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QUEST FOR THE DETERMINATION OF ENVIRONMENTAL FLOW ASSESSMENT FOR HILSA FISH OF THE HOOGHLY ESTUARY BY HYDRAULIC RATING METHOD

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ABSTRACT

Environmental flow is a concern for ecologically healthy river, living river and it comprises both water quality and water quantity. This is the process of optimization of river flow for maintenance of its indigenous beneficial flora and fauna, without any allowance for the opportunistic species to reign in the river system. The biotic and abiotic factors dependant on the environmental flow plays the guiding role for this maintenance of river eco system. Hence the need for the assessment of the biotic and abiotic factors for the determination of environmental flow is felt. Integrated Water Resources Management (IWRM) is to balance water allocation keeping in view to the different users and uses among human and other living creatures of the nature. This is because in many cases of the flows of the rivers of this world are increasingly being modified through impoundments such as dams and weirs, abstraction for agriculture and urban water supply, drainage return flow, maintenance of flows for navigation and structure for flood control (Dyson *et al,* 2003; Postel and Richter, 2003). It is to be noted that in the Hooghly estuary in India, Hilsa fish is the main commercial and most popular and highest profit making product of the river. Hence its abundance (Hilsa catch) along with the abiotic parameter has been considered for the assessment purpose of the environmental flow, by the method of Hydraulic Rating, which consists low cost and rapid to use (i.e. wetted perimeter, river cross section and salinity variation, River Flux Study with time; Table-1) and a befitting water quality status based on Indexing Method. Indexing Method has been applied using additive type for the determination of proper weight in respect of each water quality parameters considered here, as used by National Sanitation Foundation Water Quality Index (NSF WQI) of the U.S.A.

Keywords: environmental flow, hydraulic rating, river eco- system.

INTRODUCTION

To promulgate environmental flow for a river, several hypotheses from different corners of the several countries are still not full proof. This is because most of the human activities are pervaded under the hood of economically and/or Politically powerful users providing relatively well developed methods for quantifying and justifying their water needs, defying the need of the ecosystem - the silent water user which depend upon the subtle interaction of the air, water and river bed interfaces comprising biotic and abiotic parameters. The situation of estimating methods of Environmental Flow becomes grimmer when the focus is contemplated on estuaries rather than most of the focus of studies on rivers and wet lands in the past decade (Jowett, 1997; Gipple and Stewardson, 1998; King and Louw, 1998; Cui *et al*, 2002; Tharme, 2003; Yang *et al*, 2003; Benetti *et al*, 2004). This is because the traditional methodology of data collection gets complicated due to the complex process of fresh water mixing with saline water intrusion. Also the study based on traditional process of fluvial system does not hold well in the case of estuarine environmental flow assessment. The response of Hilsa fish abundance (an anadromous species) presents a close association with the river salinity, fresh water supply and deep traits (nearly forty feet) at the entrance channel of the river (threshold values of its requirements are in Table-2). Because of its anadromous nature, an uncommon phenomenon in tropical waters, the Hilsa live in the sea most of its life, but migrates up to 1200k.m. inland through rivers in the Indian subcontinent for spawning. Distances up to 50-100k.m. are usually normal in the Bangladesh rivers. Similarly to date, the highest salinities in which zebra mussels have been found in North America appear to be in the Hudson River estuary about 2-6 $^0/_{00}$ (Walton,1994). Quagga mussels typically occur in fresh water or in salinities up to $1^0/_{00}$ and can reproduce in salinities below 2-3 $^0/_{00}$ (Rosenberg Ludyanskiy, 1994). In the Dineper/Bug Liman (Ukraine), quagga mussels are killed by saline intrusions exceeding 6 $^0/_{00}$ (Rosenberg Ludyanskiy, 1994).

The study

The present study has been carried out on the River Hooghly, because of the fact that the Hilsa fish, mainly the species tenualosa ilisha (Hamilton-Buchanan) among others like T. toli (Valenciennes), T. Kelle (Couvier), under the genus Tenualosa has been recognized as the most important Indian riverine crop and is under the close intervention at the river mouth, with the world famous biggest riverine twin port of Kolkata and Haldia

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are situated on this river bank. Its huge hinter land comprises not only several states of India but abroad too. The Hooghli River is basically a tributary of the main River Ganga. Ganga flows eastward through Bangladesh and its south ward branch named Bhagirathi-Hooghli river system has been originated from the main River Ganga at Biswanathpur (Figure-1). The upper 242k.m. of this Bhagirathi- Hooghli river system has been christened as River Bhagirathi and rest of the lower part i.e. 281.91 k.m. from Matla Station near sand head is named as Hooghly River. However Kolkata Port Trust has the jurisdiction beyond of Matla Station (Figure-1), i.e. further up to 242.6K.M.from Fort Point near Kolkata Gowalior Monument. As a result to maintain shipping routes, a huge dredging activity along with river training works (Figure-2) might make the river prone to perturb its ecological system (both biotic and abiotic). Consequently the most popular and profitable fish Hilsha of this river, becomes the prime concern of investigation for its productivity.

Also it has been observed that from Khidderpur to Hooghly Point, average rate of travel of Flood for one nautical mile is 2.9 min and that of Ebb it is 4.9 min. However from Hooghly Point to Sagor, average rate of travel of Flood for one nautical mile is 3.1min and that of Ebb it is 4.3min. This phenomenon shows the prevalence of ebb water (sweet water) having a greater dominance in the upper reaches, which is conducive to the Hilsa breeding (Figure-3), both in respect of flow speed as well as longitudinal salinity profile (Figure-4), especially in post Farakka periods (1975) and other threshold physico chemical parameters for Hilsa (Table-2).

Since fresh water inflow induces the Hilsa shoal, a flood flux to ebb flux ratio (Table-3 and Figure-5) along with longitudinal salinity profile (Figure-4) may be an indicative feature of the conducive Hilsa catch. However the wetted perimeters (Reiser *et al*., 1989), hydraulic mean radius and maximum depth (thalweg) study has been contemplated at the vicinity of Nayachara near Haldia, where the river entrance plays a guiding role for brood Hilsa migration (Figures 6-9).

Regarding the migratory nature of the Hilsa it has been observed that about 4.0m - 4.5m depth from surface is favourable for migration of adult Hilsa. Thus the total depth in the system should be more than 4.0m - 4.5m for favourable migration and spawning of Hilsa (Bhaumik *et al*., 2011.a). Maximum depth variation (Figure-9) and Tidal Amplitude study (Figures 14 and 15) has been carried out for this purpose.

Observation

From the Table-3 and Figure-10, (source: Central Fisheries Research Institute, Barrackpore, W.B., India), it has been observed that a peak in Hilsa catch has occurred during the year 2000-2003. Also from Figure-11, flood havoc occurred in west Bengal on 22.9.2000. Status is as under:

A snap shot (Figure-11) of the flood havoc on 22/9/2000 in West Bengal as witnessed by the Kolkata Port Trust officials during Bhagirathi survey on 17/1/01 reveals that the water level on the ground (river bank) raised by 6.36 m above normal amounting to 12.85 m. near Mayapur (further upstream of Moyapur; c/s-347). At Swarupgunj, 11.92 m GTS, at Berhampore 19.125 m, GTS.

