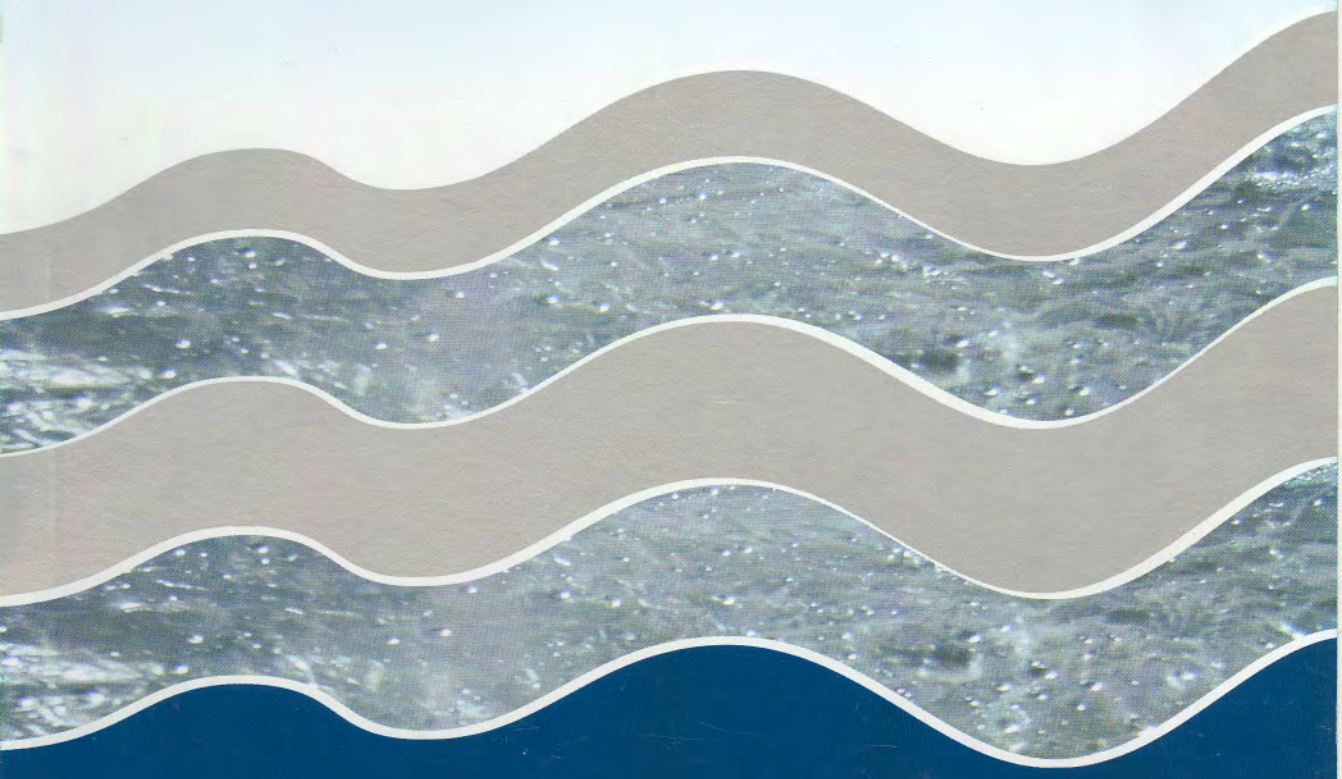
PRESENT STATUS OF HILSA IN HOOGHLY-BHAGIRATHI RIVER



भाकृअनुप
ICAR

केन्द्रीय अंतर्स्थलीय मात्स्यिकी अनुसंधान संस्थान
बैरकपुर, कोलकाता - ७०० १२०

CENTRAL INLAND FISHERIES RESEARCH INSTITUTE
BARRACKPORE, KOLKATA-700 120

PRESENT STATUS OF HILSA IN HOOGHLY-BHAGIRATHI RIVER

Dr. Utpal Bhaumik

Prof. A. P. Sharma

Bulletin no. 179

June 2012

केन्द्रीय अंतर्स्थलीय मात्स्यिकी अनुसंधान संस्थान
बैरकपुर, कोलकाता – 700 120
CENTRAL INLAND FISHERIES RESEARCH INSTITUTE
BARRACKPORE, KOLKATA – 700 120

PRESENT STATUS OF HILSA IN HOOGHLY-BHAGIRATHI RIVER

Dr. Utpal Bhaumik
Prof. A. P. Sharma

Credits

Photography & Cover

Mr. Sujit Chowdhury
Mr. M. Roy

Graphics and compose

Ms. Sritama Bose
Ms. Debashree Das
Mr. Shamik Ranjan Ghosh

ISSN 0970 – 616X

Published by : ***The Director***
Central Inland Fisheries Research Institute, Barrackpore

Printed by : Eastern Printing Processor
93 Dakshandari Road, Kolkata 700 048

Foreword

Indian shad (*Tenualosa ilisha*) commonly known as hilsa is a highly prized fish in India. It is an important migratory species in the Indo-Pacific region. The Ganga and Brahmaputra River System are the largest drainage where hilsa is prevailing. It is widely distributed species under clupeid, inhabiting the coastal waters mainly from Bay of Bengal and ascending most of the estuaries, rivers and backwaters for the purpose of breeding. The present account portrays an overview of hilsa fisheries in the Hooghly-Bhagirathi river system. Many workers have worked on hilsa during the last few decades, but present scenario in respect of the hydrology, habitat, climate change and negative human interventions has changed to a large extent. In the backdrop of such changes, the migration, growth, maturity, spawning behaviour have also changed. Indiscriminate capture of brood fish and juveniles and over-exploitation have been identified as the most dominating characteristics affecting the hilsa fishery of river system. It is believed that we have to undertake necessary conservation measures for ensuring sustainable hilsa fishery. This compendium portrays the present status of hilsa fishery in Hooghly-Bhagirathi river system *vis-à-vis*. conservation strategies. I believe that it will be highly useful for the students, researchers and other concerned agencies towards enrichment of their knowledge besides policy makers to plan effective conservation measures to conserve and harness hilsa fishery on sustainable manner..

Prof. A. P. Sharma
Director

June 25, 2012

Content

Introduction

The Indian shad, *Tenualosa ilisha*, popularly known as hilsa, belongs to the sub-family Alosinae of Family Clupeidae. The hilsa has established itself as one of the most important commercial fishes of the Indo-Pacific region. It has a wide range of distribution and occurs in marine, estuarine and riverine environments. The fish is found in the Persian Gulf, Red Sea, Arabian Sea, Bay of Bengal, Vietnam Sea and China Sea.the riverine habitat covers the Satil Arab and the Tigris and Euphrates of Iran and Iraq, The Indus and Pakistan, the Irrawaddy of Mayanmar, the rivers of eastern and western India namely the Ganga, Bhagirathi, Hooghly, Rupnarayan, Brahmaputra, Godavari, Narmada, Tapti and other coastal rivers and the Padma, Jamuna, Meghna, Karnafuly and other coastal rivers of Bangladesh. In fact, the hilsa fishery in India and Bangladesh is dependent on the single species *viz. Tenualosa ilisha* belonging to the habitats of Indo-Gangetic and Brahmaputra river basins (Fig. 1).

Fig 1. Freshwater Habitats of Hilsa in Indo-Gangetic and Bramhaputra River system

Presently three species under the Genus Tenualosa viz., *Tenualosa ilisha* (Hamilton-Buchanan), *T. toli (*Valenciennes),*T. kelle* (Couvier) have been recognized from the estuaries and coastal waters of India. The normal habitat, trend of migratory habit, maximum age and growth differ from species to species. Since, these species constitute prized hilsa fishery, they are subject to heavy fishing pressure and its irresponsible exploitation results in decline in catch. Among these three species, only *T. ilisha forms commercially fishery* and scarcely *T. toil and T. kelle* are available in Indian waters. Thus, *T. ilisha* constitutes the hilsa fishery of the Ganga river system.

Fig. 2. Hilsa (*Tenualosa ilisha*), the Indian shad

The river Ganga is the most important river system in India and one of the largest in the world. The river system covers upland stream, warm water, swampy and deltic habits during its run from upper Himalayas to the Bay of Bengal. Many tributaries join the Ganga in its course through the plain. The Yamuna is the most important tributary and meets the Ganga on its right bank at Allahabad. From Allahabad the river flows eastwards and after its entry into the state of West Bengal, the river water is regulated through a barrage at Farakka. The main chanel after Farakka barrage, flows in a southeasterly direction through Bangladesh known as the river Padma where it meets the Brahmaputra river, finally leading to the Bay of Bengal (Fig. 1). A 41 km long man-made feeder canal arises from upstream of the barrage and meets the Bhagirathi river at Jangipur in the south. Then the Bhagirathi passes through for about 150 km and thereafter, it joins with the Hooghly estuary at Nabadwip. The Hooghly flows through Kolkata and finally leading to the Bay of Bengal. The present study pertains to the total stretch of Hooghly- Bhagirathi river system.

Status of hilsa fishery of the Hooghly-Bhagirathi river system

The Institute has been conducting research intensively for last two years all along the stretch of 523.59 km of the Hooghly-Bhagirathi river system at selected sampling sites located between 24°27.253'N, 87°54.470'E and 21°34.834'N, 88°14.223'E, namely Farakka, Lalbagh, Nabadwip, Kalna, Balagarh, Tribeni, Hooghly Ghat, Nawabganj, Baranagar, Bally, Nimtala ghat, Godakhali, Raichawk, Diamond Harbour, Nischintapur, Harwood Point and Frazergunj.

(Source: Google Earth)
Fig 3. Hooghly-Bhagirathi river system and sampling sites

Nutritional importance of hilsa

While studying the nutritional importance of hilsa , Mohanty *et. al*, 2011 indicated that the fish is endowed with valuable fatty acids and lipids which play a major role in providing pharmaceutical elements for physiological; maintenance of body tissue. Polyunsaturated omega-3 fatty acids (ω-3 PUFAs) EPA and DHA especially obtained from fish oil are reported to be potential in curing coronary heart diseases, stroke, hypertension, cardiac arrhythmias, diabetes, rheumatoid arthritis, brain development, photoreception system, cancer and depression. A 100 g hilsa contain 22.0 g Protein, 19.5 g Fat, 180 mg Calcium and 250mg of Phosphorus along with other nutrients.

Table 1 : Total amino acid profiles (in % of total amino acid) *Tenualosa ilisha*

Amino Acid	Small Size	Medium Size	Large Size
Essential			
Threonine	ND	6.32±0.17a	7.10±0.03a
Valine	6.58±0.81a	6.35±0.21a	5.80±0.81a
Methionine	3.30±0.29a	1.63±0.10b	2.72±0.02c
Iso leucine	5.35±0.12a	6.20±0.21b	4.69±0.58a
Leucine	9.25±0.33a	9.33±0.35a	8.03±0.06b
Phenylalanine	4.16±0.14a	3.71±0.42b	3.43±0.38b
Histidine	6.31±0.10a	5.47±0.41b	5.94±0.21a
Lysine	3.22±0.03a	2.35±0.25b	10.15±0.05c
Arginine	1.25±0.13a	0.94±0.03b	0.72±0.01c
ΣEAA	39.42	42.3	48.58
Non-essential			
Aspartic acid	10.48±0.04a	11.25±0.40	10.21±0.06
Serine	6.56±0.13a	7.02±0.31b	5.99±0.13c
Glutamic acid	15.16±0.47a	15.39±0.22a	13.06±0.06b
Glysine	8.46±0.39a	9.01±0.21b	8.22±0.25a
Alanine	9.34±0.28a	9.59±0.15a	8.45±0.04b
Tyrosine	1.92±0.54a	1.39±0.16a	0.84±0.16b
Proline	0.20±0.05a	1.34±0.39b	0.91±0.10b
Cysteine	0.32±0.03a	0.95±0.04b	2.11±0.06c
ΣNEAA	52.44	55.94	49.79
EAA/NEAA	0.75	0.76	0.98
Values are shown as average ± standard deviation (Source – Mohanty *et al.*, 2011)			

Besides fatty acids, hilsa is also sude in amino acids. A high plasma EAA-to-NEAA ratio is considered to be an index of positive protein nutritional status (Table 1).

The paramount importance of the hilsa in nutritional point of view is all the more enhanced by the presence of minerals. These micronutrients play a major role in the metabolic activity of the human body, by serving as co-factors of enzymes. The microelements (*viz.* Na, Mg, K and Ca) and trace elements (*viz.* Mn, F, Cu, Zn*)* are present in hilsa in good amount and their concentration per 100 g wet weight of hilsa (*Tenualosa ilisha)* are given in Table 2. These minerals are highly 'bioavailable' meaning that they are easily absorbed by the body.

The long chain PUFA (LC-PUFA) (i.e., C20 and C22) that belong to the omega (ω)-3 family, have a number of neutraceutical and pharmaceutical applications. Eicosapentaenoic acid (EPA, 20:5 ω3) and decosahexaenoic acid (DHA, 22:6 ω3) are the important ω3 PUFA. EPA and DHA are important in treatment of arthrosclerosis, cancer, rheumatoid arthritis, psoriasis and diseases of old age such as Alzheimer's and age-related macular degeneration (AMD).

Table 2: Concentration of macro and trace elements per 100 g wet weight of *hilsa*

Elements	Small	Medium	Large
Macro elements			
Na	47.95±0.04a	44.97±0.01b	34.35±0.02c
Mg	2.59±0.07a	0.84±0.02b	-
K	42.43±0.05a	41.88±0.03b	0.97±0.02c
Ca	331.16±0.10a	261.67±0.09b	252.05±0.03c
Trace elements			
Mn	0.13±0.02a	-	0.34±0.03c
Fe	0.14±0.03a	0.21±0.02b	0.16±0.02c
Cu	0.21±0.04a	0.13±0.02b	-
Zn	0.51±0.02a	0.47±0.02b	0.27±0.02c
(Mohanty *et. al*, 2011)			

Omega-3 fatty acids are considered a boon to human beings. Body functions are improved by their intake. Brain is a vital organ that keeps the body functions in proper control. These fatty acids increase the volume of grey matter which is associated with mood and regulation of emotions. The risk of dementia and Alzheimer's disease is also checked by them. They also boost the cognitive functions in elderly people, and there is improvement in osteoarthritis by prevention of loss of cartilage that acts as a cushion in the joints and checks inflammation. They protect against prostrate and breast cancer by stimulating the deaths of tumor cells. These fatty acids increase HDL cholesterol and reduce triglycerides, a condition that is favorable for the heart. These keep the blood in fluid state by decreasing platelet aggregation.

Although omega-3 fatty acids have been known as essential to normal growth health since the 1930s, awareness of their health benefits has dramatically increased the past few years. The heart-health benefits of the long-chain omega-3 fatty acids – DHA and EPA – are the best known.

