत आयोजित होने वाले इस परियोजना की जानकारी दी। कहा गया कि गंगा जीवन दायिनी है, यदि गंगा नहीं रही तो मानव सभ्यता खतरे में पड़ जाएगी। मुख्य अतिथि ने कहा गंगा में मछलियों के महत्व तथा इसके संरक्षण एवं संवर्धन बारे में विस्तृत जानकारी दी। इस मौके पर कार्यक्रम संस्थान के वैज्ञानिक वेंकटेश ठाकुर, डॉ. हरिओम वर्मा, डॉ. कल्पना श्रीवास्तव, डॉ. राकेश श्रीवास्तव, विजय कुमार, जितेंद्र कुमार, राम सजीवन, सुनील कुमार वर्मा, अमित कुमार आदि लोग मौजूद रहे।

Prayagraj on 17th November, 2018

जैव विविधता की दी गई जानकारी

जागरूकता

इलाहाबाद | निज संवाददाता

जैव-विविधता और गंगा की निर्मलता के बारे में लोगों को जागरूक करने के लिए केंद्रीय मत्स्य अनुसंधान संस्थान के 12 वैज्ञानिकों का दल मंगलवार को संगम पहुंचा। दल का नेतृत्व कर रहे संस्थान के प्रमुख वैज्ञानिक डॉ. रमाशंकर श्रीवास्तव ने घाट पर मौजूद श्रद्धालुओं, पुरोहितों, नाविकों और दुकानदारों को जैव विविधता के महत्व के बारे में जानकारी दी।

उन्होंने कहा कि गंगा मात्र पानी नहीं मानव सभ्यता का आधार है। इसकी निर्मलता जीवन प्रदान करती है। इसे स्वच्छ रखना नैतिक कर्तव्य है। गंगा में बढ़ते प्रदूषण से जलीय जीवों का अस्तित्व संकट में है। कई जीवों की प्रजातियां लुप्त होती जा रही हैं। इसलिए गंगा में गिरने वाले प्रदूषित नालों को तत्काल रोका जाना चाहिए। प्रदूषित नालों को गंगा में गिरने से हम सभी को एक सुर में इसके लिए प्रतिज्ञा करना चाहिए।

गंगा के प्रदूषित होने से कन्नौज और फतेहपुर में गंगा में चार किमी के दायरे में मछलियां मर गई हैं। इस अवसर पर वैज्ञानिकों ने जैव विविधता को बढ़ावा देने के लिए उच्च गुणवत्ता वाले 5 हजार मत्स्य बीज संगम में डाले। वैज्ञानिकों के दल में डॉ. डीएम झा, डॉ. श्यामलदास, डॉ. ठाकुर, डॉ. आलम, डॉ. हरि ओम वर्मा, डॉ. सुशील वर्मा, संदीप कुमार मिश्र, डॉ. कल्पना श्रीवास्तव, डॉ. जहांआरा शामिल रहीं।

संगम में मत्स्य बीज छोड़ते केंद्रीय मत्स्य अनुसंधान संस्थान के वैज्ञानिक। • हिन्दुस्तान

Prayagraj, 3rd October, 2018

अभियान

गंगा में डाले गए विलुप्त हो रही मछलियों के बीज

Prayagraj, 6th December, 2018

गंगा में कम हुईं मछलियां, डाले गए मत्स्य बीज

Prayagraj, 5th December, 2018

DESHER SAMAY

দেশের সময়

গঙ্গা নদীতে মাছের বৈচিত্র্য পুনরুদ্ধারের প্রয়াস

Bally, West Bengal, 09th September, 2018

ভাগীরথীর জলে মাছ ছেড়ে নদী নির্মলের উদ্যোগ

মাছের সংখ্যা বাড়াতে উদ্যোগ

নিজস্ব সংবাদদাতা

Mayapur, West Bengal, 6th November 2018

কেন্দ্রীয় মৎস্য গবেষণা কেন্দ্রে মৎস্য সমৃদ্ধিমেলা

উজ্জ্বল বন্দ্যোপাধ্যায়

উত্তর ২৪ পরগণার বারাকপুরের আইসিএআর সিআইএফ আর আই গার্ডেনে রবিবার এদিন এই মেলার উদ্বোধন অনুষ্ঠানে উপস্থিত ছিলেন আইসিএআরের ডিরেক্টর ড. বি কে দাস, কলকাতার এন ওয়াই কে এসের ডিরেক্টর নবীন নায়েক, রাজ্য সরকারের পঞ্চায়েতে ও গ্রামীণ দফতর যুগ্ম সম্পাদক আত্মজিত দাস, বর্ধমান বিশ্ববিদ্যালয়ের ভাইস চ্যান্সেলর প্রফেসর এন সাহা, প্রফেসর পূর্ণেন্দু বিশ্বাস, আই এসসির একে সাক্সেনা সহ আরও অনেকে। মাছচাষের উপর নানা বিবরণের বিষয়ের উপর আলোকপাত করেন বিশেষজ্ঞরা। উক্ত অনুষ্ঠানে রাজ্যের প্রায় সব জেলা থেকে চাষিরা অংশ নিয়েছিল। তবে উক্ত অনুষ্ঠানে সাংবাদিকদের আমন্ত্রণ করেও চূড়ান্ত অবস্থার মধ্যে ফেলা হলো। আইসিএআর কর্তৃপক্ষরা আগামীদিনে এদিকে একটু নজর দিলে ভালো হবে।

গঙ্গায় ছাড়া হল ৩০ হাজার মাছের পোনা

বিএনএ, বারাকপুর: বুধবার জাতীয় মৎস্যজীবী দিবস উপলক্ষে কেন্দ্রীয় মৎস্য গবেষণা কেন্দ্রর (সিফরি) পক্ষ থেকে বারাকপুরে গঙ্গায় প্রায় ৩০ হাজার মাছের পোনা ছাড়া হয়। পরে, একটি অনুষ্ঠানে দেশের বিভিন্ন রাজ্যের সফল মৎস্যজীবীকে সংবর্ধনা দেওয়া হয়। সিফরি-র অধিকর্তা বসন্তকুমার দাস বলেন, প্রতি বছরই এই দিনটিতে সারা দেশেই মাছ ছাড়া হয়। এদিন গঙ্গায় রুই, কাতলা, মৃগেল মাছের চারা ছাড়া হয়েছে। সাগরের বিধায়ক বঙ্কিম হাজরা সহ একাধিক আধিকারিক অনুষ্ঠানে উপস্থিত ছিলেন।

समारोह सिफरी के निदेशक डा वसंत कुमार दास ने दिया सुझाव, बैरकपुर में मनाया गया राष्ट्रीय मत्स्य पालक दिवस

नए शोध के बल पर मत्स्य की जरुरत होगी पूरी

बैरकरपुर में मत्स्य कृषक दिवस मनाया गया

कोलकाता. बैरकपुर स्थित सेंट्रल फिशरीज रिसर्च सेंटर की ओर से राष्ट्रीय मत्स्य कृषक दिवस मनाया गया. इस दौरान जैव विविधता के संरक्षण के लिए गंगा में मछलियों का जीरा प्रवाहित किया गया. इस मौके पर पश्चिम बंगाल, बिहार, झारखंड और मध्य प्रदेश के 100 के अधिक मत्स्य पालक, उद्यमी और मछली उत्पादन समूह से जुड़े लोग शामिल हुए. इनमें से 10 किसानों को मछली पालन में उनके उत्कृष्ट योगदान के लिए सर्वश्रेष्ठ मत्स्य पालक पुरस्कार प्रदान किया गया. इस मौके पर सागर द्वीप के विधायक बंकिम हाजरा सिफा के पूर्व निदेशक डॉ एन सरिंगी व भारतीय अनुसंधान परिषद के पूर्व सहायक महानिदेशक डॉ वीवी सुगनन को सम्मानित किया गया.

Barrackpore, 17th March 2019

Barrackpore, 10th July 2019

Farakka, 23rd September 2020

Nabadwip, 12th July 2020

Nabadwip, 12th July 2020

गंगा में छोड़ा तीन लाख मछली बीज

पश्चिम बंगाल के बैरकपुर से साहिबगंज पहुंचे नमामि गंगे टीम के सदस्यों के साथ झासकोफिश के निदेशक। • हिन्दुस्तान

नमामि गंगे

साहिबगंज | प्रतिनिधि

गंगा नदी में मछलियों की कमी को लेकर गुरुवार को बैरकपुर (पश्चिम बंगाल) से आईसीएआर निदेशक डॉ. बीके दास के नेतृत्व में 40 सदस्यीय टीम ने यहां गंगा का निरीक्षण किया। नमामि गंगे योजना के तहत ये भ्रमण व निरीक्षण कार्यक्रम हुआ। निरीक्षण के क्रम में गंगा में मछलियों की कमी को गंभीरता से लेते फरक्का से साहिबगंज तक गंगा नदी में तीन लाख मछली बीज स्पॉन छोड़ा गया। इससे गंगा में मछली की संख्या में बढ़ोतरी हो सके। गंगा में मछली उत्पादन कम होने से सरकार चिंतित है।

झासको फिश के निदेशक व साहिबगंज मछुआ सोसाइटी अध्यक्ष अरुण कुमार चौधरी ने बताया कि उक्त टीम की ओर से फरक्का में एक लाख, महाराजपुर में एक लाख व स्थानीय बिजली घाट पर गंगा में एक लाख मछली बीज डाला गया।

मौके पर टीम के विज्ञानी हिमांशु शेखर व मितेश रामटेक, तकनीकि अधिकारी आशीष राय चौधरी के अलावा सदस्य राजन चौधरी, दिलीप चौधरी, गोपाल चौधरी आदि थे।

Sahebgunj, Jharkhand, 23rd September 2020

COVERAGE IN ELECTRONIC MEDIA

Most of the programs conducted under CIFRI-NMCG project like ranching activity, Mass awarenessprogrammes, etc always attracted attention of electronic media as well. Telecast in TV channels especially in local channels created public awareness about Namami Gange program and NMCG.

Telecast in Bangla Door Darshan on Ganga river ranching during Fish Farmers' Day

Telecast in Door Darshan on Ganga river ranching at Law College Ghat, Patna, Bihar

Fish tagging activity under CIFRI-NMCG project covered in local channel

Awareness programme on river dolphin conservation in local TV channel

Awards under CIFRI-NMCG project

Best oral presentation award

- R. K. Manna, A. K. Das, S. Samanta, S. C. S. Das, A. Alam, B. K. Singh, K. D. Joshi, R. K. Raman, M. Naskar, U. Bhaumik and A. P. Sharma. 2017. Time scale changes of water parameters of river Ganga in relation to fisheries. In: 29th All India Congress of Zoology, CIFRI Barrackpore, 9-11thJune, 2017.

Best poster presentation award

- Manna R K., Ray A., Samanta P., Bhowmik T.S., Singh A., Munivenkatappa M.H., Ramteke M.H., Mondal S., Behera S. K. and Das B.K. 'Tuke–feka' Fishery- An Indigenous Fishing Practice to Catch Indian Major Carp in Buxae-Balia Stretch of River Ganga.in the National Seminar on "Priorities in Fisheries and Aquaculture (PFA- 2017), at College of Fisheries, Rangeilunda, Berhampur, Odisha, India.
- Singh, Aprajita,Manna, R. K., Baitha, R., Paul, S. K., Chakraborty, L. and Das B. K. 2017. A survey on trap fishery in river Ganga. In: 29th All India Congress of Zoology, CIFRI Barrackpore, 9-11thJune, 2017.
- बाएंन सुप्रीति, थांगजाम निरुपोदा चानू , दास बसंत कुमार, मन्ना रंजन कुमार, रे अर्चिष्मान, भोर मनीषा,दास गुप्ता सुभोदीप, तिवारी नितीश कुमार, मोहंती त्रुप्ती रानी, चक्रबोर्ती लोकनाथ और रामटेके मितेश हीरादास .. । .छारागंगा बील में मछलियों की बिबिधता और संरक्षण का अध्ययन Poster presentation on "जीबिका उपार्जन में अंतर्स्थलीय मात्स्यिकी की भूमिका". 140 Pp.