Also it has been seen that the almost at the entrance channel of the River Hooghly i.e. at Haldia reach, the hydraulic parameters viz wetted perimeters, river cross sectional area, hydraulic mean radius etc are remaining almost in an invariant status over the years with a deep vis-à-vis impediment (i.e. fall in depth) to the Hilsa migration route at the Lower Auckland area (Figure-6).

As mentioned earlier, dredging activity may pose perturbation in Hilsa abundance. But as evidence from the studies at Haldia region in 1992-'95, conducted by the Bose Institute, Kolkata in the past show that despite of the locally disturbed river bed by dredging activities, Planktonic population (both Phyto - Plankton and Zoo-Plankton) is fairly regained just after the end of dredging operation (Table-4 and Figure-12). Also it can be observed from the fluctuating nature of the Indexing curve (Figure-13) that the quality of water is fairly rejuvenated despite of the dredging-dumping operation in the river.

CONCLUSIONS

After marginally noting the various factors, it may be inferred that biotic factors (from the view point of Planktonic population) are not so much limiting rather than abiotic factors like fresh water inflow and a huge siltation near Auckland area, depicting continuous reducing trend of Hydraulic Mean Radius and increasing trend of wetted perimeter (Figures 7-9), at the entrance path of the Hooghly Estuary (Figure-6), thus making the estuary shallow and wide. This is due to that on account of aging and insufficient fresh water inflow to the entrance region of the estuary, siltation causes aggradations of the river bed along with frequent changes in the deep water channels making them deep water flood cul-de-sac, thus causing the migration route of the anadromous Hilsa very difficult each year. This type of Hindrance in the migration rout of Hilsa also can be seen from the creation of Farakka Barrage, which causes lesser availability of Hilsa in the upper reaches of the River Ganga, compared to the earlier days.

Dredging activity might limit the Planktonic abundance by reducing the Sunlight intensity due to enhancement of water turbidity. However it is seen, that dredging operation causing agitation of the bed, takes its normal form readily just after completion of the dredging operation (Figure-12). Conversely continuous dredged route from sea face to the Port of Kolkata may be congenial to the brood fishes for migration (Figure-2). However from the observation of highest depth (Figure-9) Tidal Curves (Figures 14 and 15), it is seen that the requirement of desired depth of the Hilsa fish is fairly available still at this stage (i.e. Tidal variation/Range of 5.0 m in the Spring and 2.1 m in the Nip and a tidal rise of 3M

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and 1.8 M from Mean Tidal Level plus 10 (7+2.82) to 15 (12+2.82) M maximum depth (thalweg depth).

But the dominant role making the Hilsa abundance scanty might have been occurred on account of an irreversible huge siltation process (vide H.M.R., Depth variation curves; Figures 8 and 9) at the mouth of the lower estuary near Jellingham and Auckland area (Figure-6) are the root causes of mating the passage flood cul-de-sac.

Rather it to say that effect of the fresh water inflow as evidenced from the flood havoc snap, along with subsequent Hilsa catch (Figure-11), might be one of the factors for the requirement of greater amount of fresh water inflow along with the clear migrating route (by dredged channels from sea face), for induction of brood Hilsa fishes from the sea face.

Table-1. Major advantages and disadvantages of environmental flow assessment methodologies.

Methodologies	**Duration of assessment** (months)	**Major advantages**	**Major disadvantages**
Hydrological Index	1/2	Low cost, rapid to use	Not site-specific
Hydraulic Rating	2-4	Low cost, rapid to use	Ecological links assumed
Habitat Simulation	6-18	Ecological links included	Extensive data collection and use of experts, high cost
Holistic	12-36	Covers most aspects	Requires very large scientific experts, very high cost, not operational

Table-2. Threshold values of physio-chemical parameters for Hilsa migration, breeding and rearing.

Parameter	**Breeding activities**	**Nursery activities**
Depth	20 m and above for migration and pre-breeding congregation	Comparatively shallower depth near river-estuarine margins above the congregation ground
Turbidity (NTU)	100-140	Comparatively low turbid areas (70-80 NTU)
Temperature (ºC)	29.3-30.2	29.8-30.8
Salinity (ppt)	<0.1	<0.1
D.O. (ppm)	5.0-6.8	4.8-6.8
pH	7.7-8.3	7.9-8.4
Chlorophyl (µg/l)	0.114-0.180	0.140-0.180

Source: Central Fisheries Research institute; Barrackpore; W. Bengal; India.

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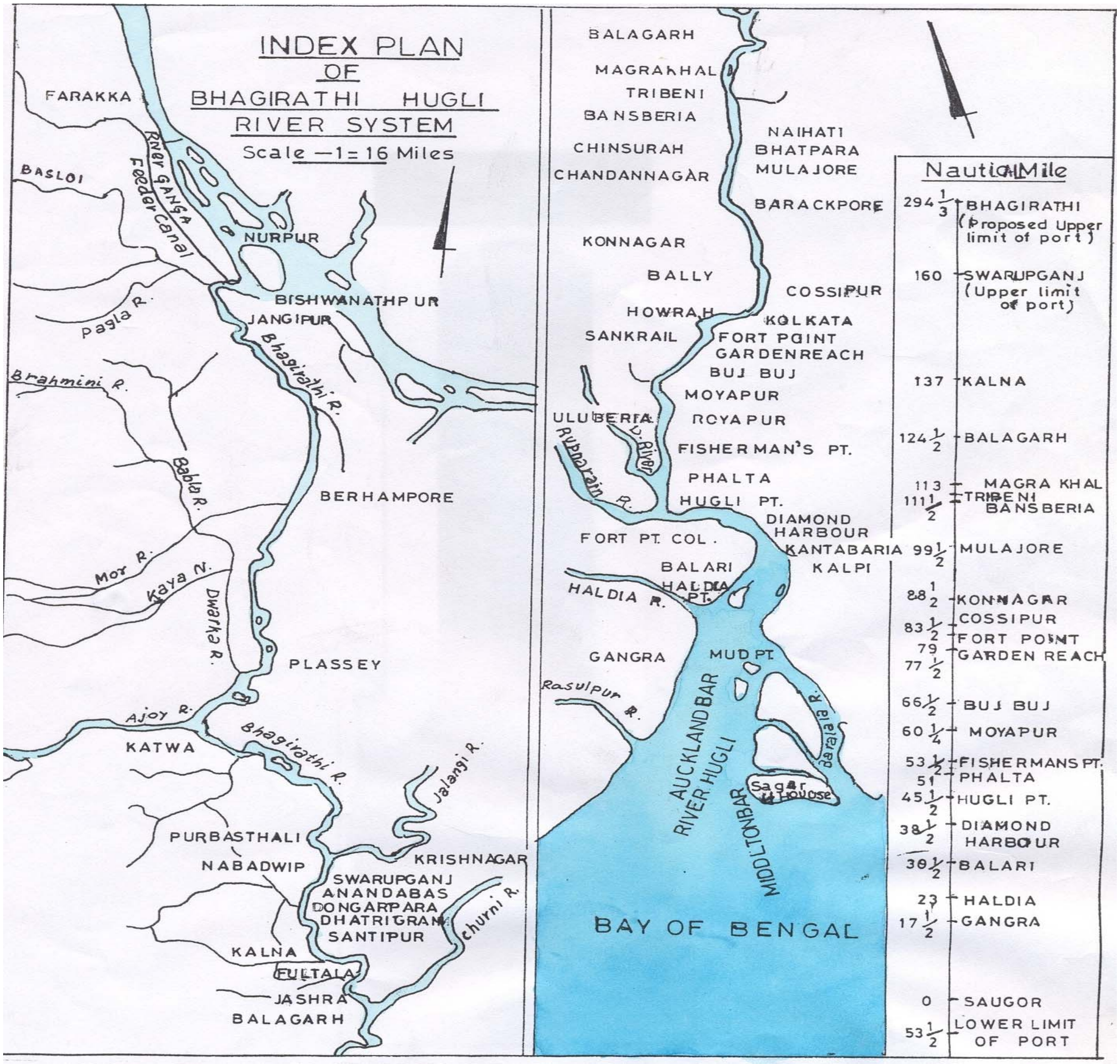