Scenario of the hilsa fisheries in the Bhagirathi-Hooghly river system

Hilsa is the major component of fishery in the Hooghly-Bhagirathi river system accounting for about 20-25% of the total fish landing. The annual fish catch of hilsa from the Hooghly-Bhagirathi river system is highly fluctuating over the years (Fig 5). During pre-Farakka barrage period (1957-74), the annual landings of this species varied between 114 and 6573 t with an average of 1,427.6 t. But, increased level of yield was observed during post-barrage period. The average annual harvest of hilsa was

recorded as 2,471 t and 6,370 t during 1975-76 to 1990-91 and 1991-92 to 1998-99 respectively (Annual reports, CIFRI). Hilsa landings in the Hooghly-Bhagirathi river system during 2000-01 to 2011-12 varied between 12,733 and 77,912 t (Department of Fisheries, West Bengal). The observations on production indicates that tremendous increase in effort from nineties with improvement of mechanization to catch this higher congregation of hilsa in the estuary mouth also contributed to this many-fold increase of hilsa landing. In general, about 80-90 percent of the hilsa is captured during monsoon months (July to October). Based on the investigation conducted at the Institute, it can be stated that commercial hilsa fishery exists with the mean fish length varying in the range of 300 mm to 500 mm during June-August, in the middle range of 300 mm to 480 mm during September-November and in the lower range of 285 mm to 430 mm during January to March (Bhaumik and Sharma, 2011c).

Fig 4. Harvested Hilsa ready for transport

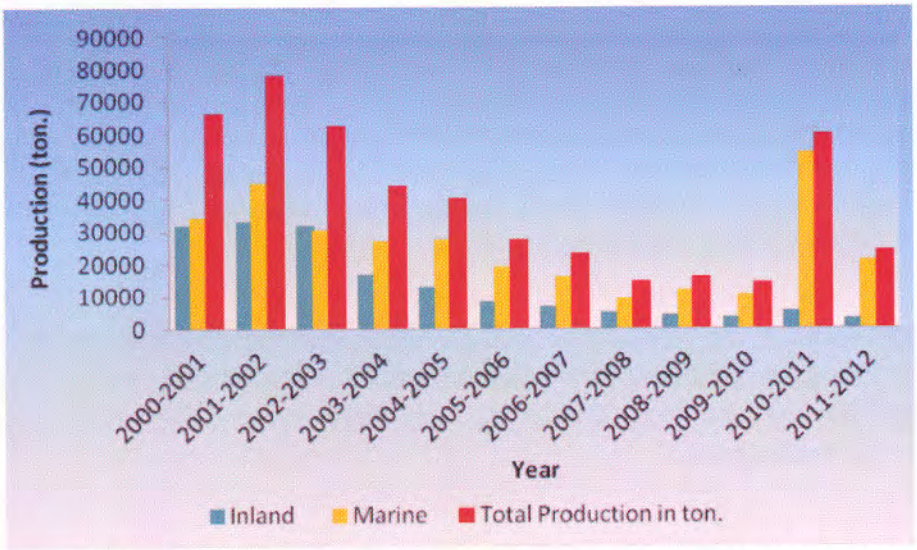


Fig 5. Total Hilsa catch of Hooghly-Bhagirathi river system during 2000-2001 to 2010-12

Meteorological observations

Perusal of the Fig 6 and Fig 7 reveals that month-wise average rainfall during 2010 was almost static between May to August (123.0-169.0 mm) with little rise in September (288.5 mm). Low rainfall and resultant shortfall in required depth and related hydro-ecological conditions affected the breeding migration and population recruitment of hilsa during 2011. Rainfall during 2011 was much higher with rising trend from June

onwards and attained peak during August (646.8 mm). The temperature was higher (24.24-34.31°C) during June to October in 2010 compared to 2011-12 (22.20-32.87°C) for the same period. The impact of inadequate rainfall and temperature variation on breeding failure in 2010 was reflected in the magnitude of migration *vis-a-vis* poor catch of hilsa in following 2011.

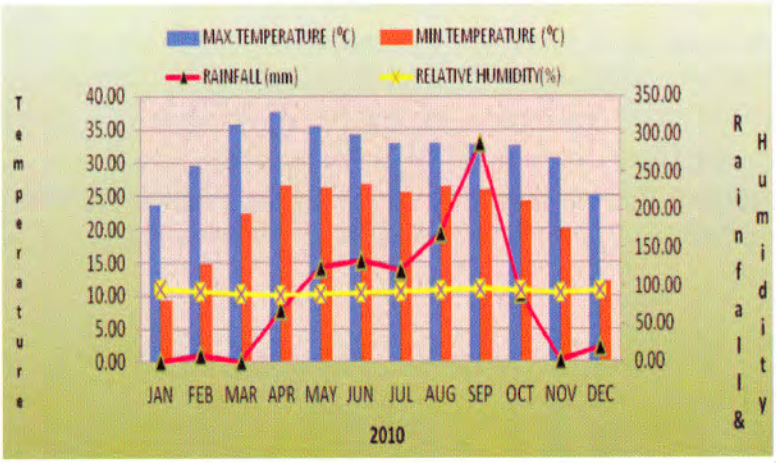


Fig 6. Variation in Temperature (Max-Min), Rainfall & Humidity in 2010

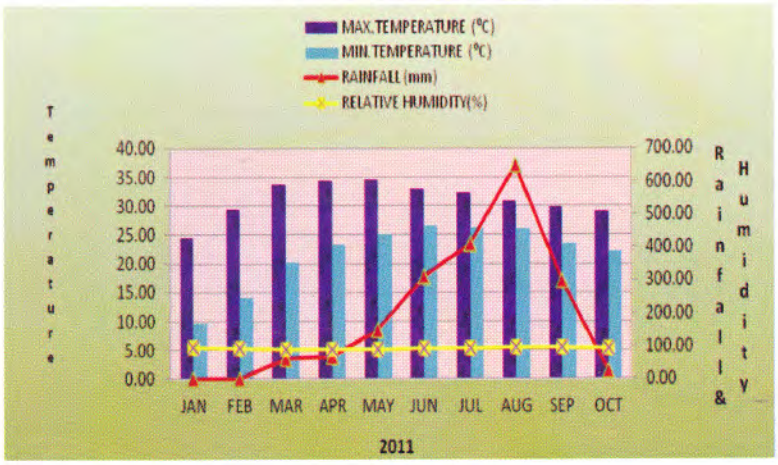


Fig 7. Variation in Temperature (Max-Min), Rainfall & Humidity during January-October, 2011

Hydrographical observations

Hydrography is the mapping of water topographic features through the measurement of the depth (besides other parameters) which plays pivotal role towards migration and spawning of Hilsa. So, depth of the system was studied regularly.

Depth

Depth profile (Fig 8) revealed unevenness of the river-estuarine course, which varied with tidal amplitude and volume of river discharge. Depth was as high as 58-68 ft (17.67-20.42 m) between Hooghly Ghat and Kalna and 60 ft (18.28 m) around Lalbagh in July-August. From September onwards the depth in upper reaches decreased whereas it increased in the lower zone below Diamond Harbour. The remaining part of the river-estuarine course was comparatively shallower with the depth ranging between 38 ft (11.58 m) and 45 ft (13.71 m) in monsoon and further reduction in post-monsoon period.

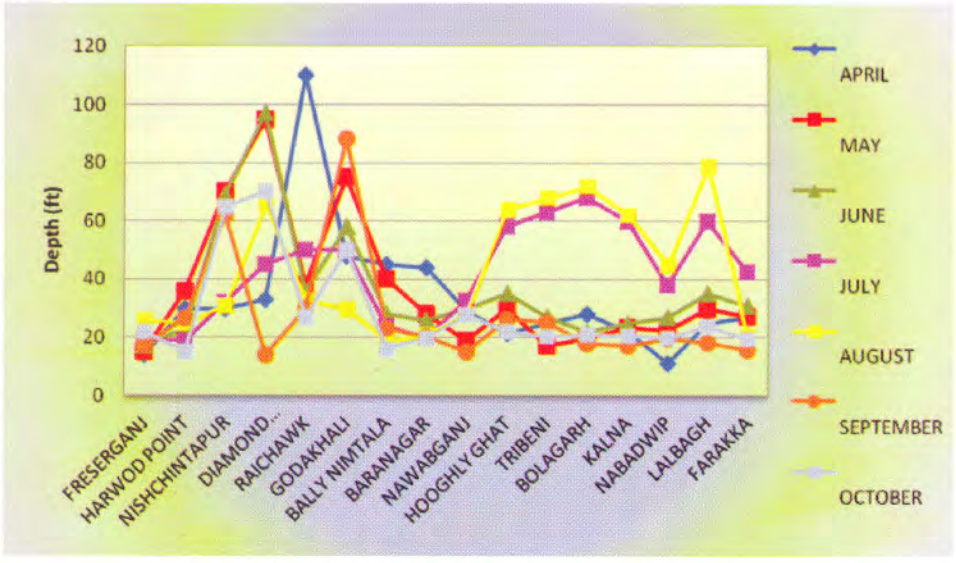


Fig 8. Variation in depth at different sampling centres.

Hydrological observations

Hydrological investigation included the study of Turbidity, Water Temperature, Transparency, Total Suspended Solids, Dissolved Oxygen, pH, Salinity and Chlorophyll in situ. Hydrological information is important since hilsa needs favourable water conditions for its migration and spawning.

Fig 9. Colletion and analyse of water samples *in situ*

Turbidity

Turbidity of river-estuarine waters (Fig 10 & 11) increased by 60 to 110% following monsoon discharge in July. The value increased in the upper reaches (120-140 NTU) between Farakka and Nawabganj at the initial stage in July. In August, there was a change in turbidity distribution pattern and was comparatively more between Balagarh and Nawabganj and further down near Godakhali-Harwood point area.

Fig 10. GIS Mapping for Turbidity

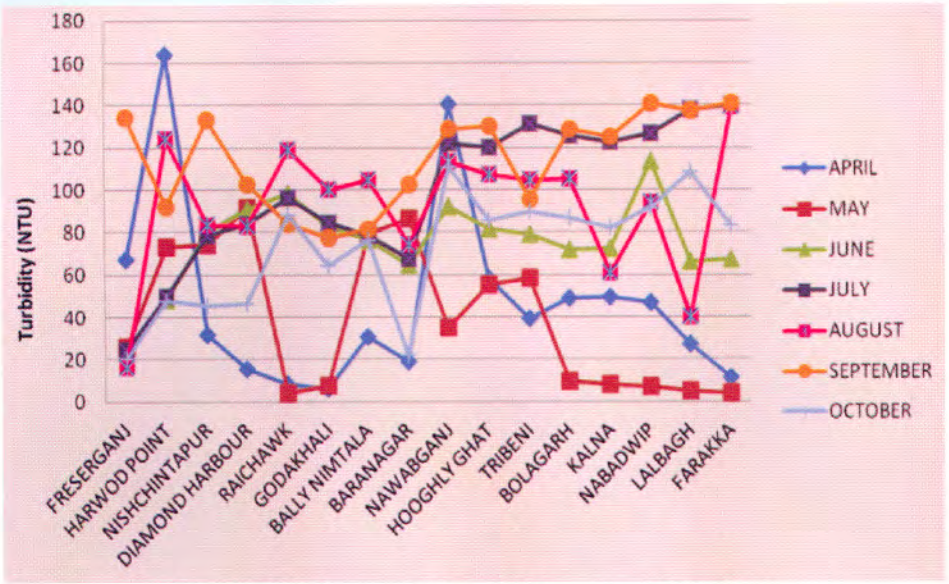


Fig 11. Variation in turbidity at different sampling centres.

Water temperature

The perusal of the Fig. 12 & 13 indicates that the ambient temperature of the water ranged between 23.8 and 33.3^{0}C during April to October 2011 and showed zonal variation. The lower zone recorded comparatively lower temperature (23.8-32.0^{0}C) while it was higher in freshwater tidal zone (29.1 to 33.3^{0}C). In upper region the temperature was again low (27.5-32.1^{0}C). The low temperature in lower zone may be due to the marine influence.

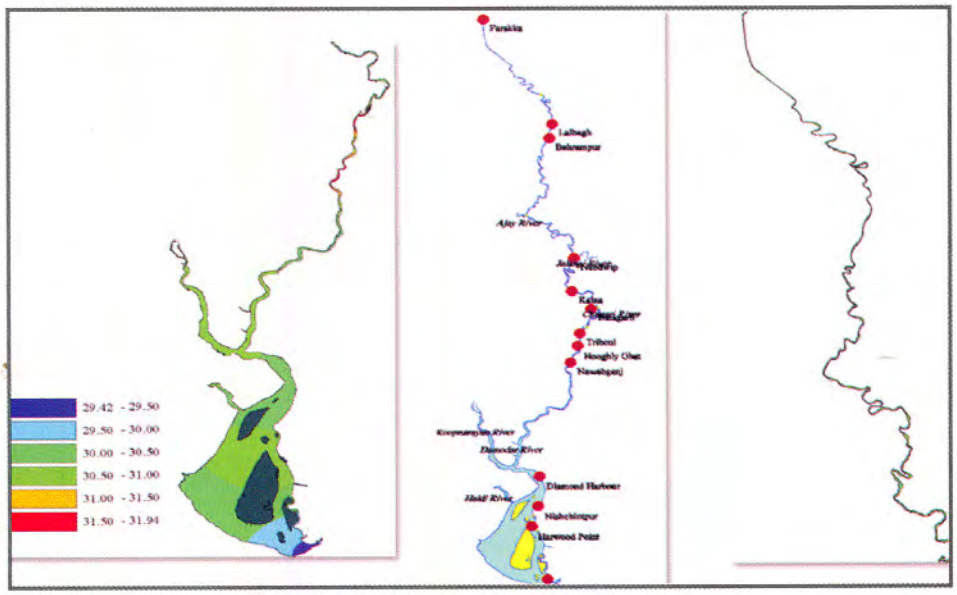


Fig. 12. GIS Mapping for Water Temperature

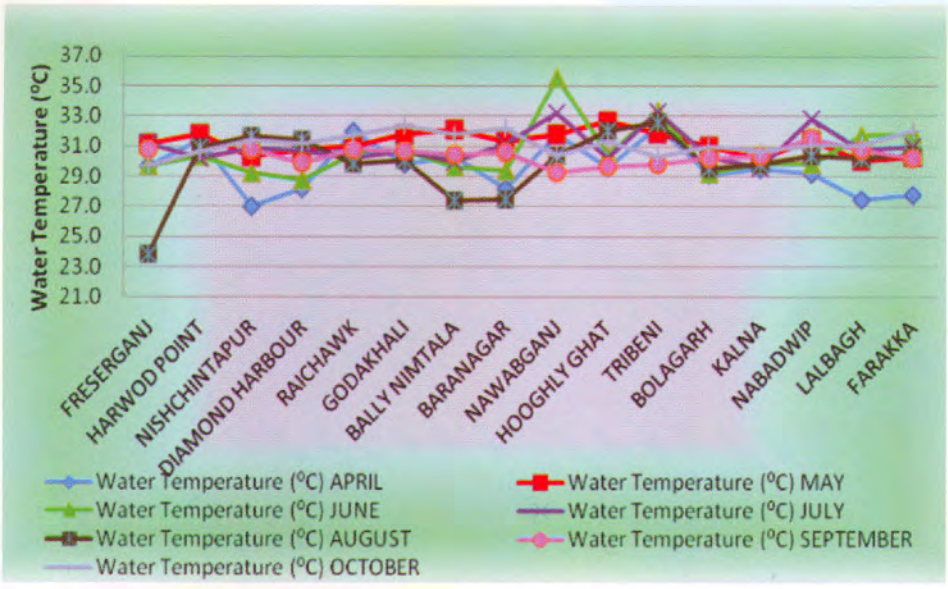


Fig 13. Variation in temperature at different sampling centres.