OBJECTIVE–VIII

IDENTIFICATION OF CONSERVATION SITES (AQUATIC BIOSPHERE/NATIONAL AQUATIC PARK) THROUGH DATA GENERATED BY THIS STUDY

Protected areas along river Ganga with respect to the sampling sites

Protected areas are considered those areas which have legal entity and do not support any human occupation and interference. In simplest expressions, protected areas are certain sections or zones of terrestrial or aquatic sites provided with definite levels of protection for conservation and preservation of biodiversity along with the socio-environmental values. Protected areas include marine parks, wildlife sanctuary, national parks etc. As per the records, protected areas along river Ganga include National Park (3), Wildlife Sanctuary (8), Biosphere reserves (2) and one conservation reserve spanning across five different states. However, the areas close to the sampling sites are only seven (Table 57).

Table 57. National Park and Wildlife Sanctuary along river Ganga

Protected site	State	Nearest sampling site	Distance (km)
Gangotri National park	Uttarakhand	Harsil	41.1
Govind National Park		Tehri	85.9
Rajaji National Park		Haridwar	21.0
Hastinapur Wildlife Sanctuary	Uttar Pradesh	Bijnor	37.0
Vikramshila Gangetic Dolphin Sanctuary	Bihar & Jharkhand	Bhagalpur	31.0
Bethuadahari Wildlife Sanctuary	West Bengal	Farakka, Balagarh	84.0
Sunderban Biosphere Reserve	West Bengal	West Bengal	100.0

Potential area for '*Gangetic fish protection site'* (on the basis of % juvenile availability)

Pattern of fish juvenile recruitment is very much essential to the survival of fish faunal diversity of any natural system. Juvenile availability in rivers of fish species is key to understand the active breeding ground. This availability directly endorses the key habitat variables required for surviving. Thus increase in available shelter can potentially increase juvenile fish populations and overall fish abundances. In the present study, fish juvenile of Ganga along few stations were studied based on length frequency data which are presented below (Table 58). In accordance withthe availability of juvenile fishes, Kanpur and Bijnor congregates the highest percentage of juveniles. On the other hand, as the number of individual fish juvenile at Bijnor is observed maximum (N=107) and this station is being close to the Hastinapur Wildlife sanctuary,this areamay be designated as one of the '***fish protection site***'.

Table 58. Fish juvenile of Important fishes recorded from different station of Ganga stretch

Sl.	Sites	% of fish juvenile	Important fishes
1.	Bijnor	30.88	IMC, *A. mola*, *M. armatus*, *Channa punctata*, *C. Marulius* etc.
2.	Kanpur	34.69	IMC, *Wallago attu*, *Sperata* sp., *Channa* sp. etc.
3.	Prayagraj	26.42	IMC, *C. reba*, *Sperata* sp., *W. attu* etc.
4.	Varanasi	27.0	IMC, *Anabas testudineus*, *S. seenghla*, *G. giuris*, *G. manmina* etc.
5.	Buxar	36.56	IMC, *W. attu*, *C. marulius*, *G. giuris*, *G .chapra*etc.
6.	Patna	36.30	IMC, *R. corsula*, *G. chapra*, *M. armatus*, *J. coitor* etc.
7.	Bhagalpur	32.87	IMC, *W. attu*, *C. marulius*, *G. giuris*, *S. aor* etc.
8.	Farakka	29.84	IMC, Minor carp, Small and Large catfishes
9.	Balagarh	29.82	IMC, Minor carp, Murrels Small and Large catfishes
10.	Godakhali	45.37	*Tenualosa ilisha* (only has been estimated)

Bijnor (Uttar Pradesh) as active fish protection site

Bijnor is a city, located in the Bijnor district of Uttar Pradesh. It covers a total area of 4561 sq. kilometers. The city is located only 12 Km to the west of river Ganga. The Bijnor district receives average 100-110 cm rainfall. The major rainfall received during month of June to September. Although the rainfall regime in Bijnor is not continuous through out the year, the amount has been found to be suitable for natural lotic breeders like carps for spawning.

Key fish species in Bijnor

The study revealed the occurrence of 107 fish species belonging to 10 orders, 32 families, and 78 genera in Bijnor. The most dominated family wasCyprinidae (42%), followed by Sisoridae, Bagridae and Schilbeidae (7%), Siluridae, Ambassidae (4%), Osphronemidae, Channidae, Mastacembelidae, and Cobitidae (3%), Clupeidae, Claridae, Mugilidae, Nemacheilidae, and Notopteridae (2%), Anguillidae, Anabantidae, Tetraodontidae, Gobiidae, and Cichlidae (1%) were recorded at Bijnor.

A total 6 exotic fish species namely Tilapia/Kawai (*Oreochromis niloticus*), Common Carp/ Chaina (*Cyprinus carpio*), Big head carp (*Hypophthalmichthys nobilis*), Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodon idella*), Mangur/ thaimagur (*Clarias gariepinus*) were observed. Small indigenous fish species such as *Chaca chaca, Erethistes pusillus, Pethia gelius, Megarasbora elanga, Opsarius tileo, Oreichthys cosuatis,* etc.were also recorded at Bijnor..

The middle stretches of the river Ganga from Bijnor to Narrora are known as Ramsar site. The Ganges ecosystem, give rise to unique habitat mosaics, which support distinctive biodiversity and provide substantial ecosystem services, creating a strong imperative for their protection and restoration. They are being impacted globally by divergent but frequently concurrent processes including water pollution, over-fishing, and alteration of natural flow regime, invasive species, climate change and human-induced habitat loss.

Management action Plan

(1) Maintenance of water quality and habitat modification (e.g. wetland restoration and proper flow)

(2) Stock enhancement of the depleting population of fishes mainly by ranching

(3) Declaration of stretches with wide variety of habitat as fish sanctuaries and declaration of some flood plain wetland as Ramsar site

(4) Control of invasive fish species mainly *O. niloticus* and *C. carpio*.

(5) Awareness through community participation

(6) Development of the breeding technique for the native fish species irrespective of their commercial importance.

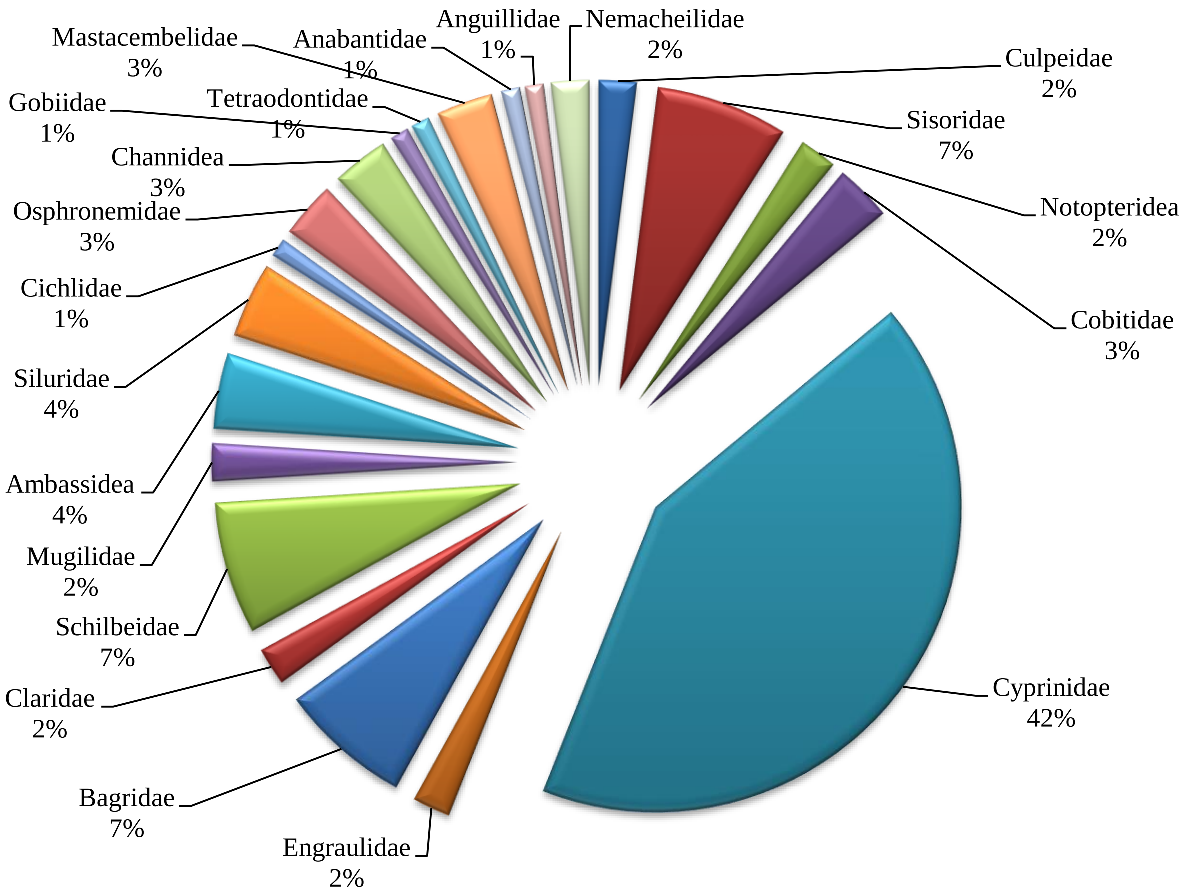

Fig. 223 Family wise percentage distribution

Juvenile availability on riverine spawn assessment

Evaluation of fish spawns as breeding ground

The studies carried out during the present survey focused upon both qualitative and quantitative production output of fish seed from the river. The average fish spawn production has been estimated to be only 21 ml (435 million) from middle and lower stretch of River Ganga. Qualitative investigation was undertaken from the lower stretch of the river viz. Farakka, Lalgola and Guptipara in West Bengal. A total of 46 species belonging to 36 genera 19 families and 8 orders during the period of 2018-19 was encountered. The species identification have been estimatedsolely from a representative samples from three different spots of the river. (Table 59). The site Guptipara has been confronted with maximum availability of fish species (0.38%) followed by Farakka (0.36%) and Lalgola (0.25%) respectively. Contribution from the economically important catfishes was merely 4.33% signifying less abundance of the species during the period.