Source: Kolkata Port Trust, Hydraulic Study Department, India. Note: 1 Nautical Mile = 1.845K.M

Figure-1. Index Plan of Hooghly Estuary (includes study zone).

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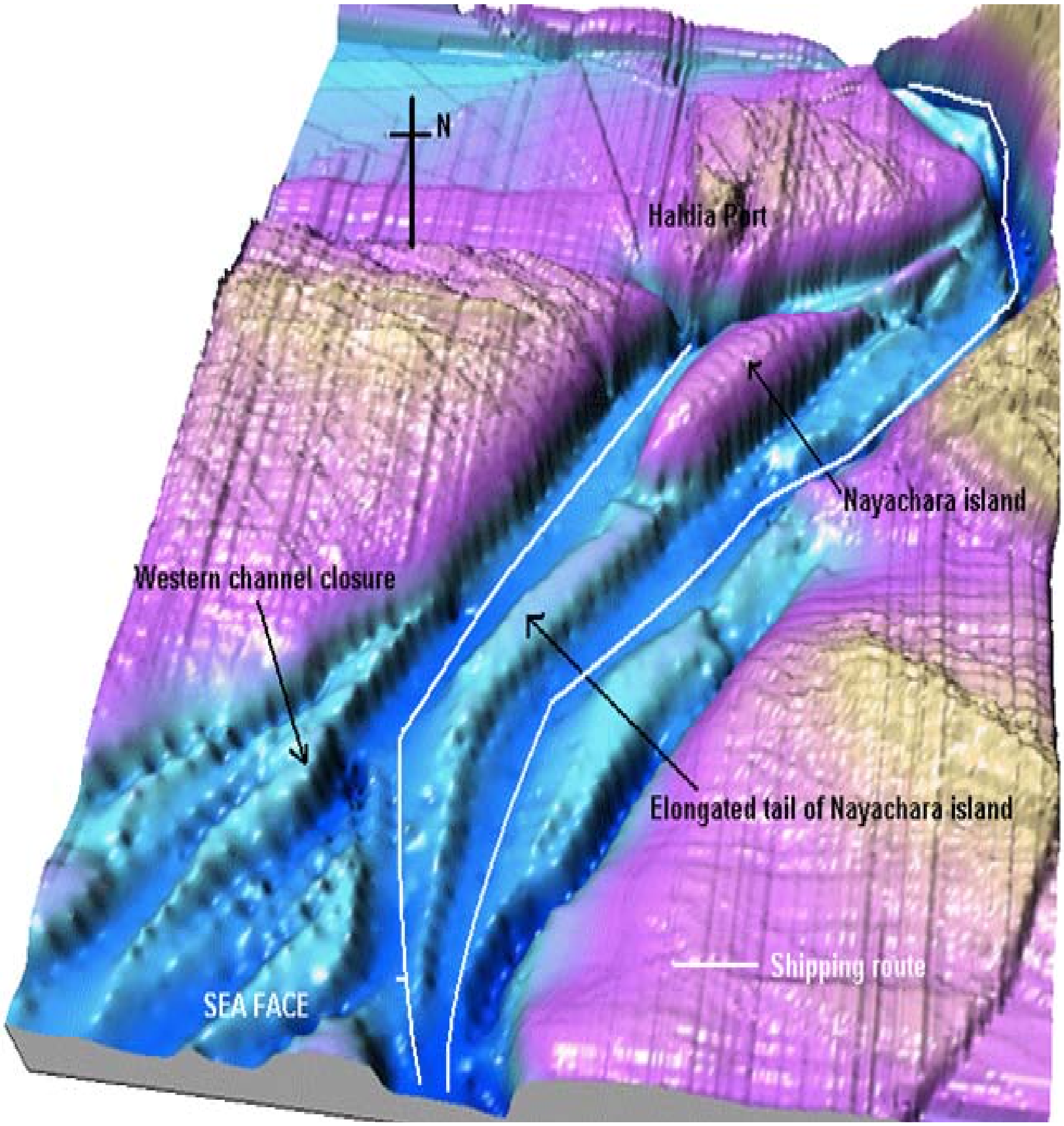

Figure-2. 3- Dimensional view of ved profile of the study zone of Hooghly River.

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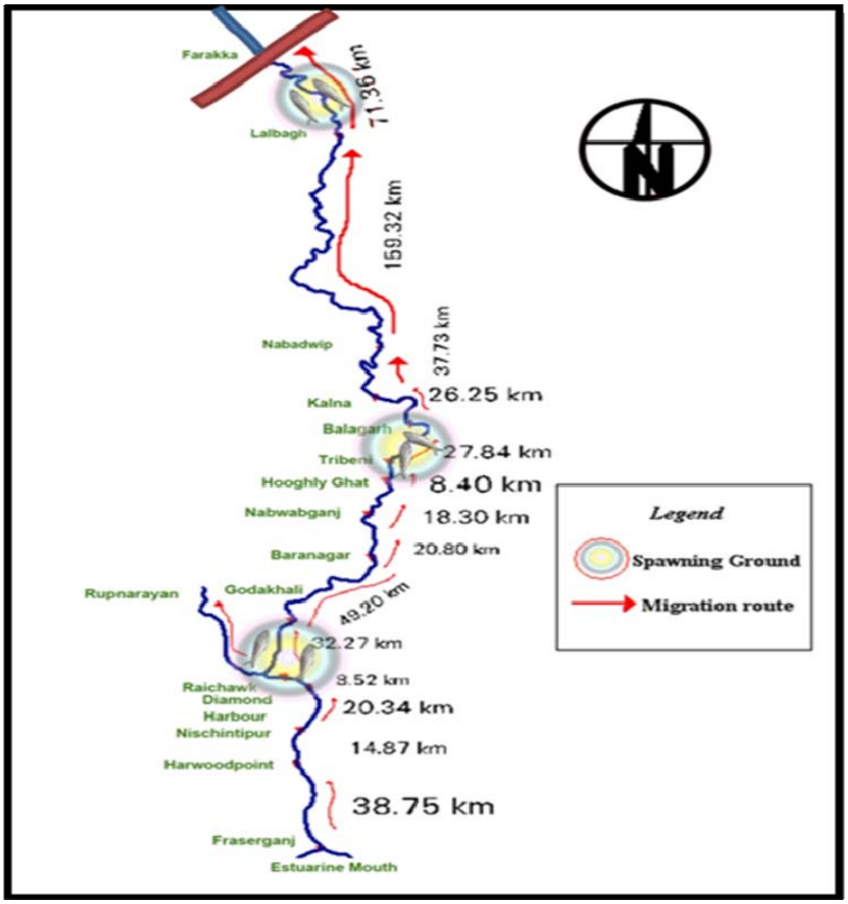

Figure-3. Natural spawning ground of Hilsa Fish in the Hooghly River.