Transparency

Water transparency (Fig 14 & 15) decreased following monsoon discharge in entire stretch of investigation. Transparency increased in post-monsoon period, which was in favour of high photosynthetic activities and overall improvement in the ecological environment.

Fig. 14. GIS Mapping for Transparency

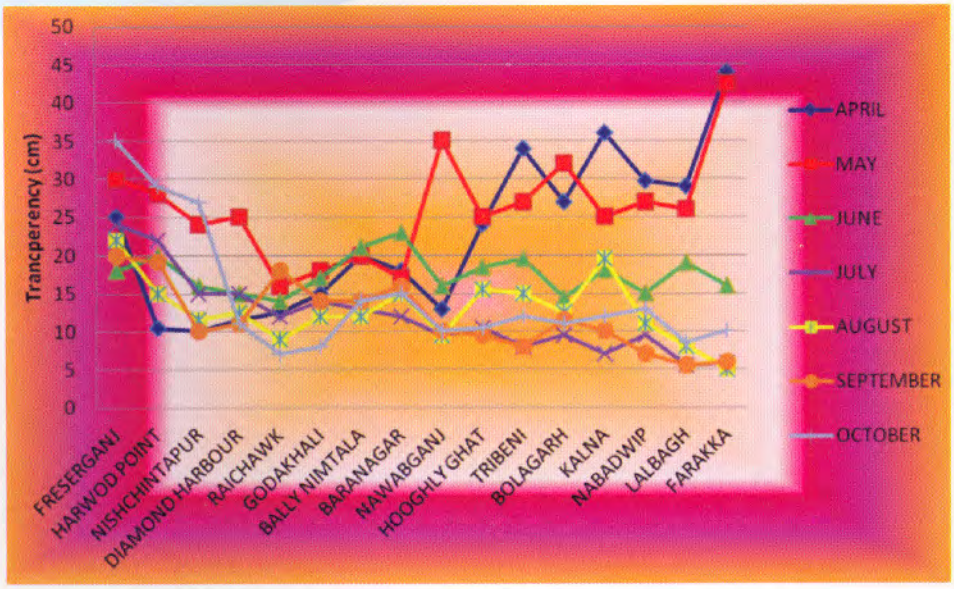


Fig 15. Variation in transparency at different sampling centres.

Total suspended solids

Total suspended solids (Fig 16) showed slight variation between surface and bottom at some of the sampling points. The value was higher at the sea face zone near Frazergunj. At the surface water the value ranged between 0.012 and 3.632 g/l while at the bottom it ranged from 0.008 to 1.364; highest value was at the Frazergunj site.

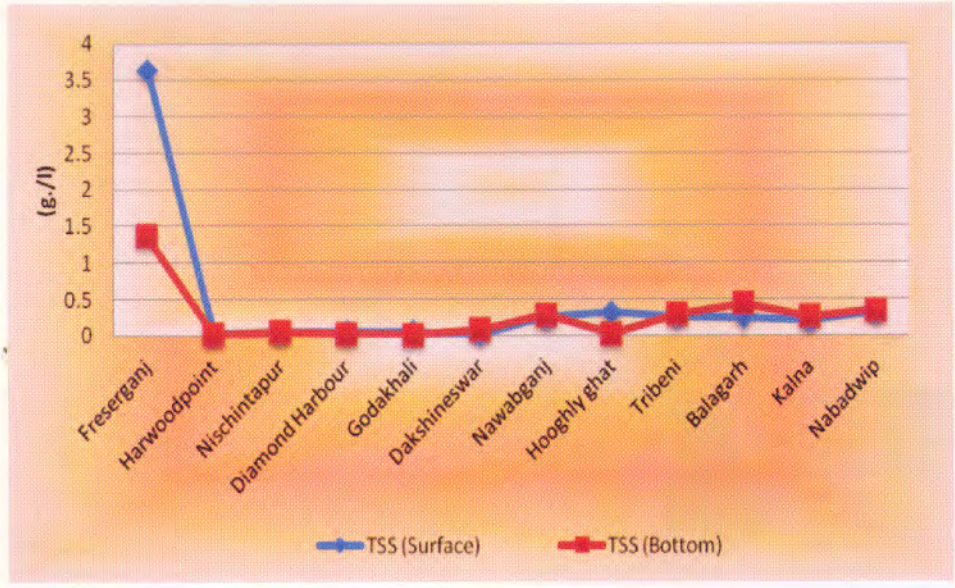


Fig 16. Variation in TSS at different sampling centers.

Dissolved Oxygen

The perusal of Fig 17 & 18 reveals that in general, dissolved oxygen was higher in freshwater zone of Hooghly-Bhagirathi system and at the sea face area. The value of the dissolved gas was higher during April and May as compared to the other months. The concentration of DO fluctuated within a moderate range of 4.0 to 7.6 ppm. The level of oxygen ranged between 5.2 to 7.4 ppm in upper freshwater zone during the period of observations, which indicated higher productivity and congenial environment for migration and nurturing of hilsa in the region.

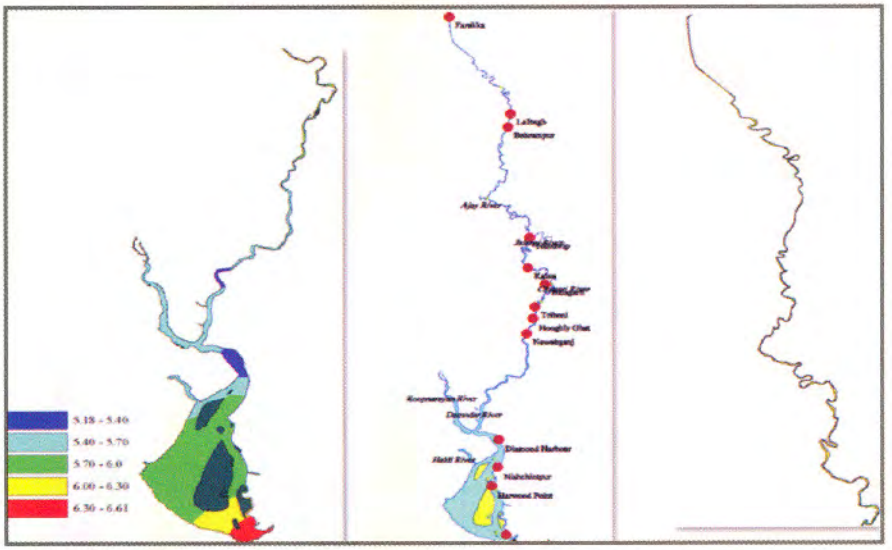


Fig. 17. GIS Mapping for Dissolved Oxygen

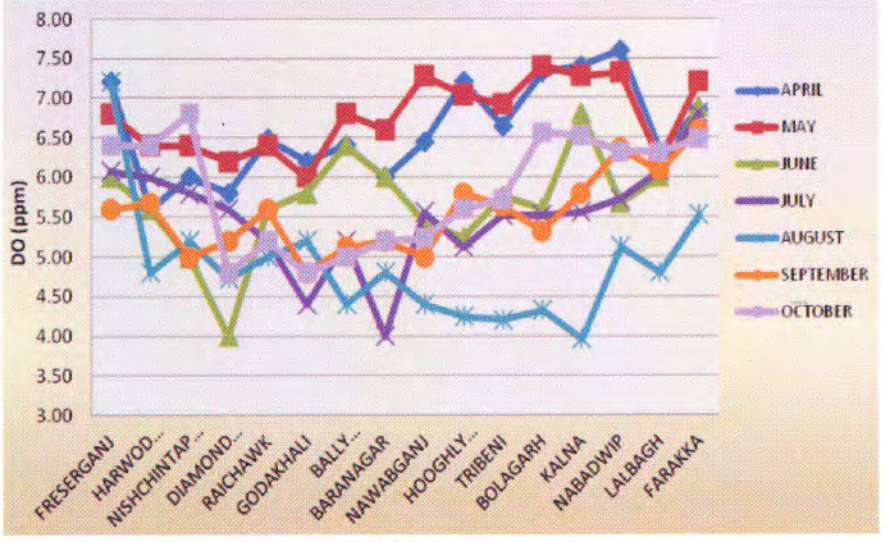


Fig 18. Variation in DO at different sampling centres.

pH

The water pH (Fig. 19 & 20) ranged between 7.2 and 8.6 thus indicated alkaline environment of the investigated system. Though marginal, the seasonal variation in pH was observed between the season and zones. In summer the water pH was low (7.2-8.0) below Baranagar as compared to the upper reaches (8.2-8.6). With monsoon discharge, the pH increased in lower zone and the entire stretch was under uniform alkaline condition (8.0 to 8.3).

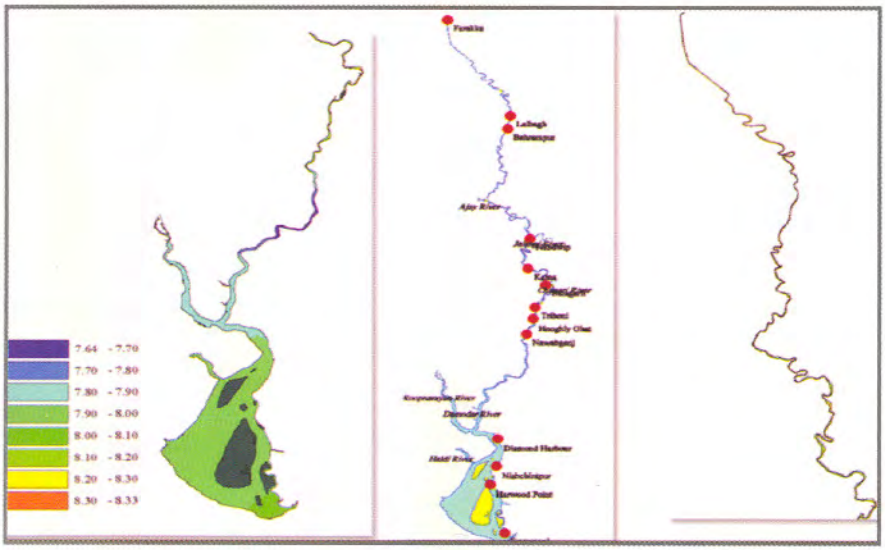


Fig. 19. GIS Mapping for pH

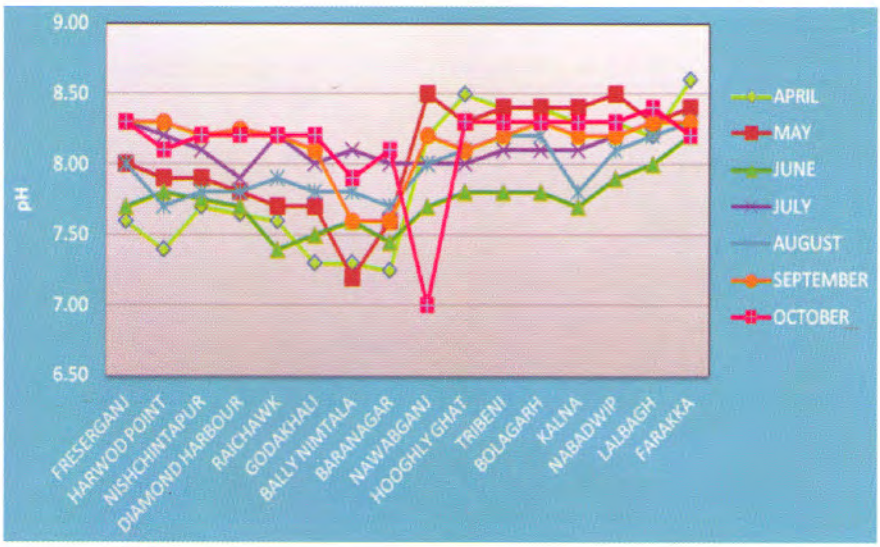


Fig 20. Variation in ρH at different sampling centres.

Salinity

The study reveals that salinity (Fig. 21 & 22) of the Hooghly estuary remained below 0.05 ppt up to Nishchintpur and below that the chloride concentration enhanced during post-monsoon period. The low salinity was ideal for breeding and nurturing of hilsa. Low salinity facilitates hilsa to breed in the fresh water zone of the river system. Further maximum juveniles of various sites were encountered in the catches in freshwater zones coinciding breeding seasons. This is in conformity with the study of Bhaumik (2010).

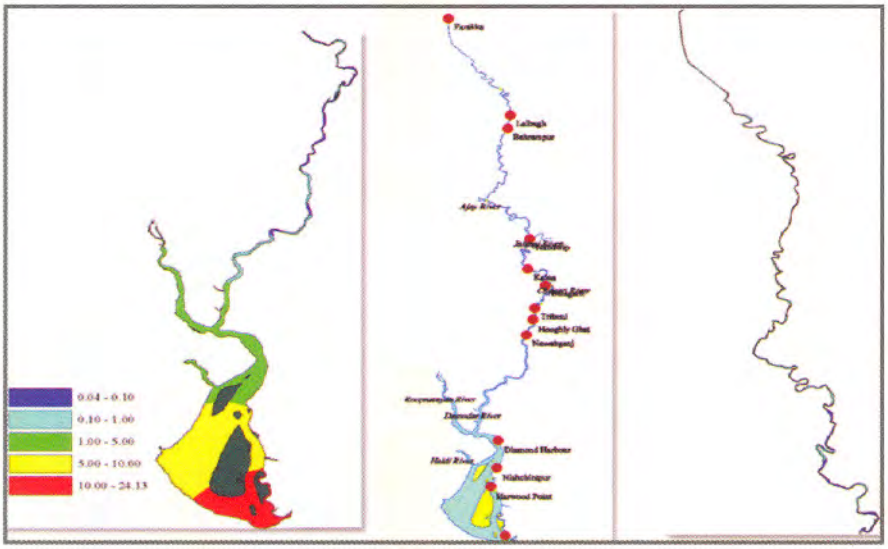


Fig. 21. GIS Mapping for Salinity

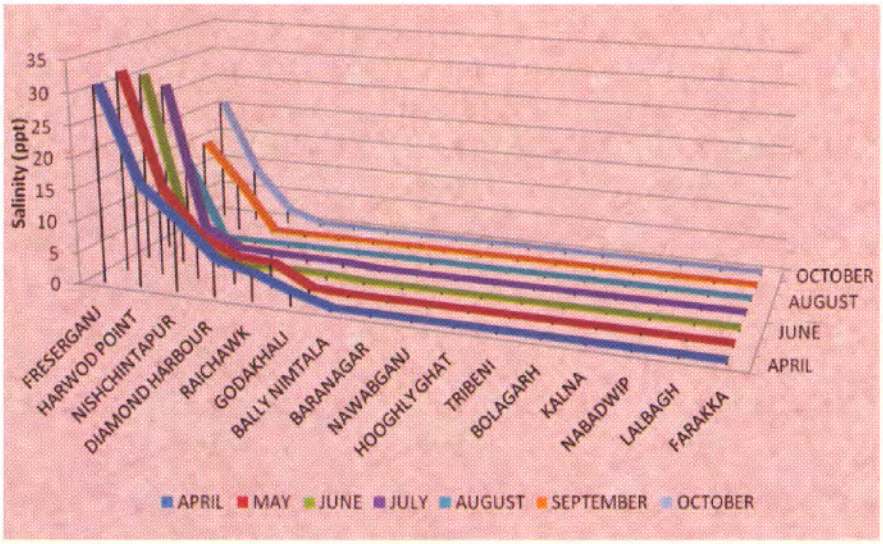


Fig 22. Variation in salinity at different sampling centres.

