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WATER QUALITY CHARACTERIZATION OF SUNDARBANS MANGROVE FOREST OF BANGLADESH: ON THE PERSPECTIVE OF AQUATIC BIODIVERSITY

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Abstract: The paper describes the characterization of water quality of Sundarbans Mangrove Forest of Bangladesh. Water samples of 28 stations, selected from the four major river systems of Sundarbans were collected. The sampling period was from January 2001 to July 2001. The values of ten water quality parameters, such as Temperature, Conductivity, pH, Alkalinity, Free CO_2, Salinity, Dissolved Oxygen (DO), Total Suspended Solid (TSS), Hardness and Chemical Oxygen demand (COD) were measured. The values of the parameters obtained indicate that the Sundarbans aquatic habitat is at suitable range for aquatic species.

Key Words: Water Quality, Habitat, Aquatic Biodiversity, and Sundarbans Mangrove Forest.

Introduction

The Earth distinguishes itself from all other planets by the presence of water. As a life supporting natural resource, importance of water is not as crucial as for its quantity rather than for quality and distribution. The diversity of fish, crustaceans, and other aquatic organisms in aquatic system depends on a suitable environment in which they can reproduce and grow. Because these organisms live in water, the major environmental concern within the system is water quality. Water quality is a somewhat nebulous and often used term that is seldom defined adequately. Water quality is the summation of all physical, chemical, biological and aesthetic characteristics of water that influence beneficial use. The condition of our water resources determines the quality of life on earth. Water quality affects the abundance, species composition, stability, productivity, and physiological condition of aquatic organisms. Therefore, the nature and health of aquatic communities, is an expression of the quality of the water. Quality of water as habitat is one of the most important parameters for the biodiversity of that aquatic system.

Biodiversity is the most significant national issues and contributes agenda that ensure enduring resource for supporting the continued existence of human societies. With the need for its protection, and the concern for conservation of biodiversity, it is necessary to characterize the status of aquatic habitats and tropic pathways. Each habitat has its own unique community of fish and other organisms, adapted over time to the features of that habitat. The quality of habitat and variety of species has declined as a result of the larger changes due to human activities. Many of our aquatic systems are little understood that we cannot accurately describe what changes have taken on the real cause. For most changes, we do not know the long-term effects, many of which will not be fully apparent for years or decades. The Sundarbans aquatic habitat is one of the most important natural resources which has been declared as the world heritage in 1999. It is the largest single continuous productive mangrove forest of the world spreading over the southern part of Bangladesh and west Bengal state of India (Chaudhuri and Naithani, 1985). The Sundarbans as unique ecosystem shows greater interest in a number of ways. The Sundarbans water support 53 species of pelagic fish belonging to 27 families, 124 species of demerasal fish belonging to 49 families, 7 species of crabs belonging to 3 families, 2 species of gastropods, 6 species of pelecypods, 8 species of locust lobster and 3 species of turtles are reported from the Sundarbans(Acharya and Kamal, D., 1994). But the productivity of Sundarbans water has gone down with water becoming polluted by the toxic effluents discharged from the huge number of shrimp farms in nearby areas, with dumping of domestic and industrial wastes from the Mongla Port. The hyper nutrition caused by decomposition of the wasted feed, faces, metabolic wastes and excess fertilizers added to the farms has already been reported(Deb 1998). The farmers in the area exchange the nutrient rich water with estuarine waters quite frequently and dump the hyper-toxicated soils of the farm bottoms to the adjacent areas; these ultimately find places in the estuaries with consequent eutrophication of the system. Further, the rivers up in the north, receive domestic wastes from the small industries and from the Mongla Port. These wastes are dispersed in the entire Sundarbans water and cause damage to the water quality varied species, especially the Penaeid shrimp. We could not find any significant literature on various water quality parameters of mangrove waters. In this study ten water quality parameters were determined from 28 sampling stations selected throughout the entire Sundarbans with the basis of the four main river systems of the forest. There is an attempt to know the key components, which could enhance the probability of extinction, and habitat loss, which epitomize our sense to biodiversity crises.