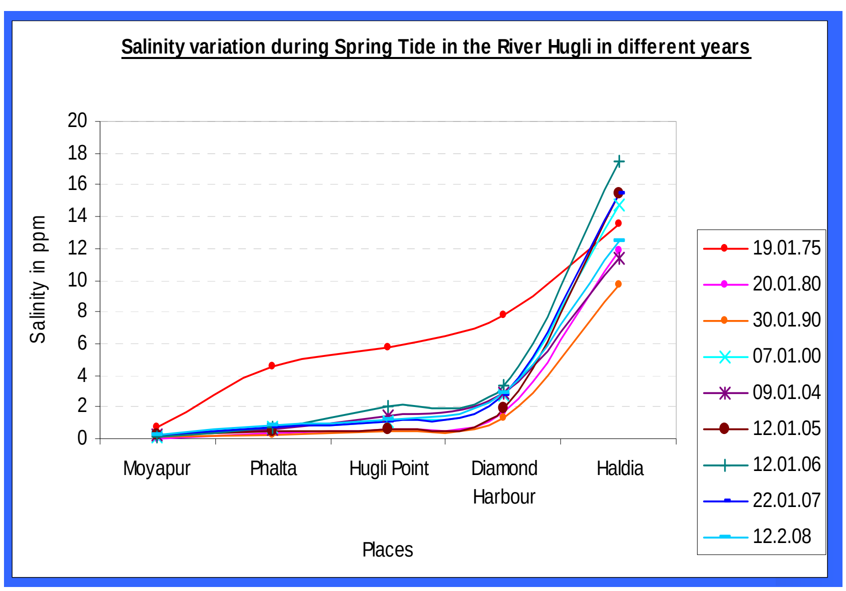

Figure-4. Variation of salinity I Hooghly River.

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Table-3. Flux sharing history in the twin channels of the study reach in Hooghly River.

Flux history (with Sagor range in M) of River Hooghly in 10^6 M^3										
Date of observation	**Sagor range in M**	**Haldia**			**Rangafalla**			**Total river** (Haldia + Rangafalla)		
		Flood	**Ebb**	**Haldia flood to Ebb ratio**	**Flood**	**Ebb**	**Rangafala flood to Ebb ratio**	**Flood**	**Ebb**	**Hooghly flood to Ebb ratio**
5/2/1992	3.6	330	302.5	1.091	980	1287.5	0.761	1310	1590	0.824
30/1/1994	4.25	510	360	1.417	825	1040	0.793	1335	1400	0.954
9/12/1995	3.48	222.5	177.5	1.254	551.25	652.5	0.845	773.75	830	0.932
24/12/1995	4.3	408.8	347.5	1.176	857.5	1008.8	0.850	1266.25	1356.25	0.934
7/2/1997	4.08	330	285	1.158	922.5	967.5	0.953	1252.5	1252.5	1.000
13/11/1997	4.3	377.5	323.75	1.166	801.25	977.5	0.820	1178.75	1301.25	0.906
2/12/1998	3.8	310	256.26	1.210						
19/2/1998	4.41	329.4	282.5	1.166	785	862.5	0.910	1114.38	1145	0.973
11/10/1999	4.06	415.9	354.56	1.173						
8/11/1999	4.27				760	951.25	0.799			
10/11/1999	4.1	395	261.25	1.512	729.74	913.38	0.799	1124.74	1174.63	0.958
5/10/2001	3.98	350.8	265.75	1.320						
7/3/2003	3.85				826.5	1082.4	0.764			
21/2/2003	4.2	467.5	360	1.299						
10/2/2005	4.5				1253.8	1277.5	0.981			
21/8/2005	5.25	592.8	388.25	1.527						
14/2/2006	3.5				862.5	1005	0.858			
15/2/2006	3.68	286.9	268.23	1.070						
22/2/2008	4.11	230	220.63	1.042						
23/2/2008	4.11				811.88	834.39	0.973			
29/12/2011	3.16	217.8	171.38	1.271	659.63	954.81	0.691	877.44	1126.19	0.779
30/1/2013	4.05	293.8	207.5	1.416	697.5	842.5	0.828	991.25	1050	0.944

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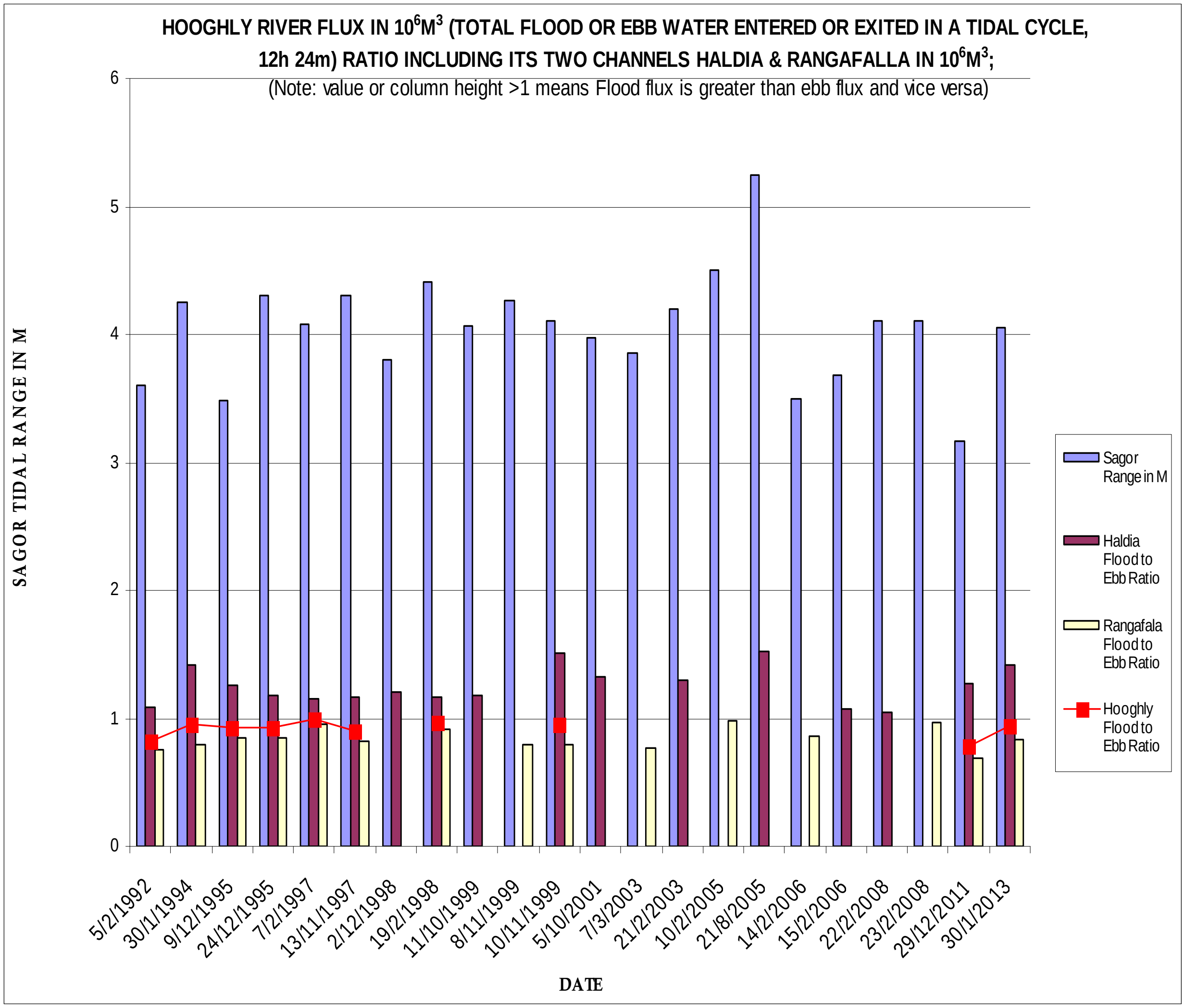