Chlorophyll

Spatio-temporal variation in chlorophyll concentration was noticed during the study period (Fig. 23 & 24). Chlorophyll concentration in general was more during post-monsoon season and it was comparatively high at the downstream stretch below Diamond Harbour and upper freshwater tidal zone. The zone of high chlorophyll concentration coincided with the nursery grounds of hilsa.

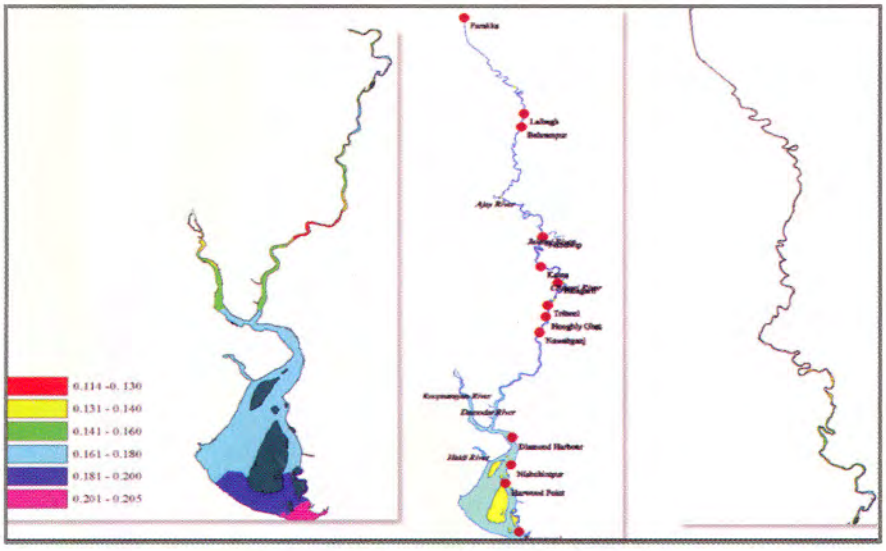


Fig. 23. GIS Mapping for Chlorophyll

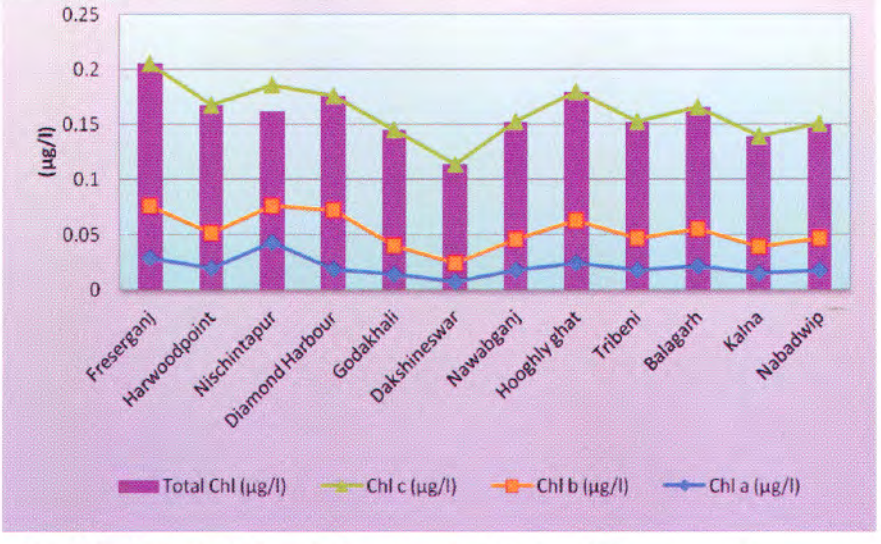


Fig 24.Variation in Chlorophyll content (a, b & c) at different sampling centres.

Biological aspects

Age and growth

The growth of hilsa seed was calculated from the date of the Full Moon of the month of October (after Dushera) when maximum breeding of hilsa takes place. This concept was validated through more than 100 fishers who possessed experience of hilsa fishing for 10 years. The average growth of young hilsa after hatching has been recorded as 26 mm to 30 mm, 40 mm to 60 mm, 61 mm to 75 mm, 76 mm to 82 mm, 83 mm to 95 mm and 96 mm to 120 mm at the end of one, two, three, four, five month and six months respectively. This is almost in conformity with the study of De, 1986 who observed growth as 28-33mm, 48-63 mm, 63-73 mm, 73-83mm, 88-93 mm and 98-103mm at one, two, three, four, five and six month respectively.

The age and growth of adult hilsa were observed to be varying in different water bodies. It is well known that growth of hilsa varies from one system to other or in the same environment due to changes in ecology, food availability, density dependent growth factors. The growth of fish as has been observed through study of otolith is depicted in Table 3. After studying the annual rings in otolith, age of a few hilsa was determined as 215 mm, 410 mm and 448 mm corresponding the age 1 year, 3 yr and 3+ yr respectively. A fair degree of agreement was observed between lengths and at ages obtained by Pillay ,1958 and De,1986 & De and Datta,1990. The maximum size of hilsa recorded so far , in India is 614 mm weighing 4250 g from Tapti River system.

Table 3. Age of Hilsa at different Length

LENGTH (mm)	AGE (Year)
215	1
410	3
448	3+

Size distribution

The size frequency distribution is depicted in Fig 25. Predictive population density estimate based on the sample of 1200 hilsa of commercial catch has been was overlaid on the histogram. The summary statistics including mean, median, maximum, minimum, standard deviation and coefficient of variation and 95 % confidence interval of mean which have been depicted in Table 4. The predictive population density estimate separately for male and female indicated that overall spread of the size distribution of female was more that of male. Female size distribution in terms of length and weight were more skewed than the size distribution of male. This indicated that chance of getting larger size fish of female was more than that of male. Comparing

standard deviation and CV (%), it can be concluded that female population was more variable in size than male population. Variability in weight was more than that in length, for both male and female. The 50% of male and female fish were of length below 284 mm and 292 mm (median length) respectively and the 50 % of male and female fish were of weight below 260 gm and 296 gm (median weight) respectively.

Table 4. Sex-wise summary statistics of size of Hilsa

Statistics	Length (mm)		Weight (gm)	
	Male	Female	Male	Female
Mean	287 (285,290)*	321 (319,323)*	277 (273,281)*	362 (356, 370)*
Median	284	292	260	296
Standard deviation	25.7	40.1	85.5	205.6
Maximum	425	525	780	1700
Minimum	207	206	140	110
CV (%)	8.9	12.5	30.9	56.8

* The values within parenthesis are 95 % confidence interval of mean.

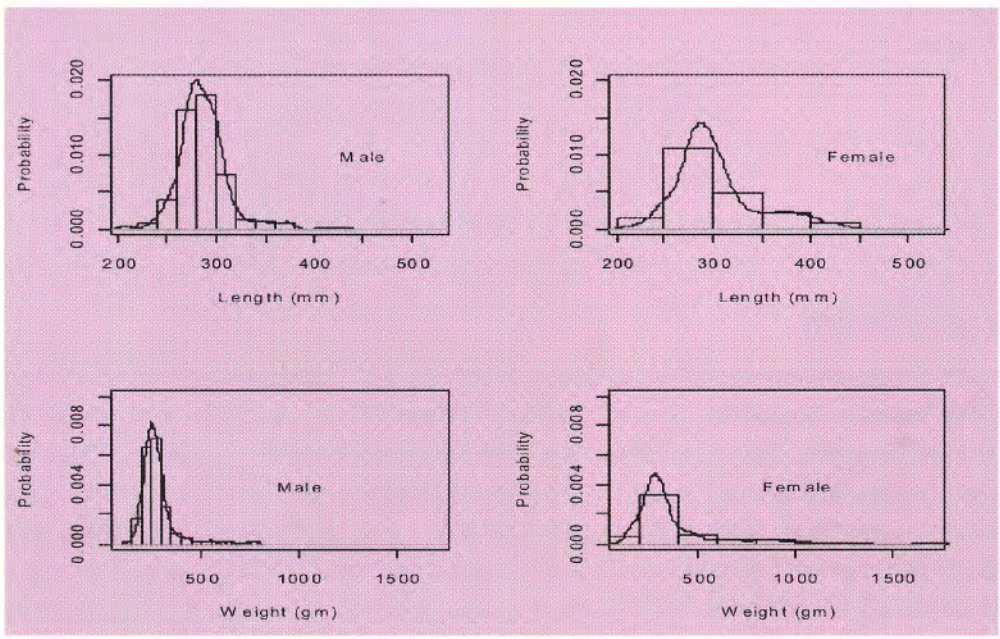


Fig. 25. Sex-wise observed and predictive size distribution of Hilsa

Maturity

Maturity of hilsa fishes were studied collecting samples from 10 stations (Table 5). Minimum size at maturity was observed in females weighing 105 gm (215 mm) and 212 g (208 mm). It was interesting to observe that the size of maturing/mature hilsa has come down where earlier workers mentioned that female below 300 mm size groups are rarely observed to be taking part in spawning activity. The smallest mature females observed in Hooghly estuary by De, 1980 & 1986 were around 341 mm (av. wt. 550g) which are comparable to the hilsa of the Ganga where the smallest mature females observed at Allahabad, Varanasi (Mathur, 1964) and Godavari (Pillay & Rao, 1963) were 330, 310 and 370 mm respectively. Perusal of the Table 5 reveals that the maturity stages of females of the sample varied between third stage and seventh stage. The observation clearly indicates that large numbers of smaller mature females take part in spawning in the Hooghly-Bhagirathi river system.

Table 5. Maturity profile of female hilsa

(n - 457)

SAMPLING STATION	FEMALE						
	LENGTH RANGE (mm)	WEIGHT RANGE (gm)	MATURITY STAGE (per cent)				
			III	IV	V	VI	VII
Farakka	245-440	120-1130	27.42	1.59	15.03	22.96	32.79
Lalbagh	263-451	184-963	24.07	4.74	18.60	26.35	26.97
Nabadwip	244-437	159-912	33.58	6.12	16.66	14.40	30.03
Kalna	235-404	173-631	31.30	4.64	21.20	20.88	22.09
Tribeni	258-475	142-1124	17.38	4.52	27.96	14.74	35.40
Hooghly Ghat	241-440	193.5-934	13.02	5.60	26.74	15.37	40.07
Baranagar	240-457	174-1112	9.21	5.41	13.07	29.56	43.49
Godakhali	208-445	112-1175.5	19.52	15.25	11.58	23.45	30.97
Nischintapur	250-378	105-604	27.45	16.45	7.97	12.96	36.05
Fraserganj	261-406	200-728	24.29	11.15	6.01	14.92	43.72

Fecundity

A wide range of variation is observed in the fecundity in hilsa. In the present study, fecundity of 212 sampled fishes (Table: 6) varied with size. Number of eggs in individual mature ovary of *Tenualosa ilisha* ranged from 44,002 numbers (length 274 mm / weight 234.5 g) to 15,54,894 numbers (length 403 mm / weight 855 g). It has been observed that number of ova increased with age of fish and egg diameter also increased with increasing fecundity. While Pillay (1958) recorded fecundity in the range of 2, 50,000-16, 00,000 in fish measuring 253-481 mm in length from the Hooghly estuary. De, 1986, computed the egg numbers ranging between 3, 73,120 - 14, 75,676 in fishes 334-522 mm in length. Swarup (1961) and Mathur (1964) while

working on hilsa reproduction in the upper Ganga river system near Allahabad recorded fecundity values as 2,89,000 to 11,68,622 and 3,16,316 to 18,40,179 from the fishes of 315 to 506 mm and 310 to 436 mm size range respectively.

Table: 6. Fecundity of hilsa (*Tenualosa ilisha*)

(n = 212)

Sl. no.	No. of sample	Weight(g)	Total length(mm)	Gonad weight(g)	Fecundity (nos.)
1)	17	105-352	208-250	6.35-50	65,394-10,67,220
2)	69	173-332	251-300	2.78-56.39	44,001-5,69,539
3)	36	250-605	301-350	3.19-92.03	50,003-10,66,903
4)	61	142-957	351-400	4-155.97	67,996-10,08,592
5)	27	631-1175.5	401-445	7.14-183.62	72,312-15,54,894
6)	2	1086-1112	457-475	136-149.27	13,99,984-14,28,663

Fish catch under experimental fishing

The data on experimental fishing in the sampling stations conducted every month depicts the sex-wise length and weight of 1528 nos. of harvested hilsa in Table 7 and Table 8.

The perusal of Table 7 reveals that as many 43.39 per cent of hilsa belongs to size group of 250 mm to 300 mm followed by 300 mm to 350 mm (22.5 per cent). Minimum size range recorded as 450 mm to 500 mm (0.26 per cent). It is interesting to observe that more number of male belonging to the size range 250 mm to 300 mm appeared during the month October which is the month of peak breeding season whereas female of that size group appeared more during February.