Table 59. Presence absence data of fish spawns along lower stretch of river Ganga during 2017-2019

Sl.	Species	Family	Farakka	Lalgola	Guptipara
1.	*Amblypharyngodon mola* (Hamilton, 1822)	Danionidae	-	-	+
2.	*Aplocheilus pancax* (Hamilton, 1822)	Danionidae	-	-	+
3.	*Bagarius bagarius* (Hamilton, 1822)	Sisoridae	+	-	-
4.	*Batasio batasio* (Hamilton, 1822)	Bagridae	-	-	+
5.	*Chanda nama* (Hamilton, 1822)	Ambassidae	+	+	-
6.	*Channa punctata* (Bloch, 1793)	Channidae	-	-	+
7.	*Channa striata* (Bloch, 1793)	Channidae	-	-	+
8.	*Chitala chitala* (Hamilton, 1822)	Notopteridae	+	+	+
9.	*Cirrhinus mrigala* (Hamilton, 1822)	Cyprinidae	+	+	+
10.	*Cirrhinus reba* (Hamilton, 1822)	Cyprinidae	+	+	+
13.	*Danio devario* (Hamilton, 1822)	Danionidae	-	-	+
14.	*Danio rerio* (Hamilton, 1822)	Danionidae	-	-	+
15.	*Eutropiichthys vacha* (Hamilton, 1822)	Schilbidae	+	+	-
17.	*Glossogobius giuris* (Hamilton, 1822)	Gobiidae	+	+	-
18.	*Gudusia chapra* (Hamilton, 1822)	Clupeidae	+	-	-
19.	*Heteropneustes fossilis* (Bloch, 1794)	Heteropneustidae	-	-	+
46.	*Hyporhamphuslimbatus* (Valenciennes, 1847)	Belonidae	+	-	-
20.	*Labeobata* (Hamilton, 1822)	Cyprinidae	+	+	+
21.	*Labeo calbasu* (Hamilton, 1822)	Cyprinidae	+	+	+
16.	*Labeo catla* (Hamilton, 1822)	Cyprinidae	+	+	+
22.	*Labeo rohita* (Hamilton, 1822)	Cyprinidae	+	+	+
23.	*Leiodon cutcutia* (Hamilton, 1822)	Tetraodontidae	+	-	-
24.	*Macrognathus aral* (Bloch & Schneider, 1801)	Mastacembelidae	+	-	-
25.	*Macrognathus pancalus* (Hamilton, 1822)	Mastacembelidae	+	+	-
26.	*Mastacembelus armatus*(Hamilton, 1822)	Mastacembelidae	+	+	+
27.	*Mystus bleekeri* (Day, 1877)	Bagridae	-	-	+
28.	*Mystus cavasius* (Hamilton, 1822)	Bagridae	+	-	+
29.	*Mystus tengra* (Hamilton, 1822)	Bagridae	-	-	+
30.	*Notopterus notopterus* (Pallas, 1769)	Notopteridae	-	-	+
31.	*Pachypterus atherinoides* (Bloch, 1794)	Schilbidae	+	+	+
32.	*Parambassis baculis* (Hamilton, 1822)	Ambassidae	+	-	-
34.	*Pethia conchonius* (Hamilton, 1822)	Cyprinidae	+	+	+
35.	*Pethia ticto* (Hamilton, 1822)	Cyprinidae	+	+	+
33.	*Pisodonophis boro* (Hamilton, 1822)	Ophichthidae	-	-	+
36.	*Puntius sophore* (Hamilton, 1822)	Cyprinidae	+	+	+
12.	*Rasbora daniconius* (Hamilton, 1822)	Cyprinidae	+	-	+
37.	*Rhinomugil corsula* (Hamilton, 1822)	Mugilidae	+	-	-
38.	*Salmostoma baciala* (Hamilton, 1822)	Danionidae	+	-	+
39.	*Salmostoma phulo* (Hamilton, 1822)	Danionidae	-	-	+
40.	*Sperata aor* (Hamilton, 1822)	Bagridae	-	-	+
41.	*Systomus sarana* (Hamilton, 1822)	Cyprinidae	+	-	+
11.	*Tariqilabeo latius* (Hamilton, 1822)	Cyprinidae	+	+	+
42.	*Trichogaster fasciata* (Bloch & Schneider, 1801)	Osphronemidae	-	-	+
43.	*Trichogaster lalius* (Hamilton, 1822)	Osphronemidae	-	-	+
44.	*Wallago attu* (Bloch & Schneider, 1801)	Siluridae	-	-	+
45.	*Xenentodon cancila* (Hamilton, 1822)	Belonidae	+	+	+
46.	*Pterigoplicthys* sp.	Loricariidae	-	+	-

Availability of Major Carp juveniles

The data generated during the present investigation highlighted abundance of prized carp juveniles in all the three spots. Rohu was found to be the significant contributory species among major carps with 65.7%, 25.3% and 9.1% from Farakka, Lalgola and Guptipara indicating its availability in Ganga. Similarly, Catla (38.9%) and Mrigal (36.3%) were recorded to be maximum from Guptipara and Lalgola respectively (Fig. 220) The data clearly indicates the proportion of IMC juveniles in lower Ganga stretch during monsoon months. Congenial environment coupled with depth and flow might be the key factor for availability of carp juveniles.

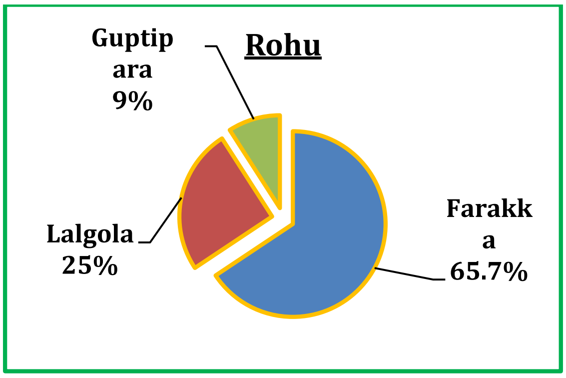

Fig. 224 a Availability of rohu juveniles

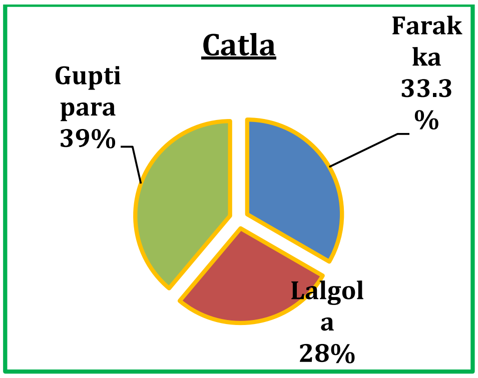

Fig. 224b Availability of catla juveniles

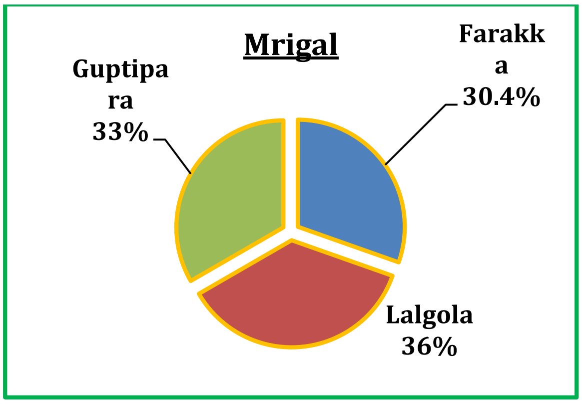

Fig. 224c Availability of mrigal juveniles

Fig. 224 a-c Availability of Major Carp juveniles

OBJECTIVE–IX

PREPARATION OF THE FISHERIES CONSERVATION AND RESTORATION PLAN FOR THE GANGA RIVER SYSTEM

Fishing Gear vis-à-vis conservation

Fishing gear plays an important role towards fish conservation. Indiscrimateor over fishing is a major threat to the freshwater fishes of Ganga. However, different fishing gears are heterogeneous in their spatial extent and their impacts on different species. Therefore, treating different fisheries homogenously with regard to their spatial management likely causes unnecessary conflict between fisheries and conservation priorities. As gill nets are most common fishing gear used in river Ganga, our results highlight areas of high conservation concern for particular fishing gears, and areas of high overlap between multiple fishing gear threats and multiple species of conservation concern (Table 60).

Table 60. Percentage of important species caught below first maturity from Ganga

S. No	Species	Length at first maturity (L_m)	Source	% caught below L_m from River Ganga	Gear used for targeting juveniles
33.	*Labeo rohita* (Rehu/Rui)	579 mm	Chondar, 1999	65.27	Gill net, Seine net
34.	*Labeo catla* (Catla/Bhakur)	550 mm	Natarajan, 1963	51.68	Gill net, Seine net
35.	*Cirrhinus reba* (Reba bata)	135 mm	Hossain et al., 2013	62.17	Gill net, Seine net
36.	*Cirrhinus mrigala* (Mrigal/Naini)	349 mm	Hanumantharao, 1971	32.97	Gill net, Seine net
37.	*Labeo calbasu* (Kalbasu/keronchi)	278 mm	Dwivedi et al., 2009	61.22	Gill net, Seine net, Hook
38.	*Labeo gonius* (Goni)	200 mm	Choudhury, 2003	98.16	Gill net, Seine net, Hook
39.	*Sperata seenghala* (Tengan,/Aarh)	770 mm	Saigal, 1982	94.73	Gill net, Seine net, Hook
40.	*Sperata aor* (Tengan/Aarh)	840 mm	Saigal, 1964	81.04	Gill net, Seine net, Hook
41.	*Mystus cavasius* (Tengan/GulsaTengra)	100 mm	Bhatt, 1971	34.52	Gill net, Seine net
42.	*Mystus tengara* (Tengan/DishiTengra)	90 mm	Gupta, 2015	28.64	Gill net, Seine net
43.	*Mystus gulio* (Nona tengra)	82 mm	Jhingran V.G, 1969	47.87	Gill net, Seine net, Hook
44.	*Rita rita* (Rita)	300 mm	Rahaman et al., 2013	92.51	Seine net, Hook & line
45.	*Chitala chitala* (Chital/Moi)	700 mm	Chonder, 1999	84.44	Seine net, Hook & line
46.	*Notopterus notopterus* (Folui/Moi)	238 mm	Hamza, 1980	74.52	Seine net, Hook & line
47.	*Gudusia chapra*(Chapra/Sugwa)	80 mm	Hossain et al., 2010	82.53	Gill net
48.	*Gonialosa manmina* (Chapra/Sugwa)	80 mm	Azadi (2008)	88.73	Gill net
49.	*Anabas testudineus* (Kawai/koi)	80 mm	Hora & Pillay, 1962	32.60	Gill net, Seine net
50.	*Tor putitora* (Mahaseer)	330 mm	Pathani& Das, 1980	57.55	Gill net, Hook & line
51.	*Schizothorax richardsonii* (Asila)	324 mm	Agarwal et. al, 2010	61.47	Cast net, Trap
52.	*Tenualosa ilisha* (Ilish)	341 mm	De (1986)	89.75	Gill net, Bag net and lift net
53.	*Polynemus paradiseus* (Topshe)	160 mm	Gupta, 1968	89.24	Gill net, Bag net
54.	*Clupisoma garua* (Garua)	171 mm	Hasan et al., 2020	50.16	Gill net, Hook & line
55.	*Eutropiicthys vacha*(Vatchwa)	140 mm	Hossain et al., 2012	45.33	Gill net, Hook & line
56.	*Johnius coitor*(Bhola)	114 mm	Sarkar et al., 2017	70.12	Gill net, Seine net
57.	*Mastacembelus armatus*(Bami/Bam)	362 mm	Alam et al., 2020	67.21	Hook, trap & seine net

58.	*Macrognathus pancalus*(Pakal)	131 mm	Pathak et al., 2013	73.91	Drag net, trap & seine net
59.	*Heteropneustes fossilis*(Singhi)	120 mm	Khan, 1972a	54.43	Drag net, trap & seine net
60.	*Ompok bimaculatus*(Pabdah)	232 mm	Mishra et al., 2013	94.11	Seine net, Hook, drag net
61.	*Channa punctata*(Sal)	120 mm	Prasad et al., 2011	57.70	Seine net, Hook, drag net
62.	*Channa marulius*(Gojal)	300 mm	Chacko, 1956	55.55	Seine net, Hook, drag net
63.	*Harpadon nehereus* (Bomla)	145 mm	Ghosh, 2014	72.22	Bag net, Gill net
64.	*Systomus sarana*(Sorputih)	250 mm	Alikhuni, 1957	87.66	Gill net

A critical analysis was made to determine the commercially important prized fishes of river Ganga caught below their maturity length (L_m). The data was assessed for selective 32 fish species combining with various length at first maturity parameters of female from Gang River basin. The result showed significant variations in Near threatened designated fishes like *Harpadon nehereus, Chitala chitala* and *Ompok bimaculatus* where the percentage caught below the maturity size is 72.22 %, 84.44 % and 94.11 % respectively. This indicates over exploitation of fishes below its maturity length thus creating growth overfishing. Similarly, exploitation rate of India Major Carps in terms of maturity length is 65.27% (Rohu), 51.68% (Catla), 32.97% (Mrigal) and 61.22% (Calbasu). Among all the major carps, *Labeo calbasu* is caught extensively in the river stretch owing to its year round availability. The study suggests that gillnet fisheries represent a greater threat along Ganga River threats . Thus, proper management plan should be implemented based on mesh size regulation of gill nets for conservation as well as sustainable fisheries at Ganga River stretches.