Figure-5. Flux sharing history in the twin channels of the study reach in Hooghly River.

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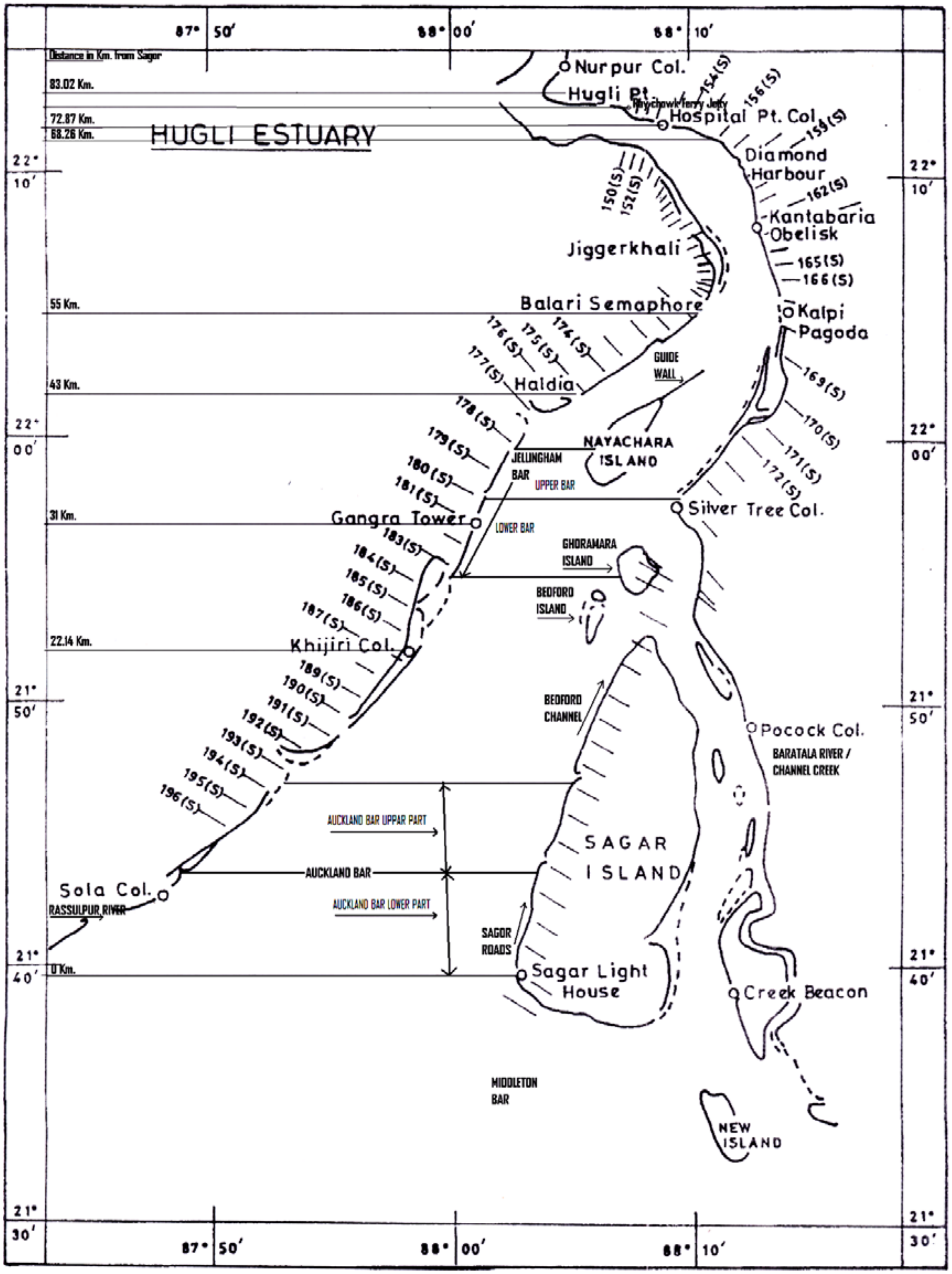

Figure-6. Study zone of the Hooghly River with cross sectional markings for vivid survey.

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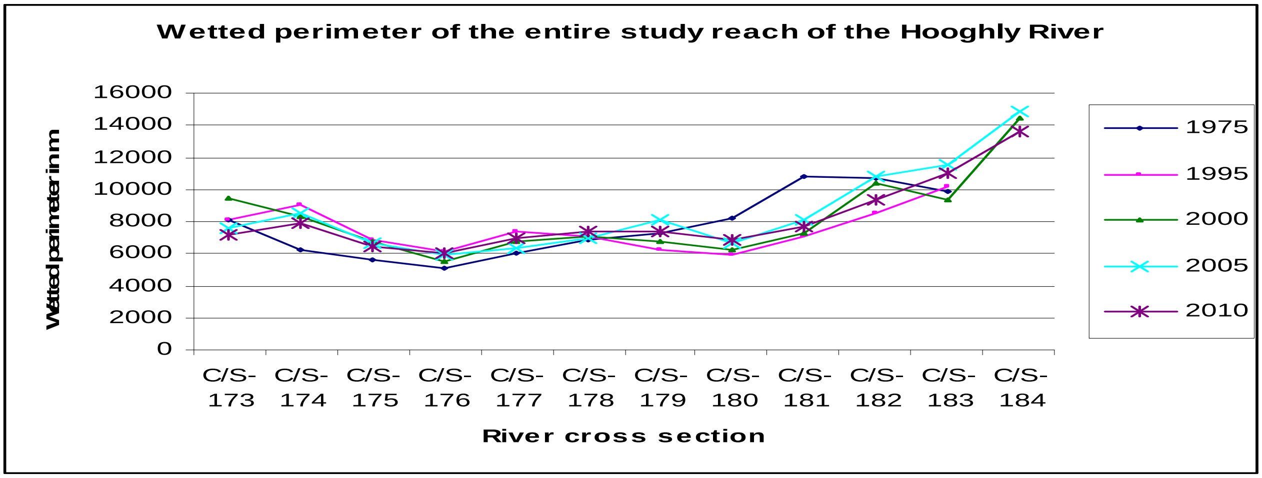

Figure-7. Different Hydrological Parameter study of the study zone of Hooghly River.