Methodology

A total of 28 stations were selected from the four river systems of Sundarbans in which every river system covered 7 stations. Sampling locations are indicated in the Fig.1. The groups performed sampling during

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winter season (From 23-29 January 2001) and in rainy season (From 20-25 July, 2001). The samples were analyzed in the FMRT Discipline Water Quality Laboratory. The Research work was carried out under Sundarbans Biodiversity Conservation Project (SBCP) through Fisheries and Marine Resource Technology Discipline, Khulna University. Some important water quality parameters were determined in *Situ* and some others in the laboratory by preservation and analytical methods as shown in Table1.

Table1: Preservation and analytical methods to be followed for different water quality parameters.

Parameter	Preservation	Analytical Method	Reference
Temperature	In Situ analysis	Thermometer	-
pH	In Situ analysis	Electrometric	Instrumental manual
Conductivity	In Situ analysis	Electrometric	Instrumental manual
Salinity	In Situ analysis	Refractometric	Instrumental manual
Alkalinity	In Situ analysis	Titrimetric	APHA, 1992
Free CO2	In Situ analysis	Titrimetric	APHA, 1992
DO	In Situ analysis	Titrimetric	APHA, 1992
Hardness	1 ml Conc. H_2NO_3/L	Titrimetric	APHA, 1992
COD	1 ml Conc. H_2SO_4/L	Open Reflux	APHA, 1992
TSS	No preservative	TSS dried at 103-106^{0}C	APHA, 1992
		TDS dried at 180^{0}C	
TDS	No preservative		APHA, 1992

Result and Discussion

One of the major objectives of water quality characterization is the maintenance of most natural waters as life supporting systems. Any characteristic of water in aquatic systems that effects survival, reproduction, growth, and production of aquatic organisms, influences management decisions, causes environmental impacts, or reduce product quality and safety can be considered a water quality variable. In order to do this job, measurement was designed with choice of parameters for analysis regarding the types of information sought. Some important parameters were determined in situ and some were determined in the laboratory after sampling. These intensive variables determine primarily the type of commonly present organisms in the water. The Table 2 and Table 3 show the values of the parameters of water quality of Sundarbans during the investigated period.

Temperature: Temperature plays an important role in determining the distribution of species of organisms, which can live in a particular water body. Water temperature affects the natural productivity of aquatic ecosystems and directly or indirectly affects all other water quality variables. Fish and crustaceans are poikilothermic or "cold-blooded." This means that their body temperature is roughly the same as the temperature of the water surrounding them, and because water temperature changes daily and seasonally, the body temperature of fish and crustaceans also changes frequently. The rate of all biochemical processes is temperature dependent. Each aquatic species has its own optimum or preferred water temperature range, since the of photosynthesis increases with rising temperature up to a maximum and diminishes sharply with further rise of temperature. Thermal stress of aquatic animals often causes impairment of osmoregulation. Thermal tolerance therefore interacts with other aspects of water quality that affects osmoregulation. Two important modulators of thermal tolerance are salinity and environmental calcium concentration. The ability to withstand sudden changes in temperature and the ability to survive at extremes of water temperature are greatest when animals are living in water near the optimum salinity for the species in question. Calcium is also important because it affects the permeability of gill membranes to ions and water. The effect is species-specific and incompletely documented but, as an example, the lower lethal temperature of red drum (*Sciaenops ocellatus*) may be reduced by as much as 5^{0}C as environmental calcium concentrations increase from less than 10 to over 100mg Ca^{2+}/L (Procarione 1986).The latitudinal limits of occurrence of organism in the sea are determined by temperature, with north-south extensions of the limits occurring only where warm coastal currents modify the climate. Mangroves are found approximately between the latitudes 32^{0}N and 38^{0}S. Reduction of species diversity depends including salt regulation and excretion, and root respiration. Extensive and good mangrove development occurs only when and where the average air temperature of the coldest months is higher than 20^{0}C and where seasonal range does not exceed 10degrees (Walsh, 1974). Optimum temperature for photosynthesis in mangroves appears to be around 30^{0}C with little or no photosynthesis occurring at or above 40^{0}C. There appears to be a correlation between varying temperatures and distribution of mangrove species. From the present study it was observed that the average temperature range varied below 25 to 30^{0}C and this was in the suitable range of variation of sustenance of that habitat.