OBJECTIVE–X

SOCIO ECONOMIC STATUS OF FISHERMEN COMMUNITY ALONG DIFFERENT SITES OF RIVER GANGA

The Ganga basin is recognised as one of the most populated river basins in the world and nurture vast biodiversity. A significant number of fisher populations depend on fisheries of river Ganga to sustain their daily livelihood and nutritional security. According to Govt. of India Census (2011) report, the rich riverine ecosystem of Ganga supports around 2.82 million fisherfolk population. The Ganga river system has been experienced of habitat degradation of fish fauna due to several anthropogenic activities which may leads to rapid biodiversity loss including fish stock declination (Sarkar et al. 2012).

Fish along with fisheries resources provide an important role in improving social and economic status, besides generating employment opportunities (Akther et al. 2017). Fishing is considered as main occupation of fishers and contributes approximate 70% of total income of family in Bhagirathi-Hooghly stretch of river Ganga (Pandit et al. 2019). Livelihoods define the way of lifestyle which allows the people to live according to their needs through different activities (FAO, 2007). The studies on diversification of livelihood from a different country like Nigeria (Adeleke et al. 2013), Brazil (Giesbrecht, 2011), Bangladesh (Akther et al. 2017) indicate the issues related to artisanal fisheries and the economic vulnerability of small-scale fishers. Insufficient information regarding social, cultural and economical aspects leads to a serious issue related to social as well as economical conditon for the weaker section of fisher and creates difficulties in the improvement of their daily livelihood. By studying both the social and economic aspects of communities, we can manage fisheries and protect species in a way that works best for everyone. Economic and socio-cultural analyses help managers evaluate the benefits and costs of different activities, prioritize needs, and encourage policies that maximize societal benefits from natural resources. The present study described in details of educational level, household pattern, job opportunity, involvement in fishing, fishing experience, income generation, trend of fisheries and livelihood pattern of fisherman communities at Ganga River stretch. The present study also focused on social and economical aspects of fishers of river Ganga as well as fisherman involved in hilsa fishing at the lower stretch of Ganga.

Methodology

The ICAR-CIFRI conducted research on economic and socio-cultural aspects offishers'communities depending on river Ganga resources.

Sampling methodology

Focus-group discussion, community meetings were conducted to collect general information.A semi-structured interview schedule was developed and was used to collect data related to socio-personal and socioeconomic variables and the data thus obtained were statistically analyzed. The distribution of sampling stations and the sample size is described in Table 62.

Survey Period

The survey was conducted during September 2017 to December 2019.The present survey was planned to study the social, cultural and economic aspects of the fishermen community, specifically those involved in fishing activities in river Ganga. Semi-structured schedules were prepared and finalized after pretesting in some nearby villages.

Targeted Variables and their measurements

Table 61.Variables & Their Measurements

SlNo.	Variables	Measurements
A	**Socio-economic & Personal variables**	
1	Age	Direct questioning
2	Education	Direct questioning
3	Occupation	Direct questioning
4	Family size and Family Type	Direct questioning
5	Experience in Fishing	Direct questioning
7	Family income	Direct questioning and schedule developed
8	Social participation	Schedule developed

Study area coverage

A significant number of fisher population depend on fisheries of river Ganga to sustain their daily livelihood and nutritional security. Based on GSI information the total number offishingvillagesintheGanga riverstretch is 3795 which coversfivestates and 47 districts. The study was conducted across the lower, middle and upper stretch of the River Ganga in 24 selected districts from Uttarakhand to West Bengal (Fig. 225). Overall, 141 villages were surveyed and a total of 1059 fishermen were interviewed during the survey (Table 62). A combination of direct observation, household surveys with semi-structured interview schedule, focused group discussion with key informants (community leaders and resource users); and data collected from secondary sources, such as state-wise fisher's population censuses (Fig. 226) and fisheries records, were used to gather information and triangulate results.

Table 62. State-wise sampling station at Ganga river stretch

River Stretch	State	Station	Sample size
Upper stretch	Uttarakhand, Uttar Pradesh	Roorkee, Haridwar, Bijnor,Bulandsahar, Amroha	53
Middle stretch	Uttar Pradesh, Bihar, West Bengal	Farrukhabad, Kanauj, Kanpur,Kaushambi, Fatehpur Varanasi, Mirzapur, Prayagraj, Buxar, Patna, Bhagalpur	574
Lower stretch	West Bengal	Farakka, Murshidabad, Behrampore, Jangipur, Rejinagar, Jiaganj, Balagarh, Nabadwip, Swarupganj, Bally, D. Harbour, Godakhali, Fraserganj	446

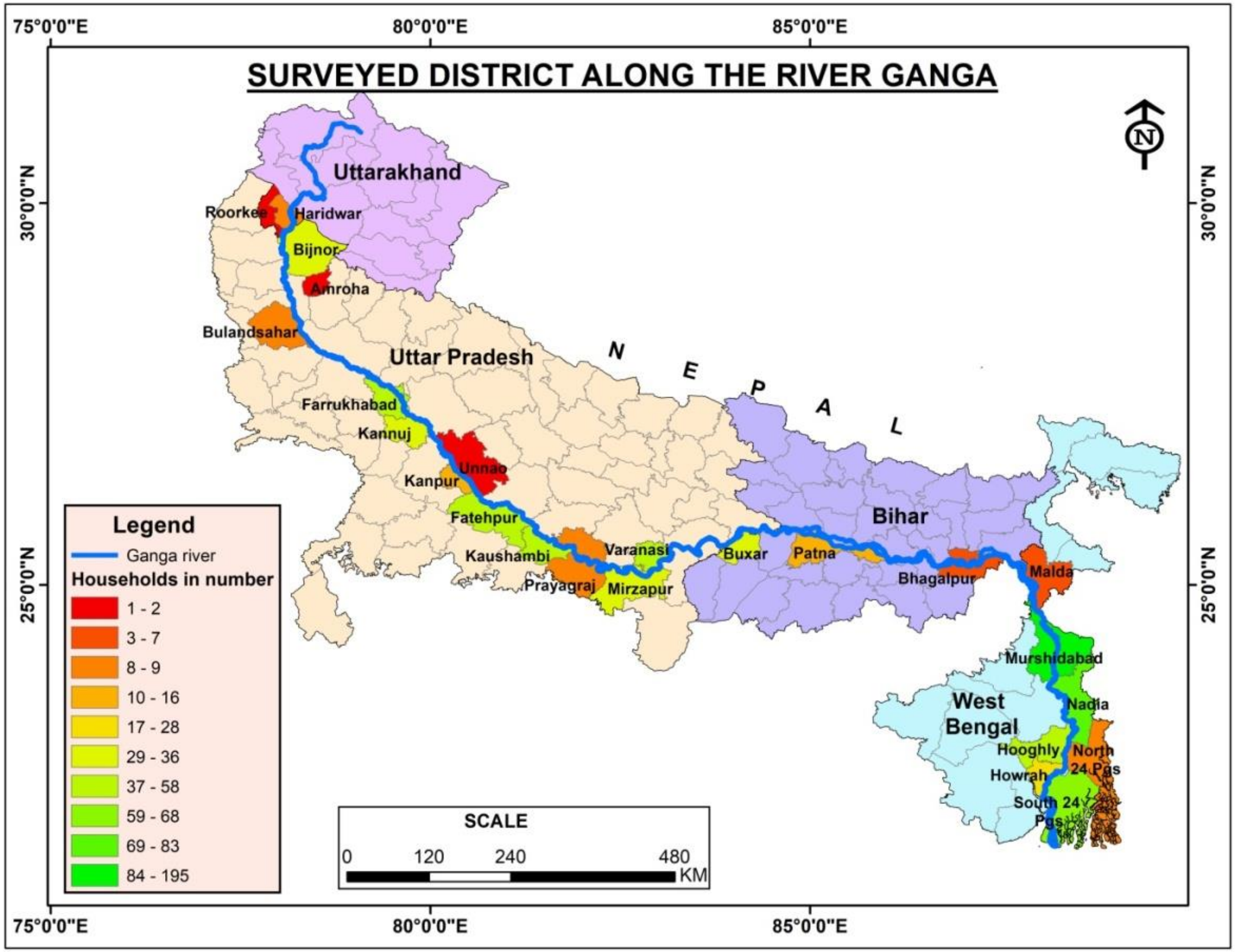

Fig. 225 Surveyed district along the River Ganga

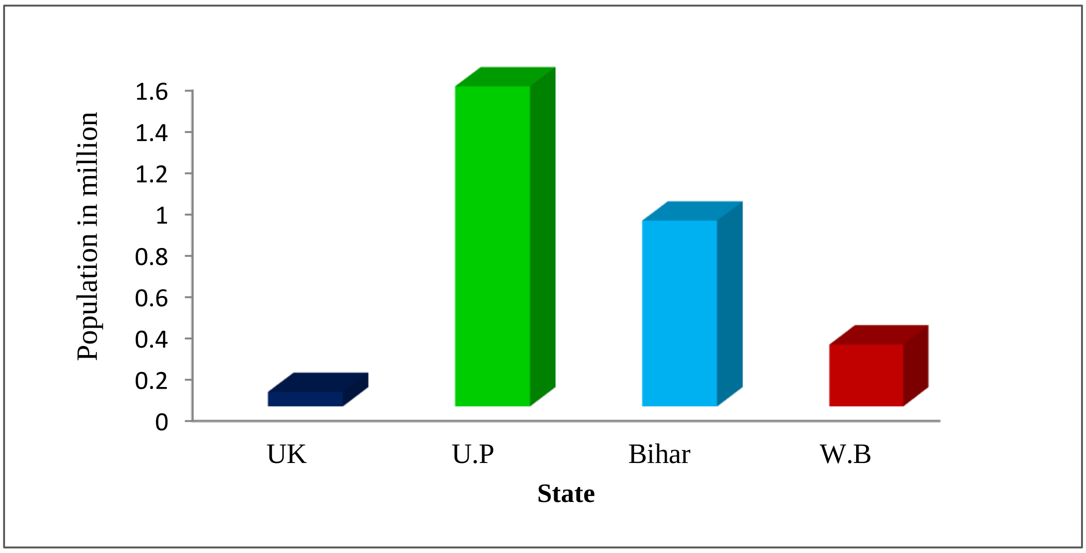

Fig. 226 Fisher's population along river Ganga (Source: Govt. of India Census report, 2011)

Demographic Characteristics

Table 63. Summary of Socio-economic Status of Fishers in Lower, Middle and Upper stretches of Ganga

Sl. No	Variables	Lower Stretch	Middle stretch	Upper stretch
1.	Average age	44.06	43.67	49.20
2.	Average years of education	3.17	3.55	1.47
3.	Average no of members in a family	6.15	7.9	7.09
4.	Average no male members in a family	2.56	3.16	2.63
5.	Average no of female members in a family	2.23	3.38	3.47
6.	Average no of children below 10 years in a family	1.67	1.71	1.37
7.	Average no of earning members in a family	1.86	2.24	1.1
8.	Average no of years in the fishing	29.04	24.48	29.97
9.	Average income of fisherman	Rs. 7283	Rs. 5866	Rs. 4345

Age Structure of Fishermen

The average age of fishermen in lower, middle and upper stretch of the river was found to be 44.06, 43.67 and 49.20, respectively. In all the stretches maximum percentage of fishermen fell in the category of 40 to 50 years of age (Fig. 227). Extent of youth (15 to 30 years of age) participation was less in all the three stretches with least youth participation found in the upper stretch. Uncertainty of income from riverine fishery may be the main reason behind it.