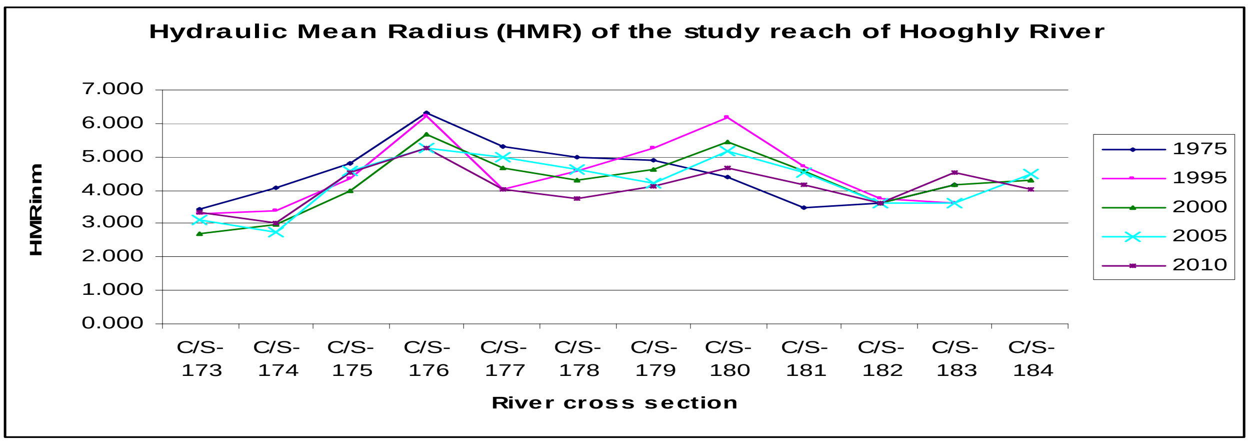

Figure-8. Different Hydrological Parameter study of the study zone of Hooghly River.

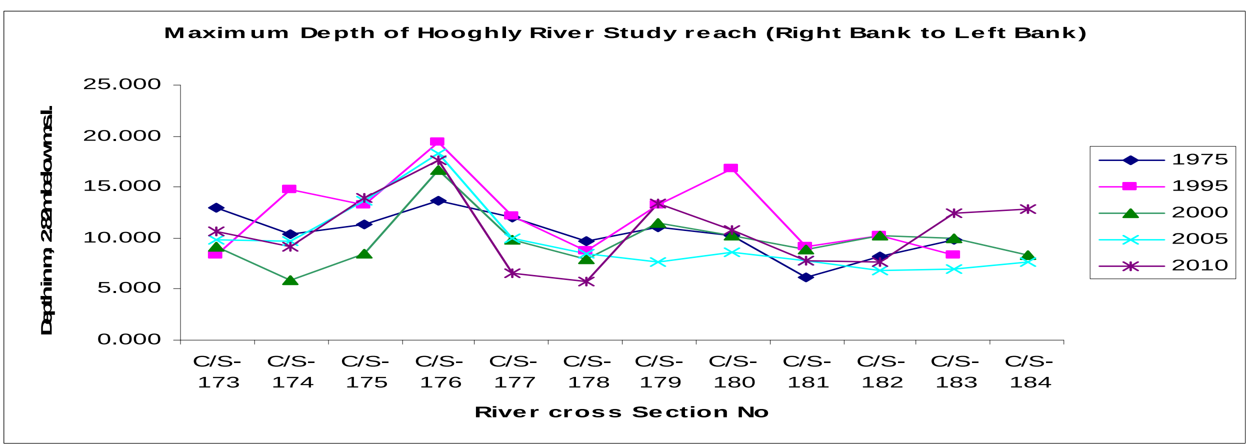

Figure-9. Different Hydrological Parameter study of the study zone of Hooghly River.

N.B. Depths are in M reduced to Chart Datum, which is 2.82M below Mean Sea Level. i.e. 2.82 M should be added to this depth to get the depth w.r.t . Mean Sea Level.

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Table-4. Year wise Hilsa Fish catch history of the Hooghly River.

Inland Hilsa catch of Hooghly River					
Year	**Catch in Ton**	**Year**	**Catch in Ton**	**Year**	**Catch in Ton**
1962	1058	1982	6197	1999	11580
1963	1504	1983	1761	2000	6539
1964	1413	1984	1974	2001	32096
1965	1475	1985	1297	2002	33102
1966	887	1986	1087	2003	32100
1967	799	1987	2853	2004	17000
1968	1337	1988	1224	2005	13172
1969	678	1989	1785	2006	8520
1970	1753	1990	1489	2007	7156
1971	1731	1991	6656	2008	5207
1972	6573	1992	4276	2009	4256
1973	1219	1993	3267	2010	3445
1974	2059	1994	3455	2011	5530
1975	2080	1995	2638	2012	3172
1976	2359	1996	4468		
1977	1459	1997	10227		
1978	1947	1998	10610		

Source: Central Fisheries Research institute; Barrackpore; W.Bengal; India.