Fig. 26. Hilsa fishing operation

Table 7: Sex-wise length of harvested hilsa

(n = 1528)

Length class (mm)		150-200	%	200-250	%	250-300	%	300-350	%	350-400	%	400-450	%	450-500	%
Mar'2011	Male	2	0.13	20	1.31	36	2.36	7	0.46	2	0.13				
	Female					32	2.09	9	0.59	11	0.72	4	0.26		
Apr'2011	Male	1	0.07	9	0.59	34	2.23	19	1.24	5	0.33				
	Female					4	0.26	16	1.05	6	0.39	10	0.65	1	0.07
May'2011	Male	2	0.13	9	0.59	7	0.46	39	2.55	37	2.42	2	0.13		
	Female			1	0.07	2	0.13	9	0.59	8	0.52	6	0.39		
Jun'2011	Male			6	0.39	18	1.18	57	3.73	42	2.75	3	0.20		
	Female			1	0.07	4	0.26	3	0.20	6	0.39	1	0.07		
Jul'2011	Male			3	0.20	13	0.85	38	2.49	22	1.44	2	0.13		
	Female					7	0.46	3	0.20	12	0.79	6	0.39	1	0.07
Aug'2011	Male	1	0.07	20	1.31	38	2.49	35	2.29	11	0.72				
	Female					8	0.52	3	0.20	7	0.46	7	0.46		
Sep'2011	Male			21	1.37	38	2.49	18	1.18	9	0.59	1	0.07		
	Female			3	0.20	20	1.31	5	0.33	17	1.11	5	0.33	1	0.07
Oct'2011	Male	1	0.07	32	2.09	70	4.58	15	0.98	6	0.39				
	Female			9	0.59	20	1.31	12	0.79	9	0.59	4	0.26		
Nov'2011	Male			10	0.65	23	1.51	13	0.85	10	0.65	5	0.33		
	Female					10	0.65	1	0.07	1	0.07				
Dec'2011	Male			3	0.20	47	3.08	4	0.26	5	0.33				
	Female					7	0.46	2	0.13			1	0.07		
Jan'2012	Male			16	1.05	59	3.86	2	0.13						
	Female			8	0.52	54	3.53	9	0.59	14	0.92	10	0.65	1	0.07
Feb'2012	Male			3	0.20	38	2.49	4	0.26	1	0.07	1	0.07		
	Female			2	0.13	74	4.84	17	1.11	18	1.18	11	0.72		
Total		7	0.46	176	11.52	663	43.39	340	22.25	259	16.95	79	5.17	4	0.26

Fig 27. Collection of fish under experimental fishing

The data obtained during the study (Table 8) indicates that as many as 37.17 per cent of hilsa captured belong to the weight range 150 g to 250 g followed by 250 g to 350 g (21.6 per cent), 350 g – 450 g (13.15 per cent), 50 g – 150 g (9.3 per cent), 450 g – 550 g (6.22 per cent), 550g – 650 g (5.1 per cent), 650 g – 750 g (3.93 per cent) and 750 g – 850 g (2.16 per cent). Least weight range was 1150 g – 1250 g (0.07 per cent). As such, it is evident from the above observation that 87.44 per cent of the hilsa catch belongs to below 550 g which portrays an alarming situation due to over exploitation.

Table 8: Sex-wise weight of harvested hilsa (n = 1528)

Weight class (gm)		50-150	%	150-250	%	250-350	%	350-450	%	450-550	%	550-650	%
Mar'2011	Male	23	1.51	34	2.23	4	0.26	3	0.20	1	0.07	1	0.07
	Female	2	0.13	18	1.18	14	0.92	3	0.20	6	0.39		0.00
Apr'2011	Male	13	0.85	29	1.90	17	1.11	4	0.26	4	0.26	1	0.07
	Female			4	0.26	9	0.59	7	0.46	2	0.13	1	0.07
May'2011	Male	11	0.72	11	0.72	24	1.57	31	2.03	15	0.98	3	0.20
	Female			2	0.13	8	0.52	4	0.26	3	0.20	4	0.26
Jun'2011	Male	5	0.33	17	1.11	35	2.29	53	3.47	12	0.79	3	0.20
	Female			2	0.13	4	0.26	5	0.33	3	0.20	1	0.07
Jul'2011	Male	3	0.20	9	0.59	22	1.44	17	1.11	7	0.46	15	0.98
	Female	1	0.07	2	0.13	3	0.20	4	0.26	4	0.26	4	0.26
Aug'2011	Male	12	0.79	28	1.83	41	2.68	17	1.11	3	0.20	2	0.13
	Female			5	0.33	6	0.39		0.00	2	0.13	2	0.13
Sep'2011	Male	9	0.59	40	2.62	19	1.24	9	0.59	8	0.52	1	0.07
	Female			12	0.79	11	0.72	2	0.13	2	0.13	11	0.72
Oct'2011	Male	19	1.24	64	4.19	26	1.70	12	0.79	3	0.20	1	0.07
	Female	1	0.07	10	0.65	20	1.31	5	0.33	7	0.46	3	0.20
Nov'2011	Male	5	0.33	23	1.51	7	0.46	11	0.72	3	0.20	7	0.46
	Female			4	0.26	6	0.39			1	0.07	1	0.07
Dec'2011	Male	1	0.07	41	2.68	11	0.72	4	0.26	2	0.13		
	Female			4	0.26	4	0.26	1	0.07				
Jan'2012	Male	11	0.72	62	4.06	3	0.20	1	0.07				
	Female	8	0.52	47	3.08	14	0.92	3	0.20	1	0.07	7	0.46
Feb'2012	Male	9	0.59	32	2.09	2	0.13	2	0.13				0.00
	Female	5	0.33	68	4.45	20	1.31	3	0.20	6	0.39	10	0.65
Total		138	9.03	568	37.17	330	21.60	201	13.15	95	6.22	78	5.10

Weight class (gm)		650-750	%	750-850	%	850-950	%	950-1050	%	1050-1150	%	1150-1250	%
Mar'2011	Male	1	0.07										
	Female	4	0.26	5	0.33	2	0.13	1	0.07	1	0.07		
Apr'2011	Male												
	Female	10	0.65	2	0.13	1	0.07	1	0.07				
May'2011	Male	1	0.07										
	Female	3	0.20	1	0.07	1	0.07						
Jun'2011	Male	1	0.07										
	Female		0.00										
Jul'2011	Male	5	0.33										
	Female	4	0.26	1	0.07	1	0.07	3	0.20	2	0.13		
Aug'2011	Male	2	0.13										
	Female	3	0.20	5	0.33	2	0.13						
Sep'2011	Male		0.00	1	0.07								
	Female	4	0.26	4	0.26	4	0.26			1	0.07		
Oct'2011	Male		0.00										
	Female	4	0.26	1	0.07	2	0.13					1	0.07
Nov'2011	Male	2	0.13	3	0.20								
	Female												
Dec'2011	Male												
	Female	1	0.07										
Jan'2012	Male												
	Female	9	0.59	5	0.33	1	0.07	1	0.07				
Feb'2012	Male	1	0.07										
	Female	5	0.33	5	0.33								
Total		60	3.93	33	2.16	14	0.92	6	0.39	4	0.26	1	0.07

Sex ratio

To get an idea about the changes in sex-ratio at size (Fig. 28), the entire samples (1200 hilsa from commercial catch) were divided into four groups of equal sizes on the basis of 4 quintiles in the observed weight distribution. The sex ratio (Male: Female) expressed in percentage form was computed for each group and presented in the Table 2. The overall sex ratio found was 42:58 (Male:Female) which is significantly (p-value<0.05) different from 50:50. The 95 % confidence interval of male proportion is (0.36 to 0.41) which is far below to that of 0.5. Both of these findings indicate that Hilsa population is female-biased.

As part of empirical evidence of changing sex- ratio at size, the sex ratio of different age groups has been depicted in Figure 29. It is observed that sex ratio changes from size group 280 gm to 340 gm and it drastically changes to 18::82 (Male :: Female) in the size group of more than 340 gm. The statistical test (equality of proportion) ensured significant (p-value <0.05) differences of male proportion among different size groups. The above investigation portrayed only the evidence of changing sex-ratios at size on the basis of sample observations.

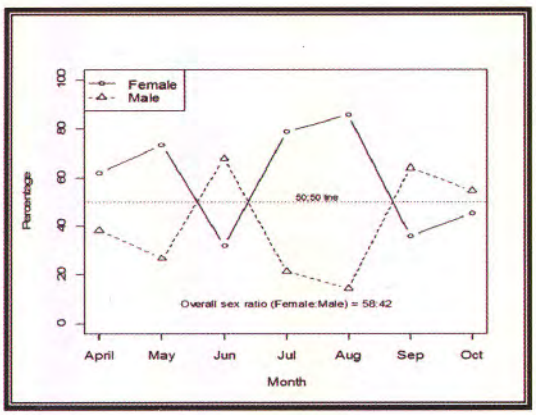


Fig 28. Distribution of sex ratio

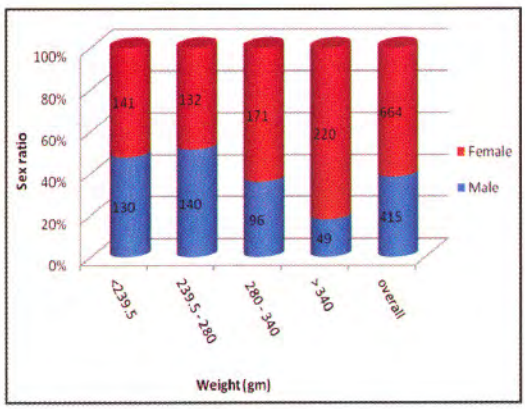


Fig. 29. Sex ratios of different size group

Gonado- somatic Index

Maturity stages *i.e.* gonado-somatic index (GSI) of the migrating spawners of hilsa (Fig. 30) varied with season and location. Advanced stages of female hilsa appeared first in the lower stretch around Nishchintapur in July. In August, the distribution of gravid hilsa was wider and their concentration was more in upper freshwater tidal zone between Hooghly Ghat and Balagarh and in comparatively lower intensity below Farakka in Bhagirathi system.

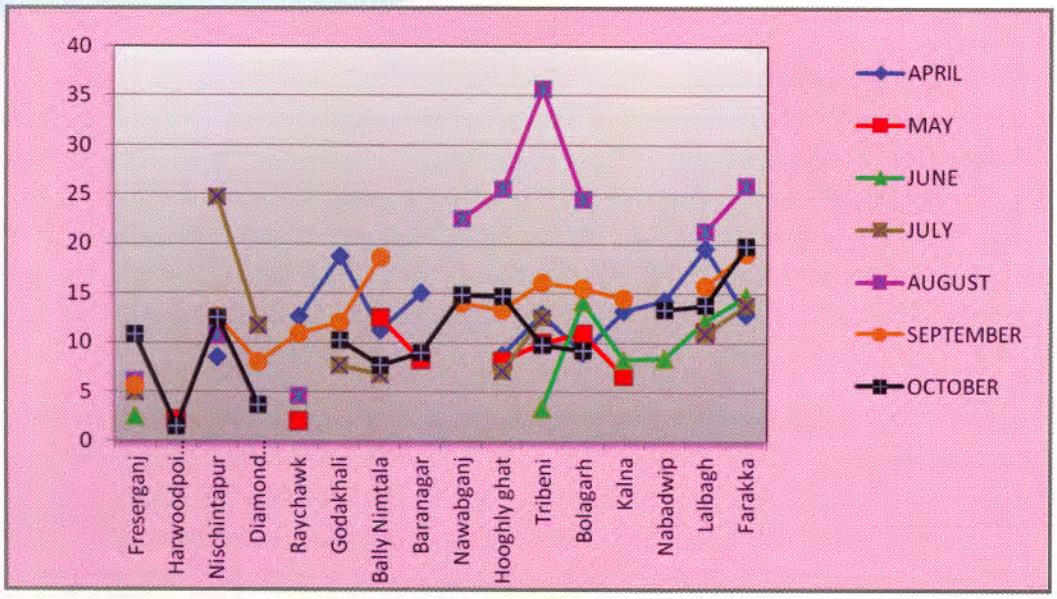


Fig 30. Variation in GSI value of *Hilsa*

Migration of hilsa

Physiological adaptabilities during migration of Hilsa

Hilsa by habitat is a marine environment species but they migrate in estuarine and fresh water zones for spawning purposes, gradually adjusting their osmoregulatory processes through kidney and gills from saline water to freshwater. In sea to minimize the loss of water, kidneys of hilsa contain less and non-functional glomeruli and the tubules. As the fish moves to fresh water environment and maintain salt balance between body and environment, the kidney starts proper functioning and unwanted salt is extruded. Chloride cells located in gills also help in salt extrusion.

It has been observed that partial cessation of feeding in female migratory hilsa occurs during the spawning period and upstream migration. At that time, stomachs are observed to be mostly empty, as they possess very little space for gut due to the voluminous growth of maturing ovary during this period.

At this point of time, physiological studies seem very important as they play immense role during movement from marine environment to fresh water zones (via estuarine waters). During this period, they perform long journeys (in Hooghly-Bhagirathi river system) without or partial feeding where the energy comes mainly from stored foods (liver and muscle glycogen). The chloride ions (Cl^-) play important role in osmoregulation by gills and ability to thrive in changed salinity circumstances (from marine 32 ppt salinity to almost 0.01 ppt in complete fresh waters).

The bioenergetic needs for long-distance swimming journeys towards spawning grounds are met not only from reserve carbohydrate sources (liver and muscle glycogen) but from sources other than the tissue reserves of glycogen. Here, the role of lipid is very important.

It has been observed that during anadromous migration for spawning purposes, not only the liver and muscle glycogen lipid levels are steadily declined, muscle total lipids (triglycerides) also record persistent diminution in levels for either sex. The decline in level of lipid in muscle and withdrawal of the same is more pronounced in case of female hilsa than the male, indicating that females withdraw and utilize more lipids than the males, from the muscle tissue lipids.

At this point, gonads do mature in females and gonadal recrudescence could account for difference in lipid contents between the sexes. The ovaries mature and mobilize (by transfer from muscles) more fats (lipids) during the process of vitellogenesis, than was needed for testicular maturation in males.

The number of ova produced by a female (with sufficient gonad, lipid contents and possibilities of formation lipoprotein membrane of ova) varies with size. By accelerating the gonad lipid reserves and lipoprotein membrane formation, the processes of spawning could be accelerated and here plays the active physiological changes in body.

The matured eggs are laden with heavy yolk mass with numerous oil globules (fats/lipoproteins). After fertilization by sperms, the size of the ova increases in diameter though absorption of water. The first cleavage takes place in about 40 minutes after fertilization. After 16 hours of development, the embryo shows faint movements. Incubation period ranges between 18-21 hours. The average length of hatchlings measures 2.41 mm. the 5 day old larvae attains a size of 5.12 mm. mouth opening is first noticed in 3 days old larvae. Then the yolk is completely observed after 8 days.

Thus, the physiology, bioenergetics under no feeding circumstances (cessation) and mobilization of proper lipids from muscle to gonad plays pivotal role in anadromous migrations *vis-à-vis.* spawning events.

Anadromous migration of hilsa

Indian shad, *Tenualosa ilisha (Hamilton)* migrates to freshwater environment of the river systems for breeding and thereafter nourishment of the young ones. The breeding success of species depends on synchronous effect of eco-environmental and biological conditions (Bhaumik and Sharma, 2011.c). The fish normally inhabits the lower region of the estuaries and the foreshore areas of the sea. Hilsa prefers to reside in this region due to the presence of sub-surface oxygen, relatively low salinity, strong tidal action, high turbidity, heavy siltation and rich growth of plankton (Pillay and Rosa, 1963). It is well known that hilsa ascends the rivers for spawning (Hora, 1938; Pillay, 1958; De, 1986 and Bhaumik *et al.,* 2011.b) and the spent fish as well as their progeny migrate down the river towards lower estuaries and coastal areas (Pillay, 1958). Most of the stocks of hilsa are anadromous, breeding much above tidal limits (Naidu, 1939). Some stocks have also been reported to remain permanently in the freshwater stretch of rivers (Hora, 1938, Hora & Nair, 1940) and some spawn in tidal areas. There is no doubt that hilsa is very salinity tolerant and inhabits freshwater, estuarine and coastal waters in the Bay of Bengal.