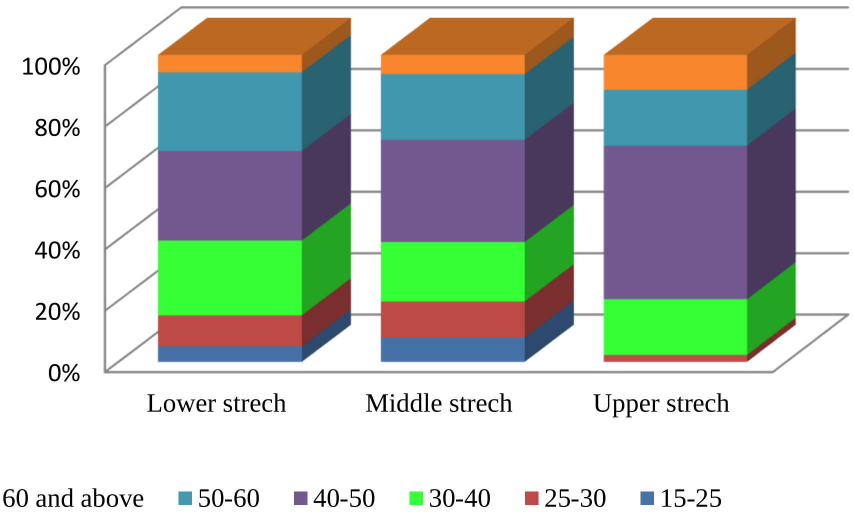

Fig. 227 Age structure of the fishermen

Education

The average years of education received by the fishermen were 3.17 years, 3.55 years and 1.47 years respectively in lower, middle and upper stretch of the river. About, 36.21%, 37.3% and 67.44% of fishermen belonged to the category of illiterate in lower, middle and upper stretch respectively (Fig.228). Around 21% of respondents were just literate in the upper stretch while in middle and lower stretch around 25% and 23% respondents respectively were found to have attended high school. Only in middle stretch three respondents were found to be graduates.

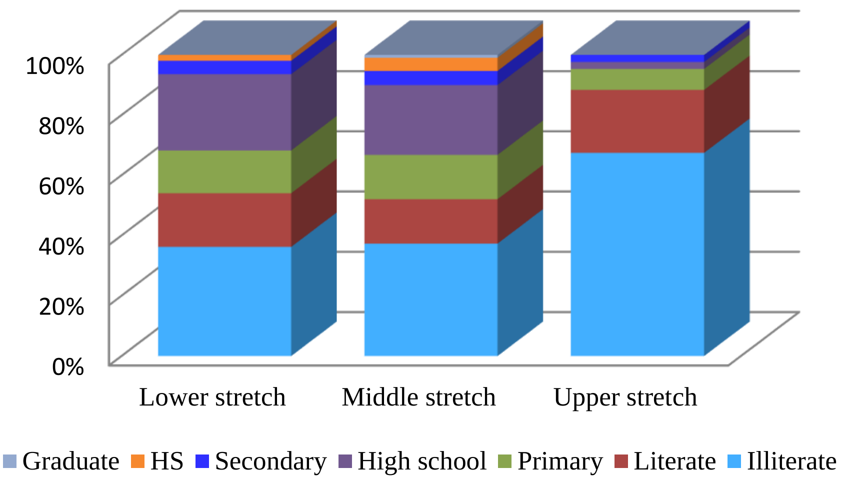

Fig. 228 Education level of the fishermen

Fishing Experience

Fishing experience indicates the degree of association of the fishermen with the fishery. On average, fishermen of lower, middle and upper stretch had 29.04, 24.48 and 29.97 years of fishing experience. The maximum proportion in lower and upper stretch had 21 to 30 years of experience while for the middle stretch the highest proportion of fishermen had 11 to 20 years of experience (Fig. 229.)

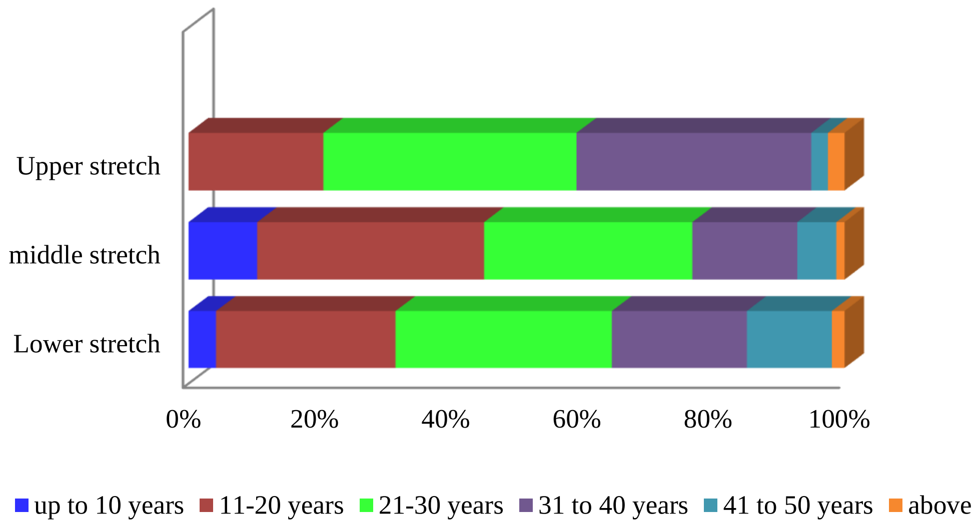

Fig. 229 Years of fishing experience

Income

Average monthly incomes of the fishermen were Rs. 7283, Rs. 5866, and Rs. 4345 in lower, middle and upper of the river, respectively. In upper stretch, all of the respondents stated to have income in the range of Rs. 0 to Rs. 5000 per month. Majority of the respondents in the middle and lower stretch reported to have monthly income in the range of Rs. 2000 to Rs. 6000 and Rs. 3000 to Rs. 12000 respectively (Fig. 230). Average monthly incomes of fishers were analysed in district wise (Fig. 231).

Income form fishing activities were estimated Rs. 243, Rs. 196 and Rs. 145 per day per fisherman from lower, middle and upper of the river, respectively.Whereas, income from river fishing was reported as Rs. 40.03 per day per fisherman (Tyagi, 2009).

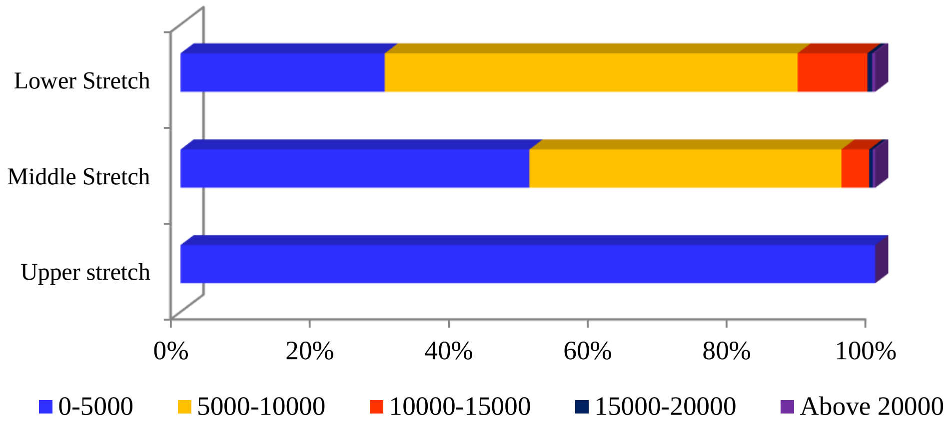

Fig. 230 Monthly income of fishermen

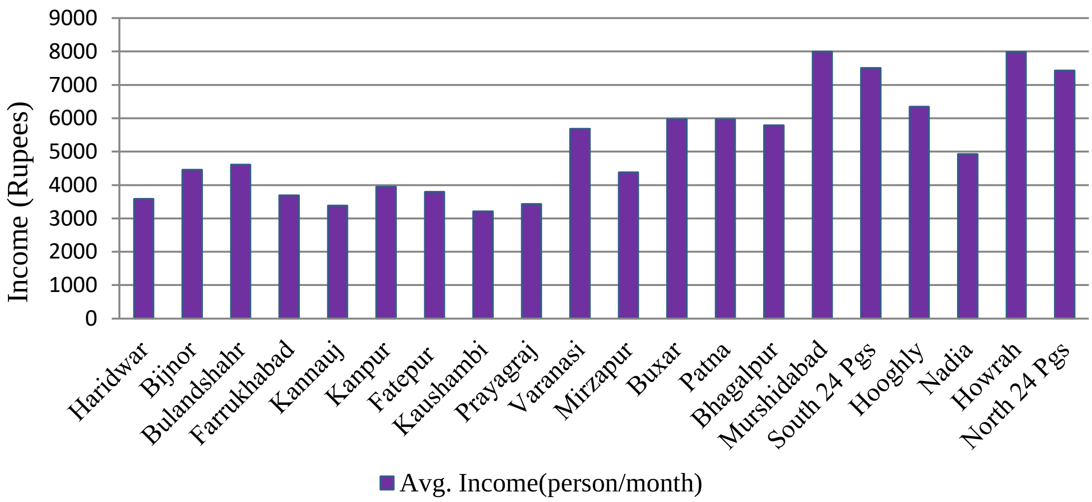

Fig. 231 Avg. monthly Income of fishers District wise at Ganga River Stretch

Occupational Pattern

Fishery is the primary occupation of the respondents. But, income is uncertain and seasonal in nature. In lower stretch 23.33% fishermen dependent on various types of work for earning additional money for their family. Most of the fishermen (25%) had fish selling as their secondary occupation followed by agricultural labourer(17.8%), other labour work (10.7%) and driving (10.7%) (Fig. 232). In middle stretch (Fig.233), 29.37% fishermen had secondary sources of income. Most of the fishermen were associated in labour work (41%) followed by spawn collection (16%) and agriculture (7.44%). In upper stretch (Fig. 234), 85% fisherman engaged with daily labour activities followed by 9% in different agricultural activities and 6% in small business.