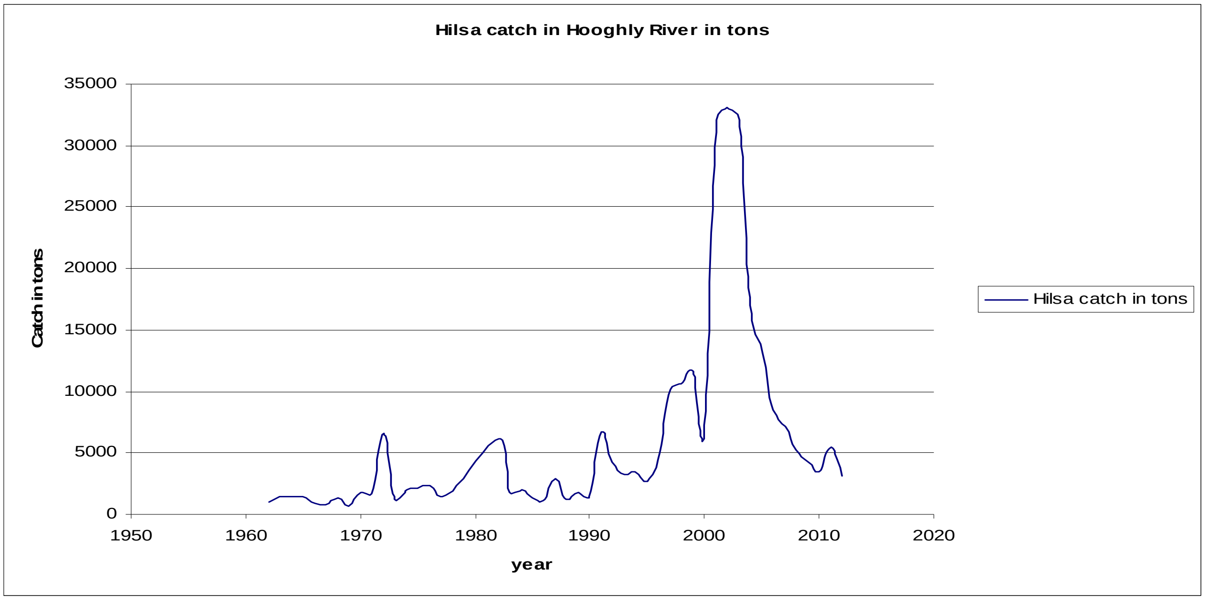

Figure-10. Graphical presentation of the Hilsa Fish catch history of Hooghly River.

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Figure-11. Snap of the field work of the author with his team members.

Table-5. Concentration of the river plankton during dredging and pre and post dredging periods.

Plankton concentration (no/100Lit) of Hooghly River water at different dredging situation												
Season/Condition of Dredging	**Haldia**						**Auckland**					
	Total phytoplankton		**Total Zoo-plankton**		**Total plankton**		**Total phytoplankton**		**Total Zoo-plankton**		**Total plankton**	
	Pre-Dredging	**Dredging**	**Pre-Dredging**	**Dredging**	**Pre-Dredging**	**Dredging**	**Pre-Dredging**	**Dredging**	**Pre-Dredging**	**Dredging**	**Pre-Dredging**	**Dredging**
1992-93-Post Freshet	1680	680	60	60	1746	740	3900	2400	40	20	3940	2420
1993-94-Pre-Freshet	380	200	80		460	200	2540	160	60		2600	160
1993-94-Freshet												
1993-94-Post Freshet												
1994-95-Pre-Freshet												
1994-95-Freshet	6860	1040	40		6900	1040	5370	980	220	40	5590	1020
1994-95-Post Freshet												

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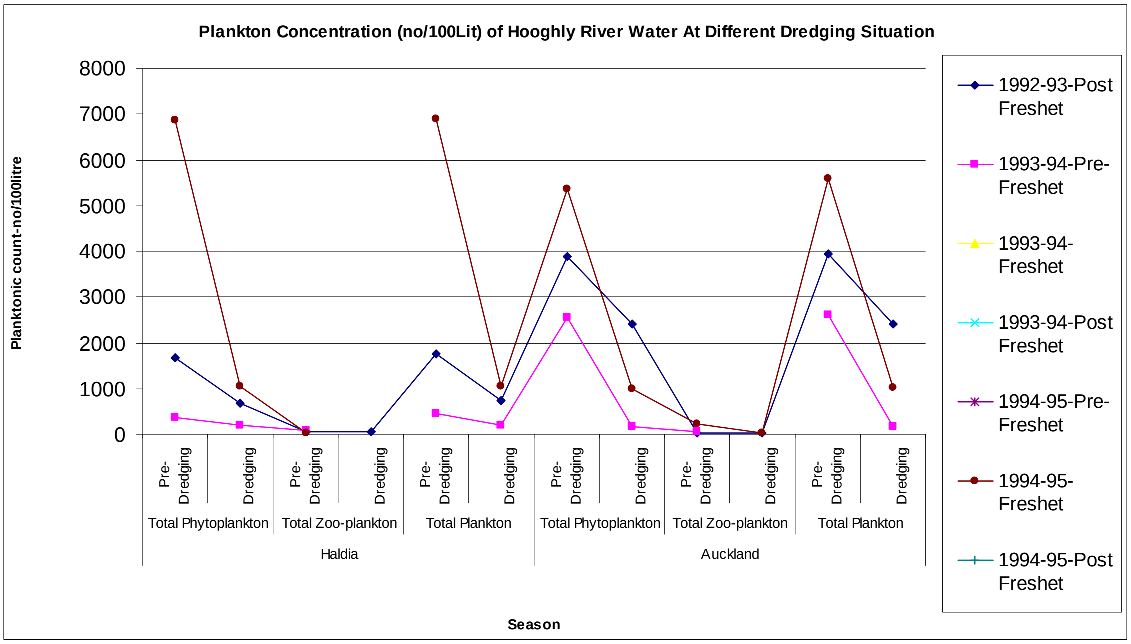

Graph showing the variation of NSF WQI values with different dredging condition and time.

Figure-12. Concentration pattern of the river plankton during dredging and pre and post dredging periods.

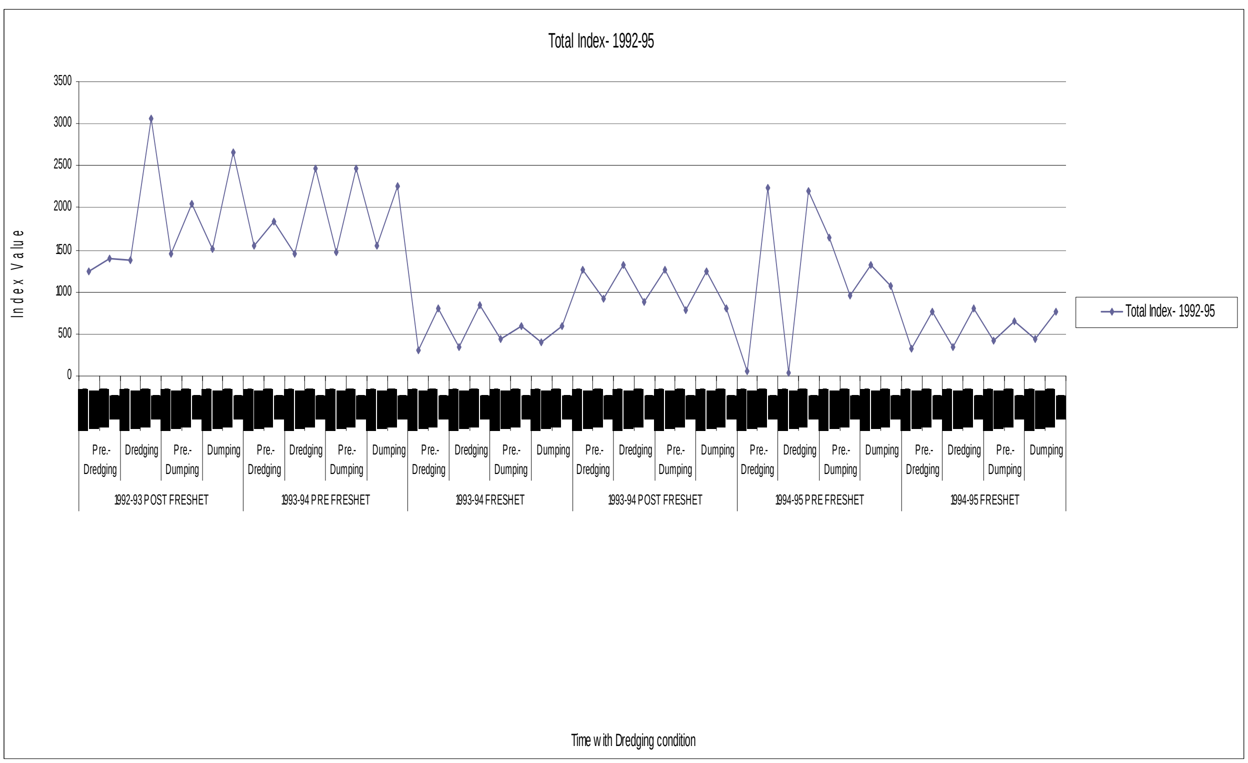

Figure-13. Pattern of the index values of the River Hooghly during dredging and pre and post dredging periods.