Table2. Some important water quality parameters determined in *Situ* analysis.

St. No.	Temperature in ^{0}C		Conductivity in mS/cm		pH		Alkalinity in $mgCaCO_3/L$		Free CO_2 in mg/L		Salinity in ppt		DO in mg/L	
	WS[1]	RS[2]	WS	RS	WS	RS	WS	RS	WS	RS	WS	RS	WS	RS
1(A1)	22	29	10.1	1.34	7.3	8.3	95.00	165	4.3	4.2	04	0.5	7.2	5.5
2(A2)	21.7	29	12.1	.88	7.5	8.4	97.5	120	3.6	5.1	06	0.5	8.1	5.9
3(A3)	21.5	30	13.6	.84	7.3	8.4	92.5	118	3.6	4.3	10	1.0	8.1	5.6
4(A4)	22	-	26.5	-	8.0	-	93.00	-	-	-	15	-	7.2	-
5(A5)	21	-	22.9	-	8.1	-	95.00	-	-	-	20	-	7.0	-
6(A6)	19.9	30	14.9	.41	7.5	8.3	98.00	108	4.0	5.7	11	3	7.1	6.2
7(A7)	21.4	29	8.01	.36	7.2	8.1	102.5	105	4.8	6.3	05	2	7.8	6.1
8(B1)	20	21	6.3	0.9	7.6	7.9	98.30	143	3.8	3.7	02	0.5	6.7	6.6
9(B2)	17	22	12.7	1.3	6.8	7.8	102.1	113	3.8	4.7	04	02	7.0	6.2
10(B3)	20	23	26.3	4.8	7.8	7.8	120.3	120	4.0	2.9	10	06	6.9	6.5
11(B4)	18	-	38.3	-	8.2	-	121.4	-	3.5	-	20	-	7.6	-
12(B5)	21	-	33.2	-	7.9	-	123.1	-	3.8	-	22	-	7.7	-
13(B6)	18	24	16.3	9.88	7.6	7.7	87.30	149	3.7	4.0	10	05	7.9	5.1
14(B7)	20	25	25.8	6.35	7.3	7.6	91.30	140	4.0	4.9	08	03	6.4	5.5
15(C1)	21	28.5	19.8	0.7	6.7	7.9	141	183	3.2	3.0	12	10	7.6	9.6
16(C2)	20.5	28	24.8	0.6	7.2	7.6	197	155	3.9	3.1	19	12	6.9	8.9
17(C3)	22	29	31.3	0.5	7.1	7.6	127	144	3.3	2.9	20	12	8	9.2
18(C4)	21	-	31.3	-	7.5	-	134	-	3.8	-	25	-	7.5	-
19(C5)	23.3	-	29.8	-	6.8	-	134	-	3.7	-	25	-	8.2	-
20(C6)	25	29	25.7	0.4	7.1	7.2	141	155	4.0	3.1	18	11	8.8	8.7
21(C7)	25	28	18.8	0.3	6.9	7.3	190	151	4.0	3.0	14	10	7.7	8.3
22(D1)	21	30	20.3	10.7	7.3	7.3	133	115	3.9	2.9	16	13	7.6	7.2
23(D2)	21	29	22.2	9.6	6.9	7.5	147	116	3.9	3.0	16	14	7.9	6.5
24(D3)	23	30	24.7	5.6	7.4	7.4	164	111	4.2	3.5	21	13	7.7	6.3
25(D4)	21	29	28.6	7.5	7	7.2	140	98	3.8	3.1	21	11	7.3	6.8
26(D5)	21	29	29.7	2.5	6.9	7.3	161	130	3.4	3.0	23	12	7.6	-6.9
27(D6)	21	-	31.2	-	7.1	-	157	-	3.8	-	26	-	7.6	-
28(D7)	22	28	26.8	9.2	7.3	7.1	176	117	3.9	2.9	21	11	7.9	7.1