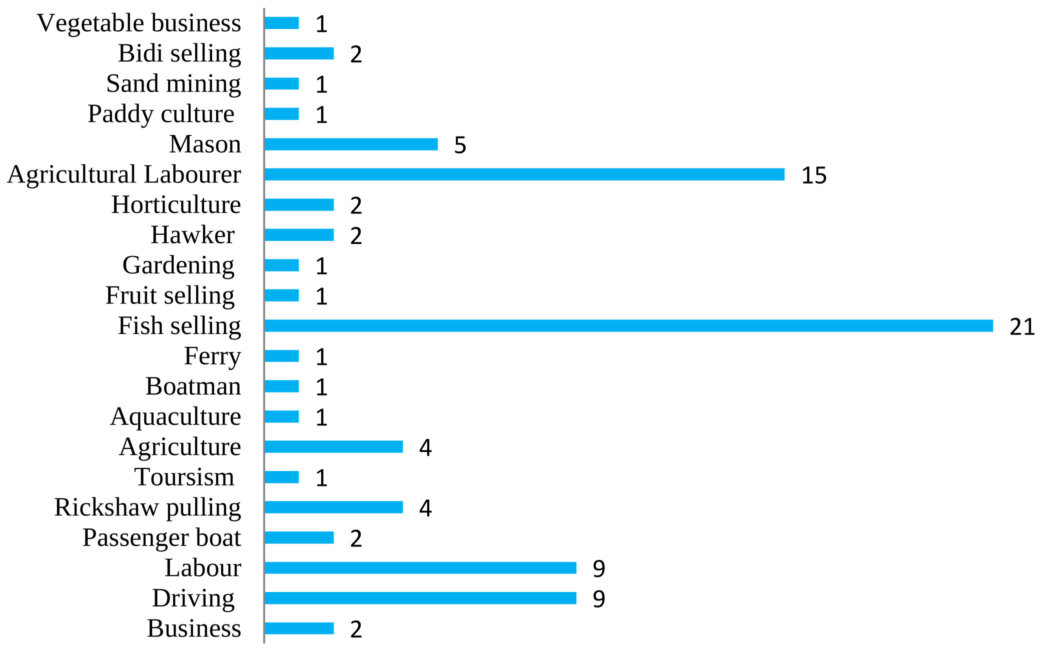

Fig. 232 Secondary Occupation of Fishermen at Lower Stretch(%)

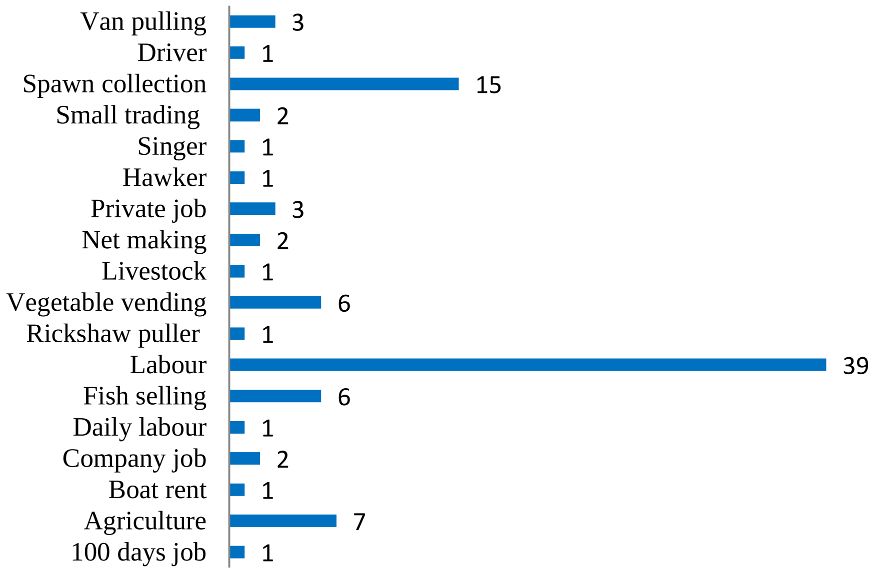

Fig. 233 Secondary Occupation of fishermen of Middle Stretch(%)

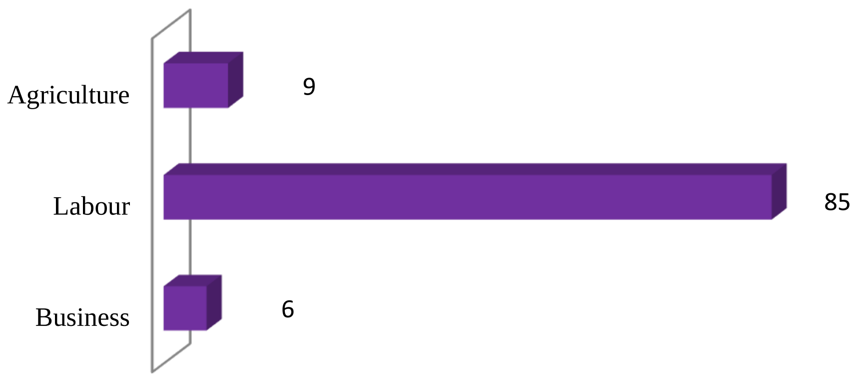

Fig. 234 Secondary occupation of fishermen of Upper stretch (%)

Fishing Gear Operation in River Ganga

Different type of fishing gear is operated at entire stretches of river Ganga. The operation depends on various aspects like targeted fishing group, water depth, tidal flow, etc. but the multispecies gear is most prevalent in middle and lower stretches of Ganga (Fig. 235). Hook and line is the most popular technique used in Uttarakhand where no other fishing gear was observed during the present study. Gillnet, dragnet, cast net and hook & line were observed in Uttar Pradesh and Bihar along with seine net. Different types of traps were also operated in the Bihar stretch of river Ganga. Several types of fishing gear were observed in the lower stretch of river Ganga. Gill net, seine net, drag net, cast net, lift net, set barrier, meenjaal, bag net, traps as well as hook and line were observed in West Bengal stretches.Various traps like Ghuni, Chokhia, Chai, Britti, Atal etc. are quite prevalent in lower stretch of Ganga.

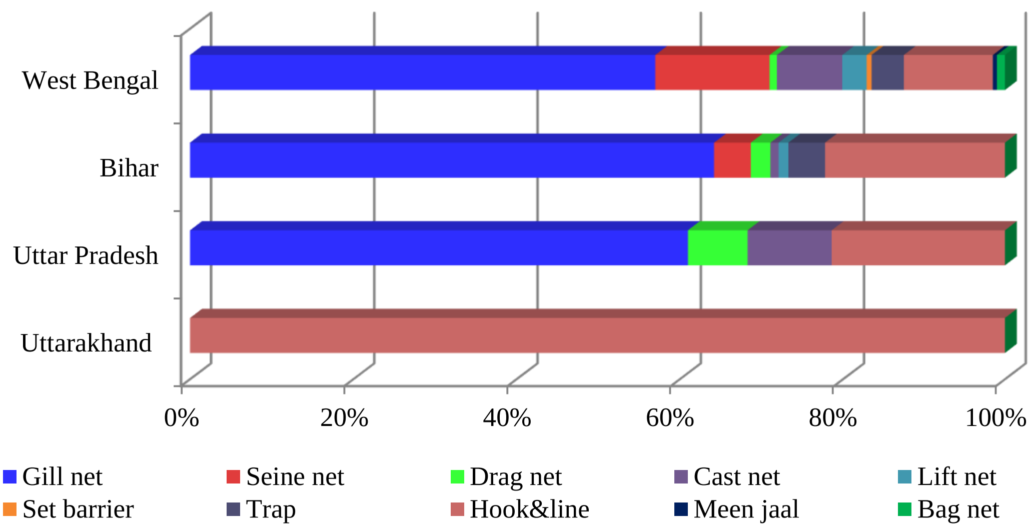

Fig. 235 State-wise Fishing Gear Profiling on River Ganga

Fishing Crafts in River Ganga

Different shape of fishing boats are used in River Ganga viz. wooden built indigenous boat, plank built boats, mechanized and non mechanized fishing boats (Fig. 236). Sometimes small primitive type of raft or tin made fishing boats called donga are used also. Tube is mostly used for fishing in Uttarakhand. However wooden boat of large, medium and small sized were found in Uttar Pradesh, Bihar and West Bengal as well as tin made donga also used for fishing.

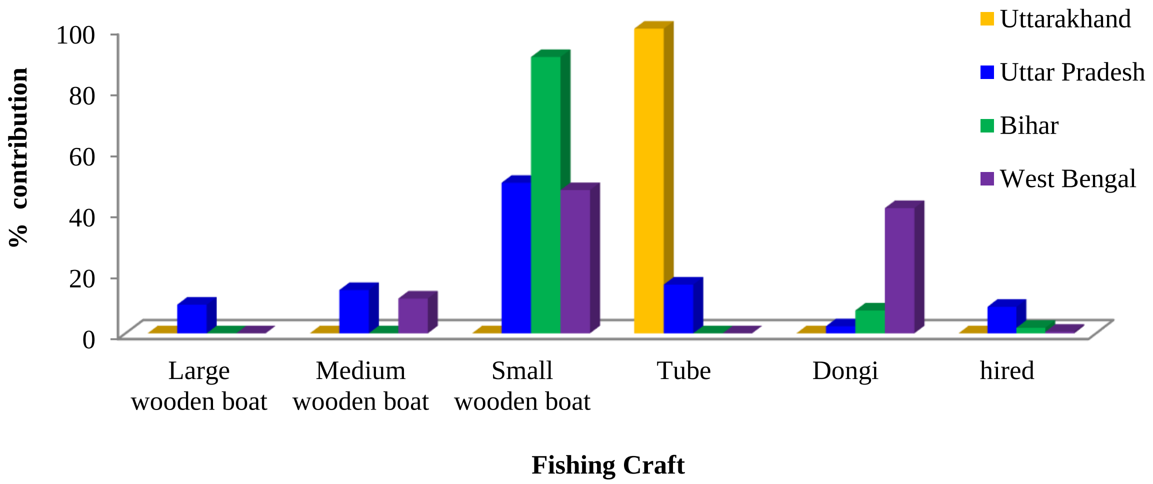

Fig. 236 State-wise Fishing Craft Profiling on River Ganga

Annual Freshwater Fish Catch Trends in River Ganga

The important fish species landed from the river Ganga were identified and commercially important fish grouped as Major carp (IMC), Catfish, Exotics and local major fishes. Catch per unit effort (CPUE) wasanalysed in station wise. Year-wise CPUE (freshwater fish catch) comparison revealed that catch from river Ganga has increased from 3796.57 t (2018-19) to 4263.55 t (2019-20). Based on the CPUE middle stretch (from Prayagraj to Farraka) contributing 47.5 % of total fish catch from river Gnaga in 2019-20 (Fig. 237).