It has been observed that hilsa move on the surface in the foreshore region whereas in the river they move in deeper zones (Bhaumik, 2010).The species move in shoals. The peak upstream migration of hilsa in most of the rivers of the country generally commensurate with south-west monsoon i.e., July and August and continues up to October or November. While in the Hooghly estuary, the period of migration is found to be prolonged and extended up to February. A wide range of pattern of upstream migration of the fish in various river systems of the country has been reported.

Regarding the migration of hilsa into the Hooghly-Bhagirathi estuary, it has been observed that the fish ascends only for spawning and their progeny generally after attainment of a size range from 80-110 mm, start their downstream migration towards coastal region which commences from February and continues up to June. The young hilsa after leaving the rivers do not go far into the sea but move about in shoals in the estuary and foreshore regions.

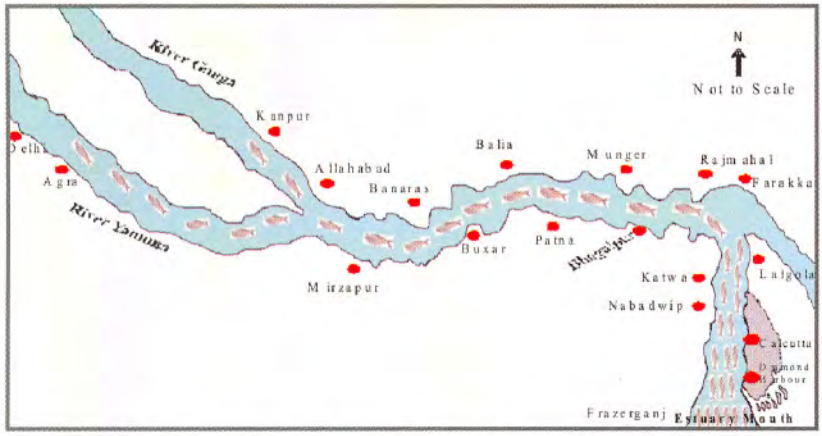


Fig 31. Migration route of Hilsa in pre-Farakka period

Earlier studies indicate that in the past (pre-Farakka barrage period), the hilsa of the Ganga river system used to migrates up to Agra, Kanpur and Delhi in the years of excessive abundance, while in normal years the fish used to migrate up to Allhabad where maximum abundance was observed up to Buxar region (Fig. 31).

The upstream migration has been observed to be associated mainly with the state of sexual maturity as well as volume of freshwater discharge from the estuary during monsoon onwards. However, the other factors like rainfall, current velocity and temperature, low salinity, turbidity, primary productivity and availability of planktonic food cannot be ignored (Bhaumik & Sharma, 2011.c).

The migratory movement of hilsa into and from the river was studied in the Hooghly river at Diamond Harbour and marine zone of the estuary off Frazergunj. Fishing of hilsa by the gill net was observed during January to March and June to November. The direction of entangling of the fish i.e. towards river or sea, and the position of entangling in the net i.e. at the top, centre or the bottom of the net were recorded. The sex, maturity and length of the fish caught during the days of investigation on board

fishing vessel were recorded. It was observed that a large number of hilsa were entangled in the gill net at the top and central portion during high tide especially in the evening hours during their migration process into the river. However, during low tide migrating spent fishes from the river into the sea were invariably gilled at the bottom of the net indicating the habitat of the spent fish. The experimental fishing to follow the movements of hilsa was conducted during peak periods of migration in monsoon, post monsoon and winter. As compared to the higher catch of hilsa obtained in the coastal areas and the lower estuary, the poor catch was recorded in the river which indicates that hilsa does not move in the river in shoals.

Based on the study of 1200 fish samples from commercial catch for length frequency as well as sex ratio and maturity condition of the migrants, it was observed that there are two well-marked migration pattern of hilsa into the Hooghly, one during monsoon (May - October) and the other during the winter (January-February). In the riverine area the large size groups of fish are abundant between May and October. After October this group declined to a minimum by December. The catch rates for the Hooghly revealed two peaks, one in May another in August. The medium- sized group was available all through the year. From November to March, medium- sized groups showed dominance over the large- sized group. Fishermen during this time also fished with smaller-meshed nets, because of the predominance of smaller to medium sized hilsa. The catch rate and GSI value were found to be higher during March. The catch rate of this medium sized fish in winter indicates a lesser degree of migration into the river. Two size groups of 280-325 mm and 300-430 mm, former being the most dominant, participate in spring migration. The monsoon run of hilsa comprises two groups varying between 250-350 mm and 400-500 mm, the later being most dominant occurring very much in the river catches. Smaller size fish of less than 285 mm also enter the river sporadically in very small numbers along with the bigger size groups of spring as well as monsoon runs of hilsa. The spring spawners that enter the river for spawning in January-March return to the sea during July-August when these are caught in good numbers. The monsoon spawners that enter the river during September- October return to the sea after spawning and these spent fishes are caught in good numbers during January- March. Similarly, the offsprings of spring spawners make journey for the sea from the river during November- January, whereas the offsprings of monsoon spawners return to the sea from the river during July- September. The return of the broods of spring and monsoon spawners to the sea is not as precise as the river- ward migrations of hilsa. Full recruitment of juveniles into the marine fishery is observed for 4 to 5 months in a year i.e. between July and January with a peak in October. The minimum size at recruitment into the sea is at 120 mm to 150 mm whereas the juveniles are fully recruited into the fishery at a length of 250 mm to 300 mm approximately at an age of one year. But the maximum exploitation of this stock is effected when they congregate in the near shore areas and lower estuaries at lengths of 300-390 mm at the age of about 2 years approximately. This also coincides with the size at first maturity of hilsa. It has been observed that migration of hilsa takes place in large numbers only when water depth, current velocity, volume of discharge stimulating flood pulse and temperature are favorable for them.

The upstream migration of winter spawners and the downstream migration of summer spawners as spent fish are likely to intermingle at various positions in one or other environment. Such intermingling cannot be ignored owing to the use of different mesh sizes in the fishing operations.

It has further been observed that some young hilsa stocks appear to remain in the freshwater zones throughout the year as per the record of regular catches. It put forth question for these population towards its migration strategy. Similar observations (whether such population is truly anadromous) were also made by Pillay & Rosa (1963). But it needs further investigation.

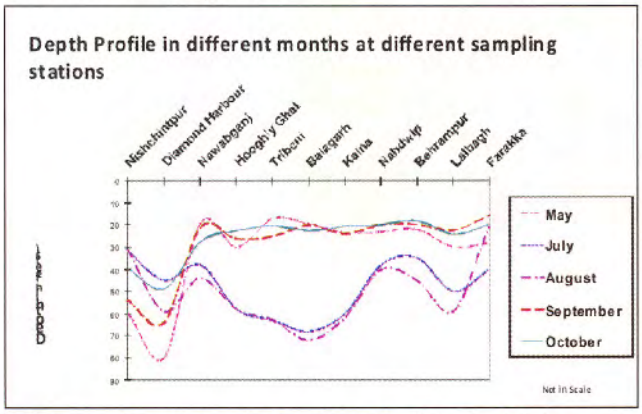


Fig. 32. Depth variation in the Hooghly-Bhagirathi river system

The depth (Fig. 32) and hilsa catch have direct correlation. At the mouth region the depth drops to less than 10.0 ft (3.04 m) and at places reduces to knee deep level during non monsoon month. With increase of depth following monsoon run off the hilsa migration/catch goes up. It has been observed that about 4.0 m-4.5 m depth from surface is favorable for migration of adult hilsa. Thus, the total depth in the system should be more than that for favourable migration and spawning of hilsa (Bhaumik *et al.*, 2011.a).

Box 1

- Migration of hilsa for spawning purpose is associated with sexual maturity
- Favourable depth is 4.0 to 4.5 metre from surface for migration of hilsa from sea to estuary
- Two well marked migration of hilsa observed during May to October (monsoon) and January to February (spring)
- Migrants of monsoon breed return to sea from January onwards whereas that of spring breed return from July onwards
- Juveniles of monsoon breed make journey to sea from July onwards and that of spring breed from November onwards.

Spawning behaviour

Investigations made by many workers on the reproductive biology of hilsa indicated that the spawning of this species is seasonal. In almost all major river systems and lagoons viz., Hooghly, Ganga, Chilika, Tapti, Indus and Padma and Meghna, the spawning season of hilsa has been noticed during the period between August and October.

Based on the study conducted at the institute in the year 2011 towards availability of hilsa seed along the entire stretch of the Hooghly-Bhagirathi (Fig. 34) indicates that the available sizes of the juveniles as 26 mm to 30 mm in November, 40 mm to 60 mm in December, 61 mm to 75 mm in January, 76 mm to 82 mm in February, 83 mm to 95 mm in March and 96 mm to 120 mm in April. It clearly indicates that major spawning takes place during October–November and minor spawning during May–July and January–March. This is in conformity with the study of Bhanot (1973) who confirmed through collection of the hilsa juveniles in the Hooghly estuary that the species breeds throughout the year with peak activity in February- March, July-August and October-November.

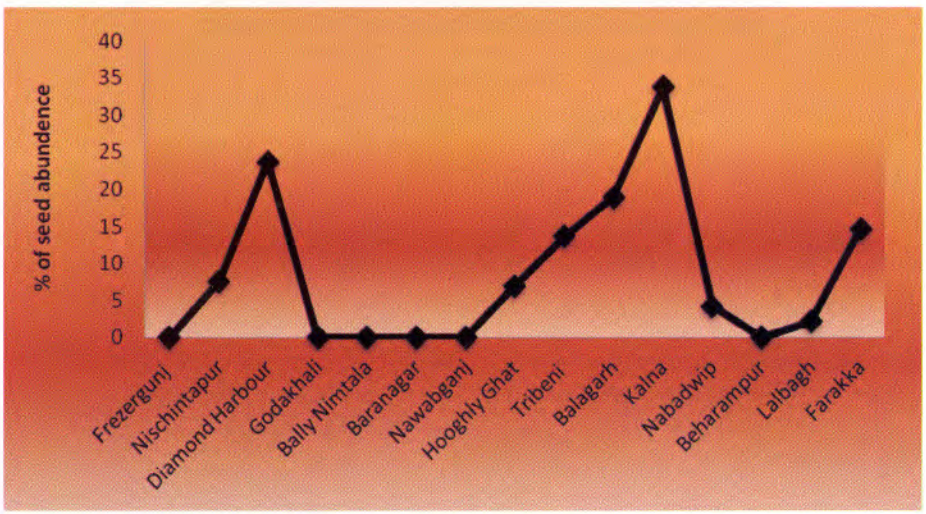


Fig. 33. Seed abundance in the sampling sites

Percentage abundance (Fig. 33) of the fry (26-30 mm) was considered for demarcating the spawning area. During July-October distinct areas between Nishchintpur-Godakhali, Hooghly Ghat-Kalna and Lalbagh-Farakka were observed as the potential breeding zones. In July-Septmber the breeding was recorded at the upper freshwater zone (Hooghly Ghat-Kalna) and in September-October the breeding area shifted to below Farakka and to Nishchintapur-Godakhali in downstream.

During the commencement of the south-west monsoon and consequent flooding of the rivers, hilsa starts its spawning migration upstream. A mature hilsa lays eggs, the eggs are deposited in fresh water where hatching takes place in about 23-26 hours at an

average temperature of 23°C. the newly hatched larvae is recorded as 2.3 mm in size and the larvae and juveniles make their way downstream to the sea during a period of several months, feeding and growing on the way. At this stage their life cycle, the juveniles of hilsa having the size range of 40 mm to 150 mm are widely available during February to May in the foreshore and riverine waters of the Hooghly-Bhagirathi river system and other deltic rivers of Sunderbans.

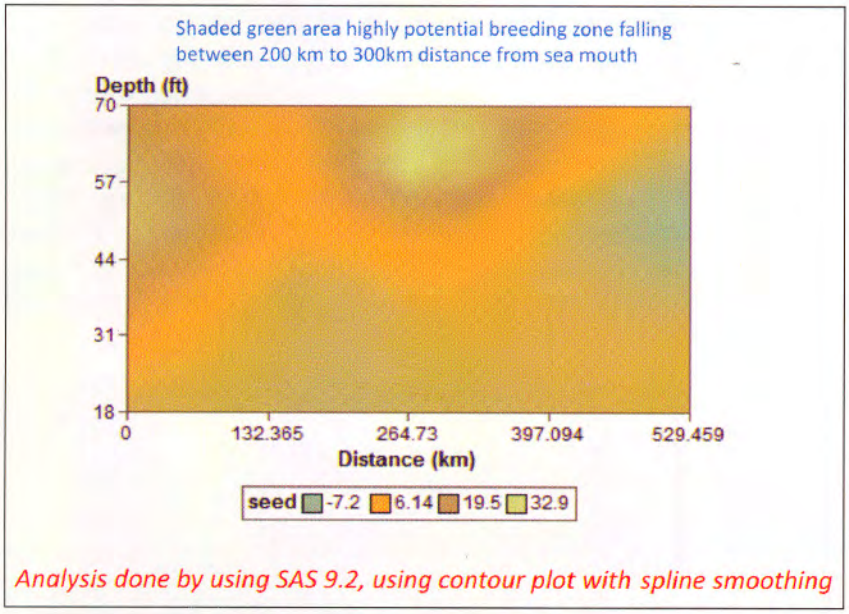


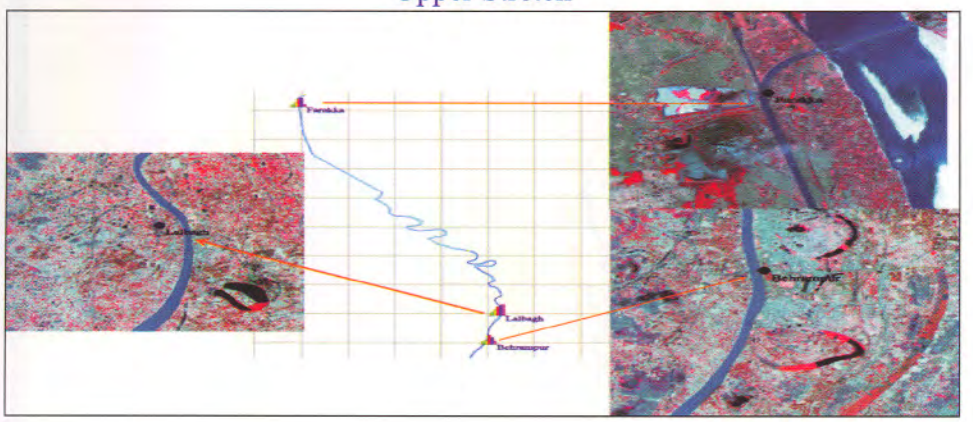
Fig. 34. Predictive map on seed availability over distance