Note: Blank spaces indicate that sampling could not be done due to weather problem. [1]WS= Winter Season; [2]RS= Rainy season

pH and Alkalinity: The significance of pH is the maintenance of proper nutritional condition of the aquatic system apart from affecting the physiological functions of the fishes (Jhingran 1975). It greatly affects the equilibria of hydroxide, carbonate, phosphate and silicate between bottom mud and overlying water and thereby the precipitation of soluble nutrients and dissolution of solid materials, sorption and dissorption of ions and the concentrations of aluminum, manganese, iron etc which have nutritional significance in aquatic habitat. The optimum pH for growth and health of most fresh water aquatic animals is in the range 6.5-8.5. The acid and alkaline death points are approximately pH 4 and pH 11, respectively. Marine fish evolved in the highly buffered seawater environment, which is not subject to a wide variation in pH. Consequently, most marine animals typically cannot tolerate as wide a range of environmental pH as freshwater animals, and the optimum pH is usually between pH 7.5 and 8.5. Fish and crustaceans living in brackish water are often exposed to a wide range pf pH values as the relative amounts of fresh water and sea water change with variations in river discharge and tidal flow. As such, brackish water inhabitants are rather tolerant of extremes of pH. For instance, acid and alkaline death points for most penaeid shrimp are roughly 4.8 and 10.6, and the optimum pH range is 5.5-8.5 (Tsai, 1990). The minimum lethal pH to Penaeus monodon in water of 32 ppt salinity is about 3.7 and the minimum acceptable pH is 5.9.

Alkalinity affects the behavior of some compounds in the water, for example, copper sulphate; used to control algal growth, snail, and many protozoan ectoparasites. It varies in its toxicity both target and the nontarget organisms. Alkalinity also contributes to the equilibrium nature of carbonate and bicarbonate with free carbon dioxide, which is necessary for photosynthesis. Generally 50ppm is considered low and above 200ppm is high. From the present analysis, it was observed that the values were within this range in which highest value was 197$mgCaCO_3/L$ and the lowest value was 87.3$mgCaCO_3/L$ indicating that in alkalinity respect also, the waters of Sundarbans mangroves are within safe limits.