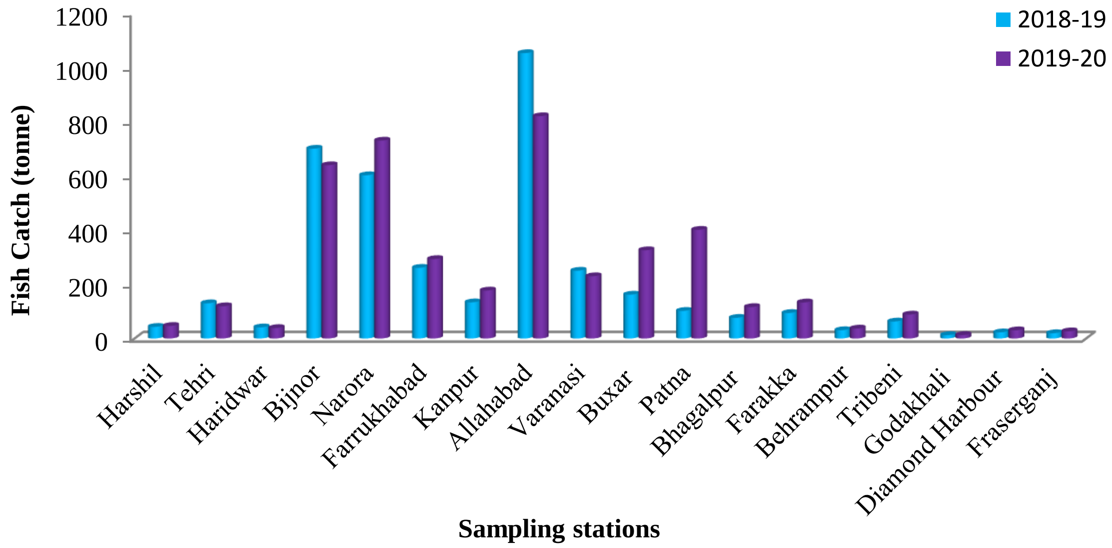

Fig. 237 Annual freshwater fish catch trends in river Ganga

Socioeconomic Factors for the Declining Fishery of Hilsa in River Ganga

The Hilsa fishery in India and Bangladesh is dependent on the single species, namely *Tenualosailisha*, belonging to the Indo-Gangetic and Brahmaputra river basins. In India, the fishery resource of the species largely lays in the Bhagirathi-Hooghly component of the Ganga river system. The lower part is around 523 km of river Ganga is consisted of Bhagirathi River stretch from Farakka to Nabadwip and Hooghly Estuary stretch from Nabadwip to Frezarganj area (Roy et al., 2016).

Tenulosa ilisha (Hamilton, 1822) popularly known as Hilsa shad is an important fish species in the lower stretch of river Ganga, having importance of economical, ecological and cultural aspects. The famous shad isalso highly demanded for incredible taste with high market prices. *T. ilisha* is a monsoon breeder with a high peak period of July to August in Hooghly River (Hora and Nair, 1940d; Hora, 1941b). 20,930 fishers were engaged in hilsa fishing operation at the lower stretch of river Ganga whereas 5600 fishers were reported from the upper stretch (Bhaumik and Shama, 2012). Annual family income of fishers' households from the Hilsa fishery around 38.84% at lower Ganga stretches (Roy et al., 2016). Bhaumik and Sharma (2012) reported that Hilsa fishery contributes 20-25% of the total fish landing of the Hooghly River. The annual fish catch of Hilsa from the Bhagirathi-Hooghly river system fluctuates greatly over the years.

According to the fishers of Hooghly- there are two seasons for Hilsa fishing; during monsoon i.e., middle June to middle September in the Hooghly-Bhagirathi river system. A major number of fishers almost 60% involved in Hilsa fishery were belonging to the Scheduled Caste known as ‘Malo’ or ‘Jele’ community and also from poorer families of society. Other groups were other backward communities (OBCs, 26%) followed by general (8%) and scheduled tribes (6%). Families pattern was observed as most of the family is nuclear in nature and average number of members of a family was five. The ratio of male and female was 1.14. Most Hilsa fishers had primary level (41.75%) education followed by secondary level (24.36%). However, 8.32% of the fishers had educational qualifications above the secondary level and 19.57% of the fishers were found illiterate. The age group of fishers involved in Hilsa fishing found predominantly belongs to middle age (32-54 years), followed by the old age group. Fishers spent 40% onHilsa fishery operation and 60% for household purposes. The annual average income from Hilsa fishery was reported rupees 67385 per annum per household. The rapid decline of Hilsa catch directly affects the socio-economic condition along with the living standard of fishers. As investigated by Roy et al, 2016 the reasons behind decline of hilsa fishery is tabulated in Table 64.

Table 64. Reasons behind decline of hilsa fishery **(**Source: Roy el al. 2016)

Sl No	**Reasons behind decline of hilsa fishery**	**Total Number of Respondents**	**Total Score**	**Mean Score**	**Rank**
1.	Use of destructive fishing gears	300	19820	66.06	I
2.	Erratic Rainfall	300	19362	64.54	II
3.	Huge catch of hilsa fish in lower part of Hooghly /sea mouth	300	18180	60.3	III
4.	Industrial pollution in Hooghly river	300	15691	52.3	IV
5.	Siltation in Hooghly river	300	12469	41.56	V
6.	Fresh water discharge/influx	300	10522	35.07	VI

There is an immediate need to formulate effective measures and also by-laws to protect precious breeders and potential breeding grounds for the development of a sustainable Hilsa fishery.

Strength, Weakness, Opportunity and Threat (SWOT) of Fishing Community along the River Ganga

Our study identified the strength, weakness, opportunity and threat of the fishers from their livelihood approach and represents these by SWOT analysis (Fig. 238). Intrinsically brave, physical strength, hardworking capacity, simple lifestyle, protein availability and women involvement in economic activities were strengths of the fishing community. Weaknesses included acute poverty, illiteracy, unemployment, poor infrastructure and linkage with a public and private organization, lack of capital and lower participation in the decision making. Vast water resources, scope of alternative income-generating sources, ecotourism, awareness rising through co-management practice were the opportunities for the fishing communities to develop their livelihood in a sustainable way. Fishers are facing some threats that included frequent occurrence of natural calamities, overexploitation, high dependency on natural resources, poor income and improper policy implication. A summary of the key strengths, weaknesses, opportunities and threats concerning the sustainable livelihood framework is given below (Fig. 238).

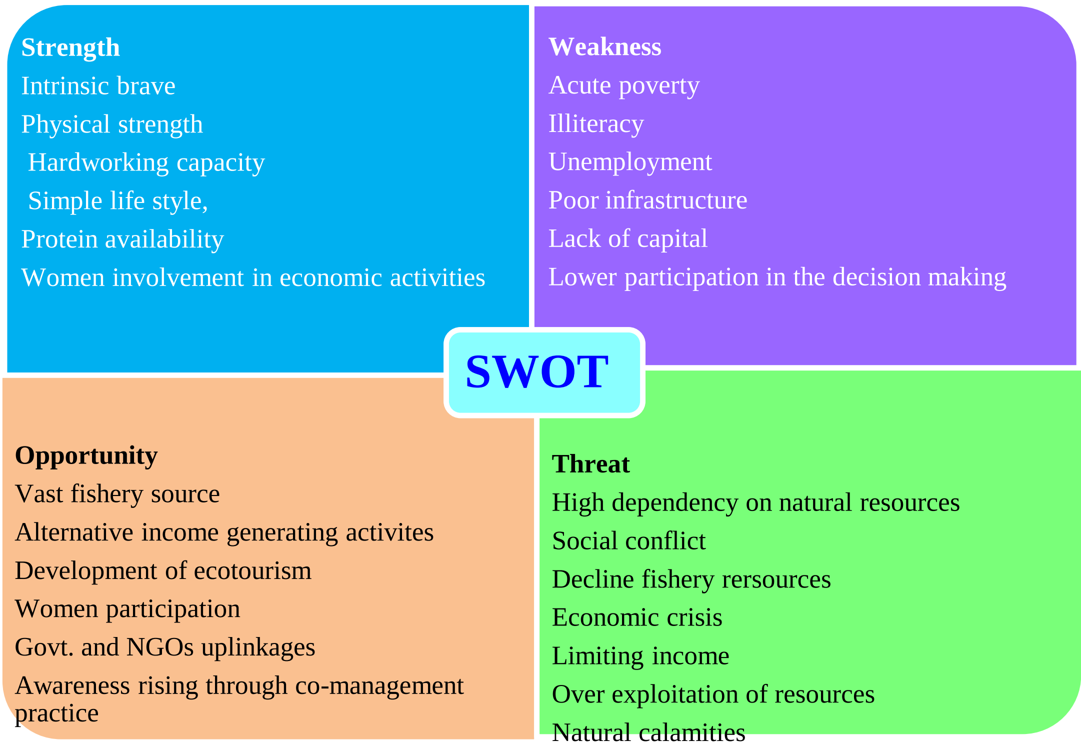

Fig. 238 SWOT analysis of the fishing communities of river Ganga

Conclusion

Fishing is an important income source contributing to the economy of fishing communities living on the banks of River Ganga. The study has carried out in 141 villages comprising 1059 fishermen from different stretches of River Gangato assess the socio-economic parameters of the fishermen of River Ganga. The study revealed various aspects of the social as well as the economic status of the fishers' community dependent on the Ganga fishery for their livelihoods.Most of the families of this area are directly involved in fishing to maintaintheir livelihood. It was found that the literacy status of the fishermen community waspoor. Fisheries-related activities form a major part of their total income and play a great role in their livelihood. The creation of alternative livelihood opportunities for fishers is vital for the current situation. Our present study based on the information collected through direct interaction by fisherman and some secondary sources inferred that River Ganga and its tributary contributing to improving fishermen's livelihood and support protein supply to Indian populations.However, declining fish catch day by day due to various reasons like climate change, pollution, irresponsible fishing, siltation, etc. have become threats to the sustainable riverine fishery. There is also a lack of sufficient baselineinformation to initiate proper developmental steps and to improvethe livelihood of fishermen. Hence, there is an urgent need to take measures to conserve and sustain the Ganga river fishery to secure the life and livelihoods of the millennia.

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Annexure I

Species		S1				S2					S3			S4			S5		Origin	IUCN status
Aborichthys elongatus Hora 1921[‡]	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Ailia coila(Hamilton 1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	NT
Ailiichthys punctata (Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	Native	NT
Alepes djedaba(Forsskål 1775)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Amblyceps mangois(Hamilton,1822)[‡]	-	-	-	+	+	-	-	-	-	+		+	+	-	-	-	-	-	-	Native	LC
Amblypharyngodon mola (Hamilton 1822)[†]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	LC
Anabas testudineus(Bloch 1792)[†]	-	-	-	+	+	+	+	+	+	+	+	-	+	+	+	+	-	-	-	Native	LC
Anguilla bengalensis (Gray 1831)[†]	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	Native	NT
Anodontostoma chacunda(Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	LC
Aplocheilus panchax (Hamilton,1822)[‡]	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	-	Native	LC
Apocryptes bato(Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	LC
Arius arius(Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	LC
Arius gagora(Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NT
Atropus atropos(Bloch & Schneider 1801)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Badis badis(Hamilton,1822)[‡]	-	-	-	+	+	-	-	-	-	-	-	-	-	+	+	+	+	-	-	Native	LC
Bagarius bagarius(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	NT
Bagarius yarrelli(Sykes 1839)[†]	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	Native	NT
Bangana dero(Hamilton 1822)[†]	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Barilius barila(Hamilton 1822)[‡]	-	+	+	+	+	+	+	+	+	-	-	+	+	-	-	-	-	-	-	Native	LC
Barilius vagra(Hamilton 1822)[‡]	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Batasio batasio(Hamilton 1822)[‡]	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	Native	LC
Bengala elanga(Hamilton 1822)[‡]	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Boleophthalmus boddarti(Pallas 1770)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	LC
Botia dario(Hamilton,1822)[‡]	-	-	-	-	+	-	-	-	+	+	+	+	+	+	+	+	-	-	-	Native	LC
*Botia lohachata*Chaudhuri 1912[‡]	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	-	Native	NE
Botia rostrata Günther 1868[‡]	-	-	-	-	-	-	-	-	-	+	-	-	+	+	+	+	-	-	-	Native	NE
Brachirus pan (Hamilton, 1822)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	LC
Brachygobius nunus(Hamilton 1822)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	NE
Bregmaceros mcclellandi Thompson 1840[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Brevitrygon walga (Müller & Henle 1841)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NT