Box 2

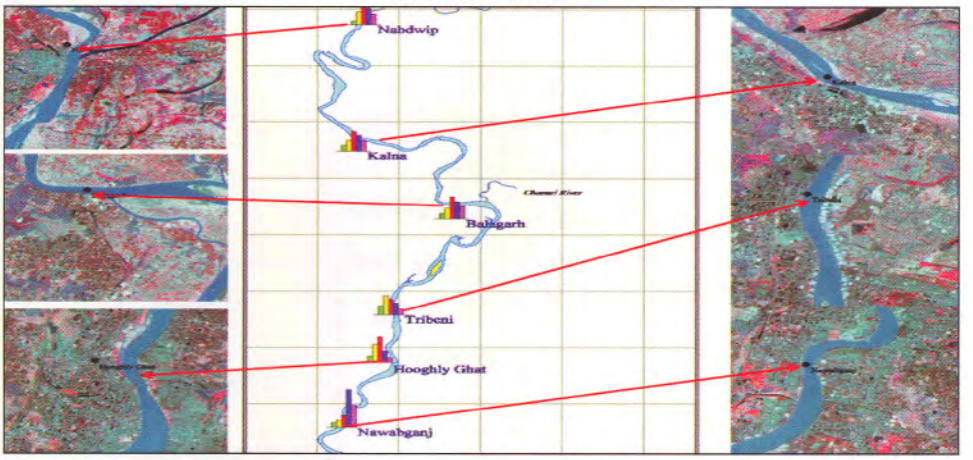
Breeding grounds in Hooghly-Bhagirathi system locate:

- Between Diamond Harbour and Godakhali (Lat. 22°10.182'N, Long. 88°12.034'E and Lat. 22°24.284'N, Long. 88°08.548'E)
- Between Hooghly Ghat to Kalna (Lat. 22°25.115'N, Long. 88°23.826'E and
- Between Lalbagh to Farakka (Lat. 24 °05.243'N, Long. 88 °27.942'E and Lat. 24°27.253'N, Long. 88°54.470'E)

Upper Stretch



Middle Stretch



Lower Stretch

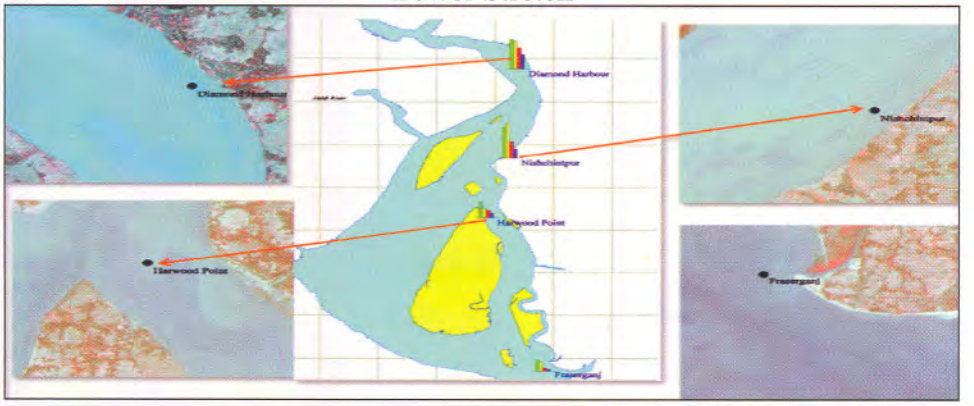


Fig. 35. Satellite images of different zones of the Hooghly-Bhagirathi stretch

Fig. 36. Migration route of Hilsa in post-Farakka period (not to scale)

Stretches between Nishchintpur and Diamond Harbour at downstream, Hooghly Ghat and Kalna in freshwater tidal zone and Lalbagh to Farakka in Bhagirathi river could be demarcated as potential breeding zones for hilsa (Fig. 36). In 2011, monsoon breeding of hilsa was first observed around Kalna in July followed by Lalbagh to Farakka during September-October. The breeding activities shifted downstream below Diamond Harbour following decreased river discharge and resultant low depth in upper reaches during September and October. Post-monsoon breeding occurred in all the demarcated breeding zones with variation in intensity and period.

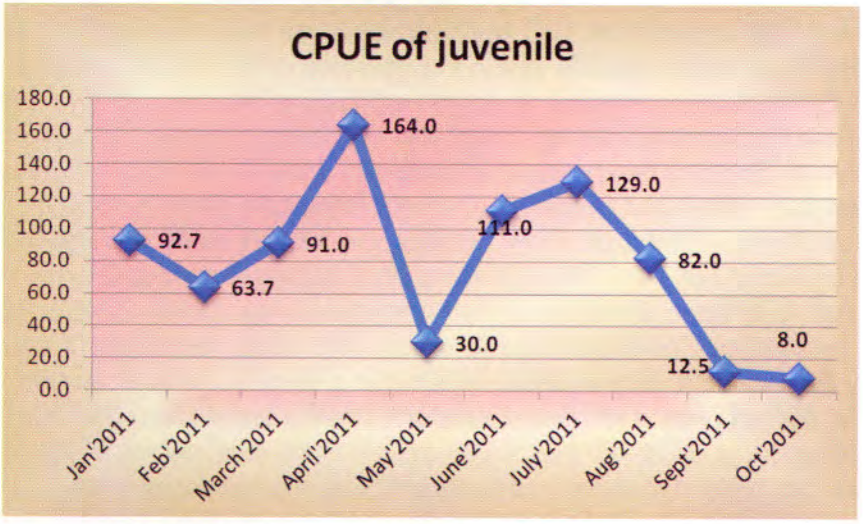


Fig. 37. Catch per unit of effort (CPUE) of juvenile Hilsa

The combined catch of fry and advanced juveniles was maximum during April and July, 2011. The catch of the advanced juveniles was more at the downstream between Godakhali and Nishchintapur. The percentage of fry in the total catch was more at the upper freshwater reaches. The presence of advanced juveniles in the entire stretch round the year needs further research.

Recruitment pattern

A mixed population of fry to juveniles (26-163 mm) was available almost round the year with spatio-temporal variability in size and density. The stretch between Nishchintpur and Godakhali produced 34.25% of the (fry) juveniles. As many as 42.17% of the recruitees was from the upper freshwater tidal zone located between Hooghly Ghat and Kalna. The pattern of recruitment was erratic during post-monsoon season. It was observed that such recruitment was maximum at Farakka region in December 2010. In followed up period of January and February 2011, the recruitment was higher in upper freshwater tidal zone between Hooghly Ghat and Kalna and comparatively low around Diamond Harbour stretch at the downstream. The advanced juveniles above 100 mm showed the trend of downward movement from April onwards. Such juveniles inhabit in the river-estuarine system and nurtured in comparatively deeper zone, which formed the potential areas for their harvest.

Method of exploitation

Crafts and Gear

The gears used for exploitation of hilsa in inland and coastal water of the Hooghly-Bhagirathi system vary with types and sizes. Swarup, 1958; Jones, 1959; Saxena, 1964; Saxena & Chandra, 1968; De, 1980 and Mitra *et al.,* 1987 reported that a number of different types of gears are deployed in the rivers, estuarine systems and coastal waters for exploitation of hilsa. The most important gears for exploitation of hilsa are gill net, boat sine and clap or purse net. Gill and boat seine nets are commonly used in coastal areas, estuaries as well as middle and lower stretches of the Ganga, whereas clap nets (*Sangla jal*) are mostly operated in upper stretches of the estuary and Ganga river system. Moreover, Bandal fishing (a trap) was very common in the Ganga during peak fishing season. There are two types of gill nets *viz.*, drift gill net (*Chandijal*) and set gill net (*Nangarjal*). *Chandijal* is one of the most important gears among the gears for exploitation of hilsa. It consists of several pieces of netting, each piece having a length of 8-20 m and height of 5 to 13 m depending on sizes and area of operation. Generally, drift gill net with large sized pieces are operated in the lower marine zone of the Hooghly estuary and adjacent coastal areas. The mesh variation in gill net and selectivity factors are highly variable. Mesh size generally varies from 60 mm to 100 mm. While, Ruben *et al.,* (1992) reported that smaller sized *Chandijal* (drift gill net) with a mesh opening of 50 - 80 mm is also used in the coastal waters of Bay of Bengal. The gill nets are made of nylon monofilament. In Hooghly estuarine system alone, more than 0.2 million drift gill nets are in operation (Mitra *et al.,* 1987 De, 1991). Presently more than 5,957 small mechanized and 1,533 non-mechanized boats (DoF, WB,2012) mostly equipped with drift gill net containing 100 to 500 net pieces (total length comes to 0.5 km to 2 km) are actively engaged in the coastal areas of West Bengal. Fishing activities are mainly confined to marine zone of the estuary within 30 to 40 km of the shore and the inshore area up to 50m depth is intensively exploited. In coastal areas, the peak fishing season lies between July and November. Generally the fishers start their journey in the morning and reach the fishing spot after 3 hours navigation. If their fishing operation is for a day they immediately start putting their nets in the water and hauls it in the afternoon whereas in case of fishing operation for 2-3 days, thay carry ice and prefer to fix nets in the evening when they get more catch. Exploitation of hilsa in fresh and estuarine waters extends almost throughout the year which peaks during post-monsoon to spring (July-August to February-March) when hilsa migrate upstream for spawning.

Remesan, Pravin and Meenakumari (2009) have dwelt upon the non-selective gears and sustainability issues relevant to Hooghly-Matlah estuary and inferred that gears *viz.* Behunti Jal, a stationary bag net with a wide mouth of 27 m and with very small cod end of mesh size (about 2 mm), Char-pata Jal, a screen barrier having very small mesh operated for harvesting juveniles and Sitki Jal, a skimming net made up of polyethylene netting of mesh size of about 2mm for collecting fry and fingerlings, are non-selective and highly hostile for sustaining the fisheries.

Table 9. Licensed Boats in Operation for Fishing in Inland and Coastal waters of Hooghly-Bhagirathi system

Year	Mechanised			Non Mechanised		
	Purba Medinipur	South 24 Parganas	West Bengal	Purba Medinipur	South 24 Parganas	West Bengal
2002-2003	174	1015	1189	2	240	242
2003-2004	395	1908	2303	9	295	304
2004-2005	843	1761	2604	72	609	681
2005-2006	754	1279	2033	146	341	487
2006-2007	830	1490	2320	43	222	265
2007-2008	989	2241	3230	Not available	Not available	Not available
2008-2009	1221	1759	2980	670	552	1222
2009-2010	1150	2382	3532	100	1136	1236
2010-2011	1656	3459	5115	131	913	1044
2011-2012	1703	4254	5957	67	1466	1533

(Source – DoF, WB)

The perusal of the Table 9, depicts the number of licensed boats operated in the Inland and Coastal sector where hilsa constitute the main catch. The size of the mechanized boats vary between (OAL) 31 ft to 36 ft fitted with 15 HP engines and (OAL) 51 ft to 58 ft fitted with 105 HP engines. In estuarine to fresh water zones only small non-mechanised boats are in use.

Fig 38. Hilsa Fishing Boats at Frazerganj Harbour

Socio-economic conditions of the fishers involved in Hilsa fishing

A large numbers of fishers are engaged in exploitation of hilsa in the marine, estuarine and freshwater zones of Hooghly-Bhagirathi river system. It has been estimated that about 20,930 fishers have been operating between Frazergunj and Raidighi (upper stretch) whereas about 5600 fishers have been operating in the freshwater zones between Dakhineshwar and Farakka (lower stretch).

In the upper stretch, fishers exploit hilsa in groups by hiring mechanised boats which are locally known as Trawlers. As many as 70% of these mechanized boats are (OAL 57-58 ft) fitted with 4-6 cylinder engines (c.105 HP) and 30% are (OAL 31-36 ft) fitted with 1-2 cylinder engines (c.15 HP). Such mechanized boats generally fish in the marine zones of the estuary i.e., 30 km from the estuarine mouth during monsoon months whereas they go up to 60 km during winter season. Each boat accommodates 8-11 fishers who share the total catch amongst them. They pay 30% of sale proceeds to the boat owner, 30% is spent towards fuel and other wear and tear of the vessel/net & food cost on board.

Out of rest of the 40% amount is divided among the co-fishers where 2% more are given to boat and engine drivers. Mostly they operate gill nets of various sizes for exploitation of hilsa. Their income varies between Rs. 5000.00 - Rs. 8000.00 on an average per head per month. Bigger mechanized boats go for fishing for 2-5 days whereas smaller mechanized boats go for daily fishing. In regard to fish catch who goes to deeper areas for 2-5 days exploits on an average 200-400 kg per day during July to September, 100-200 kg during October to December and 50-100 kg during January to march, whereas fish catch by boats operating daily exploits on an average 50-70 kg/boat/day during July to September, 30-40 kg/boat/day during October to December and 10-20 kg/boat/day during January to April.

In the lower stretch, fishers operate small boats accommodating 1 or 2 people, exploit hilsa throughout the year. They mostly operate small gill nets of various sizes and also some times operate clap trap (Shangla jaal). They catch on an average 1-5 kg/boat/day throughout the year. Their income per month varies between Rs. 3000.00 and Rs. 6000.00.

Human impact

The hilsa fishing activities in Bhagirati-Hooghly river system mostly concentrate in lower estuarine-marine zone. During peak season of migration of mostly mature fishes, thousands of gill nets are deployed. Over the past two decades the mesh size of the gill nets *vis-à-vis* the mean size of fish has remarkably reduced. In view of this unwanted changes, which have significantly affected the fish production in the system, it is felt necessary to have control over the irrational fishing pressure and also to increase the mesh size. Further, in migration, the brood stocks face unlimited fishing pressure affecting the breeding success and resultant recruitment of desired natural stock. In view of the destructive roles of irrational fishing pressure, the fishing period, effort and mean mesh size have to be taken care off. The post breeding harvest of hilsa juveniles has also negative impact on the recruitment of natural population of this species.

I) Siltation in estuary mouth

Catchment modification and resultant carriage of soil particle to the river course as remarkably elevated the bed level all throughout. The mouth of estuary is gradually affected by siltation creating serious hindrance for hilsa migration into the estuarine system.

ii) Impact of barrages, dams etc

Construction of dams, barrages, anicuts *etc* over the rivers has created an obstruction in migration of hilsa resulting in sharp decline of its fisheries at upper reaches. The barrages or dams also deprive water flow requirement for spawning and migration of hilsa. As per earlier report, hilsa used to migrate even up to Delhi through river Ganga and similarly it was also recorded from Agra and Kanpur. After commissioning of Farakka barrage over the river Ganga in 1975, hilsa fisheries at upstream of the barrage was negligible in most of the fish landing centres. Eventually an average of 92% reduction in hilsa catch at upstream of Farakka barrage was estimated by CIFRI due to construction of the barrage. Even at Allahabad, where hilsa used to occupy a significant share in total fish catch, now it forms a meager percentage in total fish catch.

iii) Juvenile fishing

Present study reveals that hilsa breeds through a prolonged breeding season as evidenced by availability of hilsa seed from August to May. This suggests that spawning is not simultaneous for all ascending individual. Traditionally hilsa juveniles are often caught in small meshed bag net, small meshed gill net, shooting net, seine net, drag net and scoop net during their migration towards sea especially during November to May and sometimes extending up to July. The recent investigation in 2010 recorded a very alarming situation when a single bagnet catch of 10 kg at Godakhali near Budge Budge had a share of 2.8 kg very small hilsa juveniles at 5-20 g weight. Similarly, the catch of scoop nets (locally called vetijal) operated between Sodepur and Budge Budge during March consisted mostly of hilsa juveniles (>90% by numbers in total fish caught).