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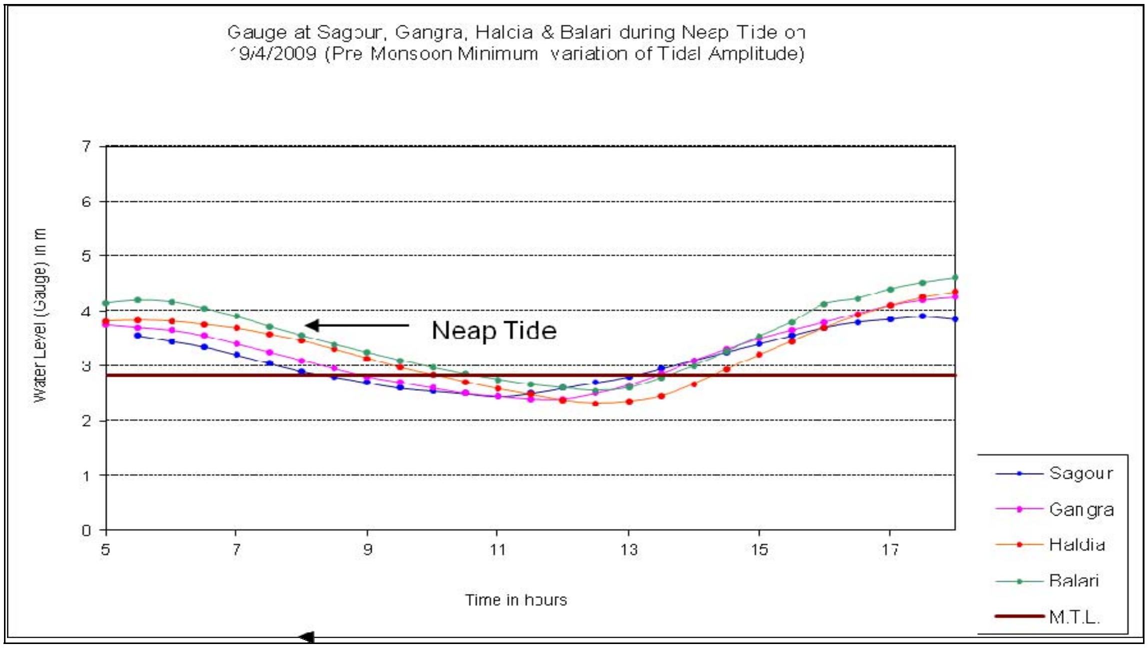

Figure-14. Variation of tidal Gauges of the Hooghly Estuary during Neap Tide period.

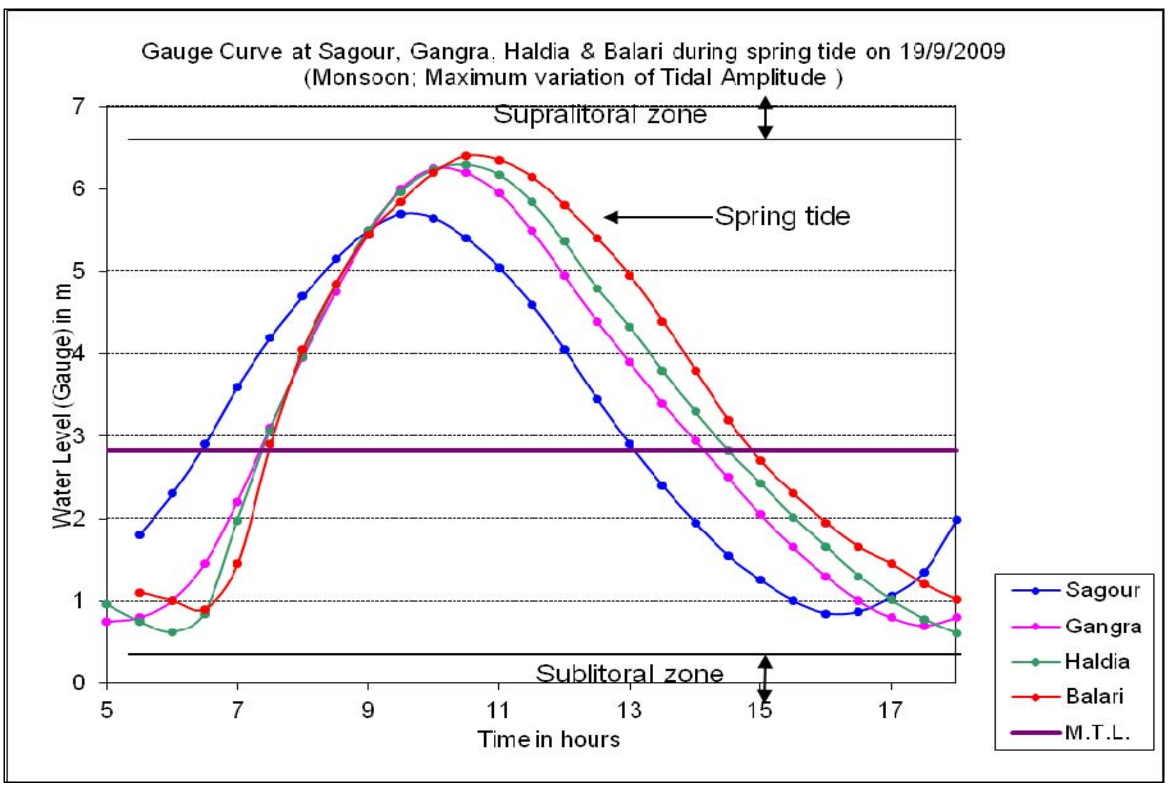

Figure-15. Variation of tidal Gauges of the Hooghly Estuary during Spring Tide period.

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Scope of future work

- The work may be reviewed by changing the target species as well as precise monitoring of the biotic and abiotic factors all the year round.
- Induction of target species may be enhanced if proper cause of low abundance of target species is identified.
- As employed in 1974 by McClelland to the Tennessee river of USA, the three dimensional graphs to display water quality profiles versus time of the Hooghli estuary, incorporating befitting water quality parameters for the NSF WQI values can be studied in a routine manner for monitoring of the estuary.

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