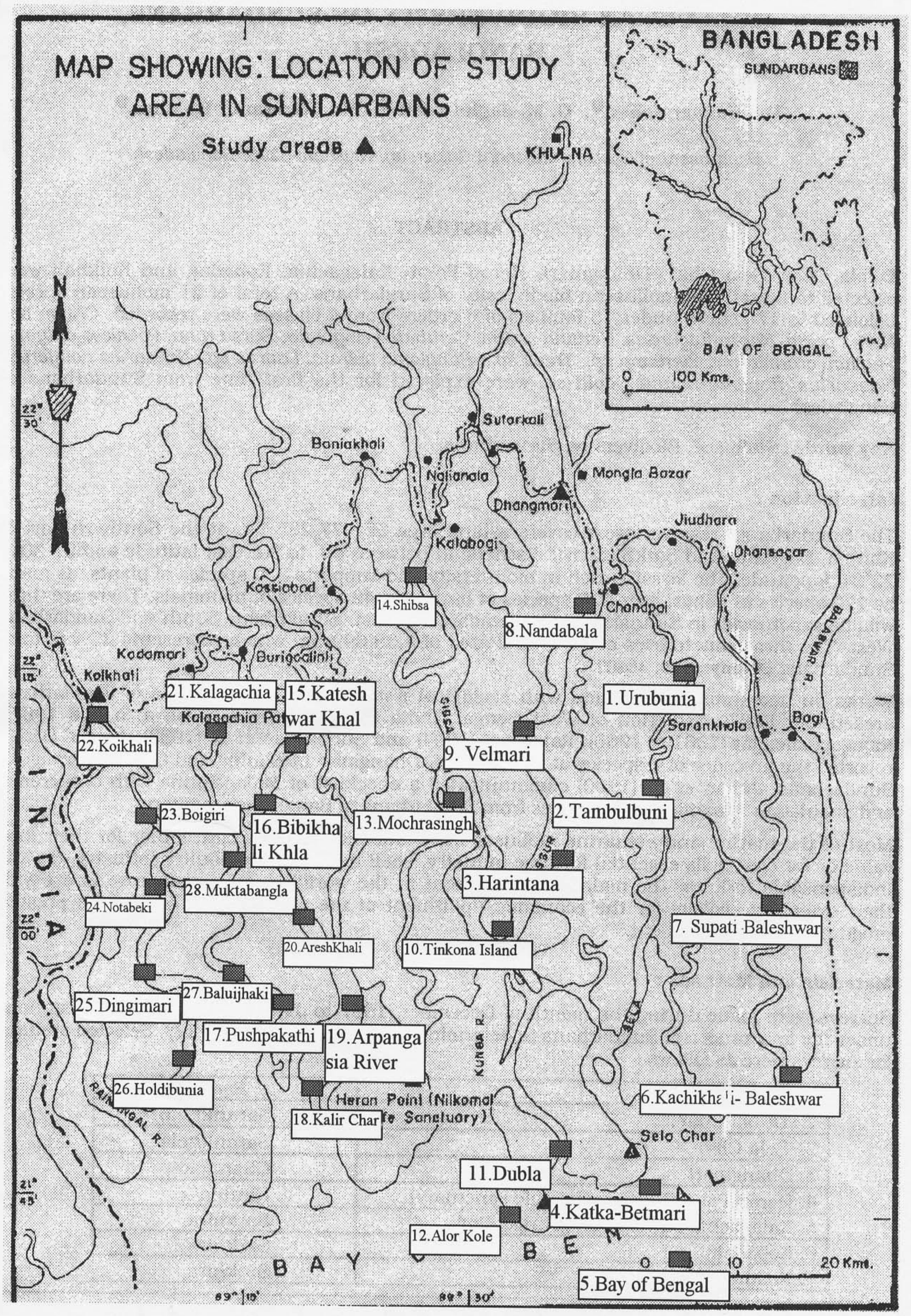

Figure1: Sampling Locations of Sundarban Reserve Foreset

Table 3. Some important water quality parameters of Sundarbans waters determined in laboratory analysis.

St. No.	TSS in mg/L	Hardness in mg $CaCO_3$/L	COD in mg/L
	Winter Season	Winter Season	Rainy Season
1(A1)	1821	1121	27.6
2(A2)	1968	1290	16.6
3(A3)	2036	1493	16.0
4(A4)	1974	3040	-
5(A5)	2060	2579	-
6(A6)	1990	932	11.0
7(A7)	1930	944	17.0
8(B1)	1898	800	28.0
9(B2)	1892	1260	22.1
10(B3)	1926	2870	11.0
11(B4)	1918	3870	-
12(B5)	1900	3610	-
13(B6)	1906	1630	21.5
14(B7)	1821	1020	38.5
15(C1)	1600	1784	33.1
16(C2)	1302	2770	38.6
17(C3)	1720	2980	27.2
18(C4)	1801	3400	-
19(C5)	2058	3050	-
20(C6)	1201	2790	16.5
21(C7)	1940	1500	34.0
22(D1)	1720	2176	16.0
23(D2)	1900	2676	33.0
24(D3)	1240	2600	27.0
25(D4)	1260	2900	27.0
26(D5)	1760	3400	23.3
27(D6)	1432	3821	-
28(D7)	1600	2970	31.5

Note: Blank spaces indicate that the sampling could not be done to weather problem.