The estimated catch of these juveniles fluctuated between 41.1 t and 151.01 t with an average of 85 t per year during 1998-2012. Their size ranged between 30 mm and 130 mm in length and 2 to 20 g in weight. An extrapolated estimation reveals that 50% reduction of the juvenile killing has the potentiality to increase the adult production by about 10%. Another estimate reports that if even 1% of this could be saved, then the production of hilsa could be increased by 4000 t/year.

iv) Exploitation of brood fishes

The present study reveals the fishermen capture gravid female hilsa during their upstream breeding migration mostly at estuary mouth during monsoon. This has a tremendous adverse impact on population recruitment and declining of hilsa fisheries. The undersized hilsa (below 500g) are being caught in huge numbers using monofilament nets at Frazerganj-Namkhana area in Hooghly estuary defeating the very cause of stock sustenance and leading to decline in of hilsa fishery of the Bhagirathi-Hooghly riverine system. Fish catch recorded from five mechanized boats at the Frazerganj fishing harbour was 5.6 t out of which hilsa alone was 3.2 t (56.3%) and 66% of them were female fish. The observations on maturity conditions revealed that 59.8% of the fishes were in 4th stage of maturity followed by 26.3% in 3rd stage, 7.5% in 2nd stage and 6.4% in 5th stage.

v) Lack of mesh size regulation

Presently fishing with small mesh sized (< 60 mm) gill nets are mainly responsible for reducing the size of hilsa in the coastal region as well as in the freshwaters of the Bhagirathi-Hooghly riverine system. In order to maintain sustainable yield and also to increase fish production, regulation of selective fishing through control of mesh size of the fishing gears are warranted.

vi) Over-fishing

The trend of fish catch in the Hooghly-Bhagirathi riverine system indicated significant increase during the post Farakka Barrage, primarily due to manifold increase in Hilsa catch. In recent years, between 1998-99 and 2002-03, the average per annum catch of hilsa has been estimated at 11,482.9 t with an impressive increase of 63.3% from the corresponding five years (6279.6 t). Over the years, however, the mean length of hilsa has declined, from 356 mm (1960s) to 300 mm or even less (2000s) - a manifest of increased efforts, indicating over-fishing.

vii) Ineffective fish pass

Fish lock provided in Farakka barrage is non functional at the present point of time. Tagging experiments conducted by CIFRI revealed that hilsa from Bhagirathi-Hooghly riverine system could not move across the barrage due to obstruction of the three tire sluice gates. However, hilsa can negotiate and pass through Farakka barrage to a small extent during monsoon from Padma side when the gates are opened.

viii) Loss of habitat

Increased water abstraction for irrigation as well as use in industrial purpose resulted in reduction of water volume in parts of upper Hooghly estuary which has caused loss of breeding and spawning habitates. Siltation in rivers created shallow water depth unsuitable for hilsa migration and it was observed that hilsa prefers migration at a depth 4-5 m. The loss in habitat is directly related to the recruitment potential of hilsa fishery.

ix) Pollution

Ecological aberrations due to industrial and domestic effluents noticed in selective zones and periodically in most of the river systems also inhibit the upstream migration. Hooghly-Matlah estuarine system flows through highly industrialized area like Haldia complex and Calcutta-Howrah metropolis and receives domestic refuse from thickly populated city areas, and effluent from industrial establishments. This exerts great stress to migratory fishes like hilsa.

Box 3

- Strict implementation of control over juvenile fishing
- Man-made obstruction through dam, barrage and similar other structures affecting the breeding migration of hilsa
- Provision of fish passes, lock gates and fish lifts need to be considered.
- Human interventions by way of waste discharge through various sources like industrial establishments, human habitations, agricultural run -off etc. contaminating the congenial breeding and nursery environment need judicious control

Conservation Strategy

To save the hilsa for sustainable fishery in Hooghly-Bhagirathi river system, it is the high time to develop rational conservation strategy. Mono-filament fishing gears possessing mesh size of 70 to 85 mm or less are being used to exploit undersized hilsa of less than 500 g at Frasergunj, in proximity to mouth of Hooghly estuary. This denies the fishes to breed and the very purpose of developing sustainable hilsa fisheries is greatly defeated (Bhaumik *et al.,* 2011). Observations in the fish catch of a few mechanized boats operating from Frazergunj fishing harbor, revealed that hilsa contributed 56.3% of total catch of 3.2 t and most of the fishes (66%) were female where 59.8% of fishes have been observed to be attaining 4th stage of maturity. A concern for bottom trawling by foreign vessels has also been raised, since besides exploiting hilsa, these are also ruining the breeding grounds of a number of fin and shell fishes. Bag net fishing is rampant and this is denying the hilsa juveniles to contribute towards fishery .These approaches cover high risk under the prevailing set of negative harvesting measures. There is practically no control on fishing efforts and compliance of observing closed season is limited and there is hardly any gear restrictions due to open access, lack of social awareness, poor control and surveillance.

Fig 39. Awareness campaign for conservation of Hilsa

Desired measures towards responsible fishery

Technical measures for effecting improvisation in harvesting methods and employing conservational measures are main concern at state as well as central level. An official fishing ban in marine fisheries sector exists from 15th April to 15th June in West Bengal which does not coincide with the period when migration of brood fishes takes place. There is a need to enforce the laws in a more realistic manner. Fine meshed gears are employed which are non-selective and cause comprehensive loss due to non-compliance of Code of Conduct of Responsible Fisheries (CCRF).

Monitoring, Control and Surveillance (MCS)

Monitoring, Control and Surveillance on the fisheries are the important aspects to be

implemented for sustainable hilsa fishery in the Hooghly-Bhagirathi river system. Presently, there is hardly any control over the exploitation systems being practised by fishers in the estuary. This is like an open access to everyone although licensing codes imposed by the State Government exists. There seems to be inadequate resource management policies where the enforcement agency expresses their helplessness due to limited man power and other infrastructure facilities. The fishers and other user groups due to poor socio-economic status find it very difficult to comply with the rules and regulations. As such, the surveillance towards responsible fishing is very poor resulting in destructive fishing not only by the fishers of national arena but also by the foreign intruders.

Possible modification of management protocols

Possible modifications in prevailing management practices may be exercised by bringing in holistic eco-system based approach of management since institutional management arrangements vested with various stakeholders do not adequately address the challenges, which the hilsa fishery faces today. A score of factors *viz.* over-exploitation, negative habitat modifications, climate change etc. have contributed to the decline of hilsa fisheries but it is the high time to render due impetus to human activities overridingly affecting the management of hilsa fisheries. Habitat improvement following stock assessment, harvest management decisions including closed season declaration, closed area provision and ban on negative fishing methods and a strong *monitoring machinery* are the need of the hour.

Box 4

- Migration of hilsa in Hoog hly-Bhagirathi system observed to be related with the amplitude of flood and depth profile of the estuarine-river course
- Spawning of the species dependent on factors like the maturity condition (gonado-somatic index), river hydrography and hydrology and meteorological parameters
- Intensive fishing in the estuarine mouth region created barrier and also dispersed hilsa on the way to breeding migration in upper freshwater environment
- Under-sized fishing through small meshed gill nets and unwanted hauling of the juveniles observed as major human factors affecting the migration, spawning and recruitment success of hilsa
- An immediate need to formulate effective measures and also bye-laws to protect precious breeders and potential breeding grounds

Recommended interventions towards conservation of the hilsa fishery in the Hooghly-Bhagirathi river system

The major breeding migration of hilsa starts during July which extends up to February. As per Government of India circular, the official fishing ban is also in force in the marine fisheries sector along the West Bengal coast during April 15 to June 30. Still there is need to strictly adhere to the mesh size (100 mm) regulation especially at estuary mouth to control exploitation of hilsa of below 500 g brooders to facilitate them to breed at least once in the life cycle.

- Complete ban on hilsa fishing in and around 10 km radius of the breeding ground at least during October-November should be enforced, in other words fish sanctuary to be declared in that area during the period. During those periods designated hilsa fishers need be given adequate compensation by the government towards maintenance of their livelihood.
- There should be a strict ban on capturing of juveniles to conserve hilsa fishery. Eventually strict vigil is required by the law enforcing authority to control wanton destruction of hilsa juveniles. As most of the juveniles start downstream migration during March-May after attainment of the size of 80-150 mm, regulation towards the use of bag net or scoop net during these three months will facilitate the juveniles to migrate to the sea and maintain the original stock.
- It is expected that most of the migrating hilsa congregate near Farakka barrage once obstructed. Fishing may be prohibited within five kilometers of the barrage to facilitate brooders for spawning.
- Improvement of aquatic habitat with more emphasis in dredging the estuary mouth may encourage more spawners to migrate upstream.
- Surveillance by the Territorial Coastal Guard is very much warranted to stop operation foreign vessels in the fishing areas of marine zone of the estuary.

Conclusion

There is an urgent need towards conservation of the species in view of the present national interest for sustaining the prized hilsa fishery in the country. Intensive fishing in all the water bodies is to be controlled without *further* lapse of time. In order to maintain sustainable yield and also increase production, regulation of selective fishing by adjusting mesh size of the gears and simultaneous control of juvenile killing should be encouraged.

Acknowledgements

Authors express their thankfulness to Dr. Malay Naskar, Principal Scientist (Statistics), Dr. R. K. Manna, Sr. Scientist (Chemistry), Dr. B. P. Mohanty (BioChemistry), Dr. B. B. Satapathy, Dr. A. K. Sahoo, Mr. Rosith C. M.(Biology) and Mr. S.K. Sahu, Scientist (GIS) for their scientific support and to Technical staff, namely S/s. C. N. Mukherjee, R. C Mandi, A. Mitra, D. Sanfui, D. Saha, A. Barui, S. Mandal, B. N. Das, A. Roy Chowdhury, and Mrs. A. Sengupta for collection of samples and analyses.

References

Anon, 2012, Report of Department of fisheries, Government of West Bengal.

Anon, 2001-12, Annual Reports, CIFRI.

Bhanot, K.K., 1973. Observations on the spawning of *Hilsa ilisha* (Hamilton) in the Hooghly estuary.

J. Inland Fish. Soc., India, 5: 50-54.

Bhaumik, Utpal, 2010 . Status of fishery of Indian Shad,(*Tenualosa iIlisha)* with reference to the Hooghly river system, 21st All India Congress of Zoology ,December 21-23, 2010: 66-81.

Bhaumik, Utpal, Srivastava, N.P, Satpathy, B.B, Mukhopadhyay, M.K and Sharma, A.P, 2011. Impact of hydro-ecology on fish migration in selected east coast estuaries. *J. Inland Fish.Soc.India,* 43(1),1-9.

Bhaumik, Utpal, Naskar, Malay and Sharma, A.P, 2011b. Size distribution, length-weight relationship and sex ratio of the hilsa (Tenualosa ilisha) in the Hooghly estuarine system. *J. Inland Fish. Soc. India,* 43(2) : 1-5, 2011.

Bhaumik, Utpal and Sharma, A.P., 2011c, The fishery of Indian Shad (Tenualosa ilisha) in the Bhagirathi-Hooghly river system, *Fishing Chimes,* 31 (8): 21-27.

De, D.K., 1980. Maturity, fecundity, and post monsoon run of Hilsa in the upper stretches of the Hooghly estuarine system, *J. Inland Fish. Soc. India*, 12(1): 54-63p

De, D.K., 1986. Studies on the food and feeding habit of Hilsa, Hilsa ilisha (Hamilton) of the Hooghly estuarine system and some aspects of its biology. Ph. D. Thesis, Calcutta University, 285 p.

De, D.K., 1991. Hilsa fisheries in the context of Farakka barrage. In course material on open water fishery resource assessment and management for FAO trainee held at CICFRI, Barrackpore, Nov 06- Dec 02, 1991. 1-8p.

De, D.K and N.C. Dutta 1990. Age-growth, length-weight relationship and relative condition in Indian shad Hilsa, *Tenualosa ilisha* (Ham.) from the Hooghly estuarine system. Ibid, 37: 199-209.

Hora, S.L. and K.K. Nair., 1940a, Further observation Bionomics and fishery of Indian shad , *Hilsa ilisha* in Bengal waters. *Rec. Indian Mus.*, 42: 35-50p.

Hora, S.L., 1938. A preliminary note on the spawning grounds and bionomics of the so called Indian shad *Hilsa ilisha* in the river Ganges, *Rec. Indian. Mus.*, 40: 147-148p.

Jones, S. 1959. Fishing methods of Indian Shad, *Hilsa ilisha* in the Indian región, Part 1 and Part 2, *Bombay Nat. Hist. soc.* 56: 250-275p.

Mathur, P.K., 1964. Studies on the maturity and fecundity of the Hilsa, *Hilsa ilisha* (Hamilton) in the upper stretches of the Ganga. *Indian J. Fish.*, 11: 423-448.

Mitra, P.M., K.K. Ghosh, B.N. Saigal, N.D. Sarkar, A.K. Roy, N.C. Mandal and A.R. Paul, 1987. Fishing gears of the upper and the middle Hooghly estuary. Bull 40. CIFRI, Barrackpor: 25p Mohanty, B.P., Das, Soma, Bhaumik, Utpal and Sharma, A.P, 2011, *Tenualosa ilisha* – a rich source of omega – 3 fatty acids, Bulletin 171, CIFRI, Barrackpore : 49p.

Pillay S.R., & K.V. Rao, 1963. Observation of the biology and fishery of hilsa, *Hilsa ilisha* (Hamilton), of river Godavari. Proc. Indo – Pacif. Fish. Coun., 10(2): 28-36.

Pillay, S.R., & Rosa, H., 1963. Synopsis for biological data on the hilsa, *Hilsa ilisha* (Hamilton) 1822. FAO Fish. Biol. Synops., 25p.

Pillay, T.V.R., 1958. Biology of the hilsa, *Hilsa ilisha* (Hamilton) of the river Hooghly. *Indian J. Fish.* 5: 201-257p.

Remesan, M.P., Pravin, P, and Meenakumari, B., 2009, Non selective fishing gears and sustain ability issues, in Hooghly-Matlah estuary, West Bengal, India, Asian Fisheries Sci. 22p.

Ruben, S., S.S. Dan, M.V. Somaraju, V. Philipose and T.V. Sathianandan, 1992. The resources of hilsa Shad, *Hilsa ilisha* (Hamilton), along the northeast coast of India. Indian J. Fish 39: 169-181.

Saxena, R.K., 1964. The fishing nets and traps in a section of the middle reaches of Ganga River System of India. Proc. Indo – Pacif. Fish. Coun., 11: 250-271.

Saxena and Chandra 1968. On the Introduction of *Phasla Jal,* a gill net , for catching hilsa in the Ganges and Yamuna near Allahabad. J. Bombay Nat.Hist. Soc. 65: 496-498.

Swarup, K., 1958. The Hilsa Fishery at Allahabad Proc. Nat. Seat. Sci., India, B, 28: 379-394.

Swarup K., 1961. The fecundity of Indian Shad, *Hilsa ilisha* (Hamilton) of Allahabad water (I): Length-weight relationship. Jap. J. Ichthyol., 12: 82-88.