Cabdio morar(Hamilton 1822)[†‡]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Chaca chaca(Hamilton, 1822)[‡]	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	Native	LC
Chagunius chagunio(Hamilton 1822)[†]	-	-	+	+	+	-	+	+	+	+	+	+	+	-	-	-	-	-	-	Native	LC
Chanda nama(Hamilton,1822)[†‡]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Channa gachua(Hamilton,1822)[†]	-	-	-	+	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	Native	LC
Channa marulius(Hamilton,1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	LC
Channa punctata (Bloch 1793)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Channa striata (Bloch 1793)[†]	-	-	-	+	+	+	+	+	+	-	-	+	+	-	-	-	-	-	-	Native	LC
Chelon parsia(Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Chirocentrus dorab(Fabricius 1775)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Chitala chitala(Hamilton,1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	NT
Cirrhinus mrigala(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Cirrhinus reba(Hamilton,1822)[†]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Clarias gariepinus (Burchell 1822)[†]	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	Exotic	LC
Clarias magur(Hamilton,1822)[†]	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	Native	*EN*
Clupisoma garua(Hamilton 1822)[†s]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
*Coilia dussumieri*Valenciennes 1848[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	LC
Coilia reynaldi Valenciennes 1848[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	LC
Corica soborna(Hamilton 1822)[†]	-	-	-	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	-	Native	LC
Ctenopharyngodon idella(Valenciennes 1844)[†]	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	Exotic	NE
Cynoglossus arel(Bloch & Schneider 1801)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	NE
Cynoglossus cynoglossus(Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	LC
Cynoglossus lingua (Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	LC
Cyprinus carpio var.*communis*(Linnaeus 1758)[†]	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	Exotic	VU
Cyprinus carpio var.*specularis* (Linnaeus 1758)[†]	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Exotic	NE
Devario devario(Hamilton 1822)[‡]	-	-	-	+	+	-	+	-	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Deveximentum insidiator(Bloch 1787)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Drepane punctata (Linnaeus 1758)[†‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Eleotris fusca(Bloch & Schneider 1801)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	Native	LC
Eleutheronema tetradactylum(Shaw 1804)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	NE
Epinephelus coioides(Hamilton, 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Erethistes hara (Hamilton 1822)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	Native	LC
Erethistes pusillus (Müller &Troschel1849)[‡]	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	Native	LC
Escualosa thoracata (Valenciennes 1847)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	LC
Esomus danrica(Hamilton 1822)[‡]	-	-	-	+	+	+	+	-	+	-	-	-	+	+	+	-	-	-	-	Native	LC
Eupleurogrammus muticus(Gray 1831)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Eutropiichthys murius(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	-	+	+	+	+	-	-	-	-	-	-	Native	LC
Eutropiichthys vacha(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Gagata cenia(Hamilton 1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	Native	LC
Gagata gagata(Hamilton 1822)[†‡]	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	Native	LC
Garra gotyla(Gray 1830)[†]	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
*Gerres filamentosus*Cuvier 1829[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Gerres oyena(Forsskål 1775)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Glossogobius giuris(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Glyptothorax cavia(Hamilton 1822)[†‡]	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Glyptothorax garhwali(Tilak, 1969)[†‡]	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Gogangra viridescens(Hamilton 1822)	-	-	-	+	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	Native	LC

Gonialosa manmina(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	Native	LC
Gudusia chapra(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Harpadon nehereus (Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	NT
Hemibagrus menoda(Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	Native	LC
Heteropneustes fossilis(Bloch 1794)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	LC
Hypophthalmicthys molitrix Valenciennes, 1844[†]	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	Exotic	DD
Hypophthalmicthys nobilis (J. Richardson, 1845)[†]	-	-	-	+	+	+	+	+	+	-	-	-	-	+	+	-	-	-	-	Exotic	DD
Hyporhamphus limbatus(Valenciennes 1847)[†‡]	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	+	+	+	Native	LC
Ilisha elongata(Anonymous [Bennett] 1830)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Ilisha megaloptera(Swainson 1838)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Johnius coitor(Hamilton,1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Johnius gangeticus (Talwar,1991)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	DD
Labeo angra(Hamilton 1822)[†]	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Labeobata(Hamilton 1822)[†]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Labeoboga (Hamilton 1822)[†]	-	-	-	+	+	-	-	+	+	+	-	-	+	+	-	-	-	-	-	Native	LC
Labeo calbasu(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Labeo catla(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Labeo dyocheilus(McClelland 1839)[†]	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Labeo gonius(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	-	+	+	-	-	-	-	-	-	Native	LC
Labeo pangusia(Hamilton 1822)[†]	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	NT
Labeo rohita(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Lagocephalus lunaris(Bloch & Schneider 1801)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Lates calcarifer (Bloch 1790)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	LC
Laubuka laubuca(Hamilton 1822)[‡]	-	-	-	+	+	+	+	+	+	-	-	-	+	-	-	-	-	-	-	Native	LC
Leiodon cutcutia(Hamilton,1822)[‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Lepidocephalichthys guntea (Hamilton,1822)[‡]	-	-	-	+	+	-	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Lobotes surinamensis(Bloch 1790)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Macrognathus aral(Bloch & Schneider 1801)[†‡]	-	-	+	+	-	+	-	+	+	+	-	-	+	-	-	-	-	-	-	Native	LC
Macrognathus pancalus(Hamilton,1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Mastacembelus armatus(Lacepède 1800)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Megalaspis cordyla(Linnaeus 1758)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Microphis cuncalus(Hamilton 1822)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	Native	LC
Minimugil cascasia(Hamilton,1822)[†]	-	-	-	+	+	+	+	+	+	+	-	-	+	-	-	+	+	-	-	Native	LC
Mystus bleekeri(Day,1877)[†]	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	Native	LC
Mystus cavasius(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Mystus gulio(Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	LC
Mystus tengara (Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	-	-	+	+	+	-	-	-	-	Native	LC
Mystus vittatus(Bloch 1794)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	Native	LC
Nandus nandus(Hamilton 1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	Native	LC
Nemapteryx caelata(Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	NE
Notopterus notopterus(Pallas 1769)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Nuchequula blochii(Valenciennes 1835)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Odontamblyopus rubicundus(Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	Native	NE
Ompok bimaculatus(Bloch 1794)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	NT
Ompok pabda(Hamilton,1822)[†]	-	-	-	+	+	+	+	+	-	-	-	-	+	+	-	-	-	-	-	Native	NT

Ompok pabo(Hamilton,1822)[†]	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	NT
Ophichthys cuchia(Hamilton 1822)[†]	-	-	-	+	-	-	-	-	-	+	+	-	+	+	+	-	-	-	-	Native	LC
Opsarius barna(Hamilton 1822)[†‡]	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Opsarius bendelisis (Hamilton 1807)[†‡]	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Opsarius tileo(Hamilton 1822)[†‡]	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Oreichthys cosuatis(Hamilton 1822)[†‡]	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Oreochromis niloticus(Linnaeus 1758)	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	Native	LC
Osteobrama cotio(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Osteogeneiosus militaris(Linnaeus 1758)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Otolithoides pama(Hamilton,1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	DD
Oxuderces dentatus(Eydoux&Souleyet 1850)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NE
Pachypterus atherinoides(Bloch 1794)[†‡]	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Pangasius pangasius (Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	LC
Pangio pangia(Hamilton,1822)[‡]	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Panna microdon(Bleeker 1849)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	LC
Paracanthocobitis botia(Hamilton,1822)[‡]	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	-	-	-	-	Native	LC
Parambassis baculis(Hamilton,1822)[†‡]	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-	+	+	-	-	Native	LC
Parambassis lala[†‡](Hamilton,1822)	-	-	-	+	+	+	-	+	+	-	-	-	+	+	+	+	-	-	-	Native	NT
Parambassis ranga(Hamilton,1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Parastromateus niger(Bloch 1795)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
*Pellona ditchela*Valenciennes 1847[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	LC
Pethia conchonius(Hamilton 1822)[†‡]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Pethia gelius(Hamilton 1822)[‡]	-	-	-	+	+	-	-	-	-	-	-	+	+	+	-	-	-	-	-	Native	LC
Pethia phutunio(Hamilton 1822)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	Native	LC
Pethia ticto(Hamilton 1822)[†‡]	-	-	+	+	+	+	+	+	+	-	-	-	+	+	+	-	-	-	-	Native	LC
Pisodonophis boro(Hamilton 1822)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	Native	LC
Planiliza tade(Fabricius 1775)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	DD
Platycephalus indicus[†](Hamilton 1822)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	DD
Polynemus paradiseus(Linnaeus 1758)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	LC
Pseudapocryptes elongatus (Cuvier 1816)[†‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	Native	LC
Pterygoplicthys disjunctivus(Weber 1991)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	Exotic	LC
Puntius chola (Hamilton 1822)[†‡]	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	Native	LC
Puntius sophore(Hamilton 1822)[†‡]	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Raconda russeliana(Gray 1831)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Raiamas bola (Hamilton 1822)[†]	-	-	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Rasbora daniconius(Hamilton 1822)[‡]	-	-	-	+	+	+	+	+	+	+	-	-	+	+	+	-	-	-	-	Native	LC
Rhinomugil corsula(Hamilton,1822)[†‡]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	Native	LC
Rita rita(Hamilton 1822)[†#]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Salmostoma acinaces(Valenciennes 1844)	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	Native	LC
Salmostoma bacaila(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Salmostoma phulo(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	Native	NE
Scatophagus argus (Linnaeus 1766)[‡]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	Native	LC
Schizothorax richardsonii(Gray 1832)[† #]	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	VU
Scoliodon laticaudus(Müller& Henle 1838)[†]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	NT
Securicula gora(Hamilton 1822)[†]	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	Native	LC

Setipinna brevifilis (Valenciennes 1848)†	-	-	-	-	-	+	+	-	-	+	+	-	+	-	+	-	-	-	-	Native	DD
Setipinna phasa(Hamilton 1822)†				+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	Native	LC
Setipinna taty(Valenciennes 1848)†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Setipinna tenuifilis(Valenciennes 1848)†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	Native	DD
Siganus javus(Linnaeus 1766)†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Sillaginopsis domina(Cuvier 1816)†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	NE
Sillago sihama(Fabricius 1775)†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	Native	LC
Silonia silondia(Hamilton 1822)†	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	Native	LC
Sisor rabdophorus(Hamilton 1822)‡	-	-	-	+	+	+	+	+	+	+	-	-	+	+	-	-	-	-	-	Native	LC
Sperata aor(Hamilton 1822)† #	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Sperata seenghala(Sykes 1839)† #	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	LC
Stolephorus baganensis(Delsman 1931)†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Systomus sarana(Hamilton 1822)†‡	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	LC
Tariqilabeo latius(Hamilton 1822)†	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	Native	LC
Tenualosa ilisha(Hamilton 1822)†	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	Native	LC
Terapon jarbua(Fabricius 1775)†‡	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	LC
Tor putitora(Hamilton 1822)†‡ #	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Native	EN
Trichiurus lepturus Linnaeus 1758†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	Native	*LC*
Trichogaster chuna(Hamilton,1822)‡	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	Native	LC
Trichogaster fasciata(Bloch & Schneider 1801)‡	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	LC
Trichogaster lalius(Hamilton,1822)‡	-	-	-	+	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-	Native	LC
Wallago attu(Bloch & Schneider 1801)†#	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	Native	VU
Xenentodon cancila(Hamilton,1822)†‡	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	Native	LC

Distribution pattern of recorded fishes in river Ganga arranged alphabetically (IUCN – International Union for Conservation of Nature; LC- Least concern, VU- Vulnerable, NT- Near threatened, EN- Endangered, NE- Not evaluated, DD- Data deficient; '+' indicates presence and '-' indicates absence of a particular species in a given site, † Food fish,‡Ornamental fish, # Sports fish

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