Total Suspended Solid: Both suspended and dissolved solids affect the transparency and the color of water. Transparency is related to the productivity. Light cannot penetrate very far into turbid water because of the high concentration of suspended matter. The mangroves act as nurseries for various aquatic animals. The estuarine areas have turbid waters, which reduce light penetration and reduce the aquatic primary productivity. Contrary to this, shallow waters within the mangroves system become a paramount factor at all levels of production. Many commercially important fish species including shrimp tend to congregate in shallow water areas for shelter and availability of food because of presence of higher organic content. Naturally, destruction of the mangrove leads to decrease of nutrients for fish, crustaceans and mollusks in estuarine and near shore areas. From this study, it was found that the TSS was high (Table-3) and consequently transparency was low. But it could not be related with the abundance and distribution of aquatic organisms. More investigations are necessary in this regard.

Free carbondioxide: The delicate balance between photosynthesis and respiration in receiving water may be perturbed by addition of either an excess of organic compounds or an excess of inorganic algal nutrients (e.g., phosphorus, nitrogen). This process is dominated by free CO_2. Water supporting good fish production usually contains less than 5ppm of free CO_2 (Ellis 1937) though free CO_2 levels may fluctuate between 0ppm during afternoon and around 5-10ppm during dawn without any apparent ill effect on fishes (Parks *et al.* 1975). In the present study although through free CO_2 was somewhat low viz., 2.5ppm but in most cases the value was around 4-5ppm which is deemed suitable for aquatic habitat.

Dissolved oxygen and Chemical oxygen demand: Dissolved oxygen (DO) is the most widely analyzed chemical parameter in aquatic system for water quality assessment. It is also one of the index parameters for organic pollution. The minimum concentration of DO, tolerated by fish, is obviously a function of exposure of time (Boyd, 1978). Afish might survive in 0.5ppm DO for a few hours but not for seven days. Further, minimum tolerable concentration of DO varies with species and size of fishes, and physiological condition. Concentrations of 3.0ppm of DO or less should be regarded as hazardous for fish and for a good variety of fish fauna the DO level should be 5.0ppm (Swingle 1947).

Since chemical oxygen demand (COD) is a measure of the total amount of oxygen which is required to oxidize all the organic matter in a sample to CO_2 and H_2O, it is necessary to know the value of COD. The optimum range may be considered to be between 80 and 100ppm. The COD value was found at low level in Sundarbans indicating that the organic waste pollution was insignificant in the Sundarbans waters.

Hardness: Toxicity of heavy metals depends on their speciation. In the case of heavy metals, the criteria are often expressed as functions of water hardness. According to some previous studies (EPA, 1984) some of the data were used to determine the fresh water criterion for maximum concentration of cadmium. Pertinent data relating to cadmium toxicity to water hardness was available for five species and the logarithms of the cadmium 96-hr TLm values were plotted against water hardness. The slopes of the five regression lines fitted to the data were plotted against water hardness. The normalized freshwater criterion for maximum concentration was then determined from the equation:

$$\textbf{Criterion for maximum concentration (ppb)} = 0.022H^{1.13}$$

Where H is water hardness in mg/L. maximum permissible concentration of cadmium for the protection of human health is 10mg/m^3 (EPA 1987). The hardness value from the study indicated that can probably reduce the toxicity besides the supply of the adequate amount of Ca and Mg which are necessary for aquatic organism.

Electrical conductivity and Salinity: Electrical conductivity is closely related to the amount of total dissolved solids and is also used as index of salt content of water. Natural water usually has EC values of 20 to 1500µS (Boyd, C.E. 1978). The salinity (ppt) can be calculated approximately from the EC values of water. Salt content of water can be expressed in either way. As the justification of the accuracy of the present results, electrical conductivity and salinity were determined by separate methodology. Since salinity influences survival, distribution, growth, reproduction and zonation of mangroves, different species prefer different level of salinity. There is an optimum salinity for miximum growth of different mangrove species such as *Rhizophora* which is an obligate halophyte where as *Heritera fomes* has strong preference for salinity and its growth rate significantly decreases with increasing level of salinity. This consideration is also valid for aquatic species like fishes. Salinity in the mangrove is regulated by tidal inundation, rainfall, freshwater discharge of rivers, evaporation etc. EC values were in the range 8.0mS/cm in the most Eastern parts of Sundarbans. This was because of increased freshwater flow through Baleswar River. But this was higher than the previous result of Hossain, *et al*. (2002) who found the value at 5.0mS/cm. The most western river (Arpangasia-Malancha River System) was characterized by high EC values of around 20-33mS/cm. The Passur-Sibsa River System, in the central part of the forest was found to have EC values of low level of 12mS/cm to 3mS/cm. The southwest part of Sundarbans gets reduced supply of freshwater since the rivers in the region are almost becoming dry. This part of Sundarbans receives freshwater through Sibsa with reduced freshwater flow and that is why the western part of Sundarbans had high level of salinity that the eastern part. This incidence of top dying and the exact cause for top dying is still unknown. Trees might have been exposed to stress condition due to single or a combination of factors including salinity, reduction of critical level of inundation, loss of canopy due to cyclonic storms, water logged condition in the soil, and excessive sediment deposition on the pneumatophores (Siddiqi 2001).

Seasonal Variation in Salinity in Sundarbans: A large seasonal variation of salinity was seen in the waters of Sundarbans. From Fig.2 it can be seen that salinity was high in the month of April to May and fell more quickly to July due to rainwater discharge.

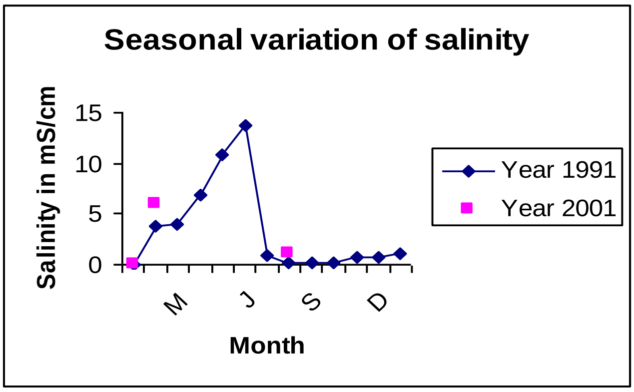

Fig.- 2. Seasonal variation of salinity at Mongla on the Passur River of Sundarbans. Year 1991data was obtained from Hassan *et al*. (1990)

Conclusion

The mangrove ecosystem in Bangladesh is under management for over 100years. However, desired information in relation to floral or faunal diversity could not be generated due to lack of well-planned and long-term studies. From the recent studies, it has to be mentioned that the Sundarbans is encountered with many problems like over exploitation, geomorphological changes, salinity increases etc affecting it overall production. The carrying capacity of the Sundarbans is unknown. Even it is not clear whether its aquatic resources are at over exploitation or at under exploitation. There has been serious threat to biodiversity. A huge number of people in the coastal areas are engaged in catching seeds of *Penaeus monodon* using small nets. In the process a huge quantity of larvae of other organisms including fin fish and Zooplankton get killed (Hoq 2003). This causes decline in biodiversity of aquatic animals. Already a good number of species are endangered or have disappeared from the areas because of unplanned capture of seeds of tiger shrimp for farming and destruction of larvae of aquatic animals. A policy is needed to ensure aquatic biodiversity of the Sundarbans by imposing restriction on fish capture, size of nets used for fishing and banning fishing in breeding season and spawning grounds.

Another important point is pollution in mangrove areas due to deposition of solid or liquid industrial effluents. Moreover, in recent years there has been increasing occurrence of oil spills in the costal seas. From the study it would be noted that water quality as aquatic habitat was found good except salinity increases which was due to the consequence of alteration of freshwater flow through Gorai river and not due to pollution. It is necessary to design a management program to combat pollution due to Mongla Port adjacent to Sundarbans. Beside these the physiological and toxicological responses of individual organism which may influence environments should also be studied in a systematic a manner.

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