Asian Fisheries Science **20**(2007):81-94
ISSN: 0116-6514
https://doi.org/10.33997/j.afs.2007.20.1.007

Asian Fisheries Society, Manila, Philippines

Southwest Monsoon Effect on Plankton Occurrence and Distribution in Parts of Bay of Bengal

M. ZAFAR*

Institute of Marine Sciences, University of Chittagong,
Chittagong 4331, Bangladesh

Abstract

The present investigation was carried out for one year from March 1988 to February 1989 and focused on hydroplankton aspects in parts of Bay of Bengal. The hydrological factors were mainly governed by the monsoon and river systems flowing into the Bay. A marked seasonal fluctuation in salinity, dissolved oxygen, water temperature and suspended particles was observed, generally which was a unique feature of the northeastern coastal part of the Bay of Bengal. The higher abundance of phytoplankton was recorded in January (3332 cells.l^{-1}) during the low turbidity and bright sunshine period. The minimum was found in August (1295 cells.l^{-1}) when maximum rainfall and fresh water discharge were recorded. Total phytoplankton population were found to have a significant negative correlation with suspended particles at four stations in the study area (S_1, $r = -0.887$, $P < 0.1$; S_2, $r = -0.920$, $P < 0.001$; S_3, $r = -0.807$, $P < 0.01$; S_4, $r = -0.920$, $P < 0.001$). Maximum density of zooplankton was recorded in September (326146.36 per 100 m^3), which indicated a seasonal influence on the distribution pattern of the different groups of zooplankton. Hydromedusae, Mysids and *Squilla* were major indicator groups and they represented only <1% of the zooplankton population. The zooplankton abundance was not significantly correlated with phytoplankton ($r = 0.24$, $P > 0.05$).

*Tel.: +880 31 710 347, 682654; Fax: +880 31 726 310
E-mail address: zafarims@yahoo.com

Introduction

The geoclimatic environment of the Bay of Bengal, particularly in the Bangladesh portion, is dominated by wind direction, precipitations under the influence of tropical monsoon climate and river discharge, which have strong influence on the marine environment affecting water circulation, salinity, turbidity, productivity and bottom topography. The coast of Bangladesh is criss-crossed by a network of complex estuaries formed by the Ganges, Brahmmaputra, Karnafully, Meghna, Mathamuhuri and other rivers, which open into the Bay of Bengal and carry large amount of nutrients, facilitating the production of high quantities of plankton in the area. Upwelling caused by the south-west monsoon wind brings about a complete reversal of the surface current pattern, which is clockwise from January to July and counterclockwise from August to December according to the direction of the wind (Lambeuf 1987).

Zooplankton and phytoplankton biomass are index of the fertility of an area and provide information on the potential living resources. There is an interrelationship among the different biotic elements of the marine and estuarine ecosystem viz. phytoplankton, zooplankton, and fish. It is well recognized that the richest fisheries of the world are closely related to the plankton production because fish and other fishery organisms are directly or indirectly dependent upon plankton for their food. Therefore, the present study on plankton occurrence and distribution of Kutubdia channel was under taken.

Materials and Methods

Field investigations were made between March 1998 and February 1989. Phytoplankton, zooplankton and water samples were collected from four stations in the Kutubdia Channel (Fig. 1). Water samples were taken from the surface using a bucket, for the determination of water temperature, dissolved oxygen, salinity, pH and settling volume of suspended particles. During sampling, air and water temperature, transparency, and pH were recorded using a thermometer, secchi disk (30 cm in diameter) and digital pH meter, respectively. Water colour was determined using Forel water colour comparator. Salinity and dissolved oxygen were determined following standard procedures (Barnes 1959). For determining the settling volume of suspended particles, one litre of water was taken in an Inhoffs cone (measuring 0.1 ml) and then allowed to settle for 24 hours. Then the volume of suspended particles was recorded from the measuring cone. After this recording, the water samples were filtered through paper filters; and suspended particles were oven dried and their weight was determined by an electric balance. Analyses of the suspended particles were done by mechanical process following "Bouyoucos Hydrometer Method" (Anon 1965).

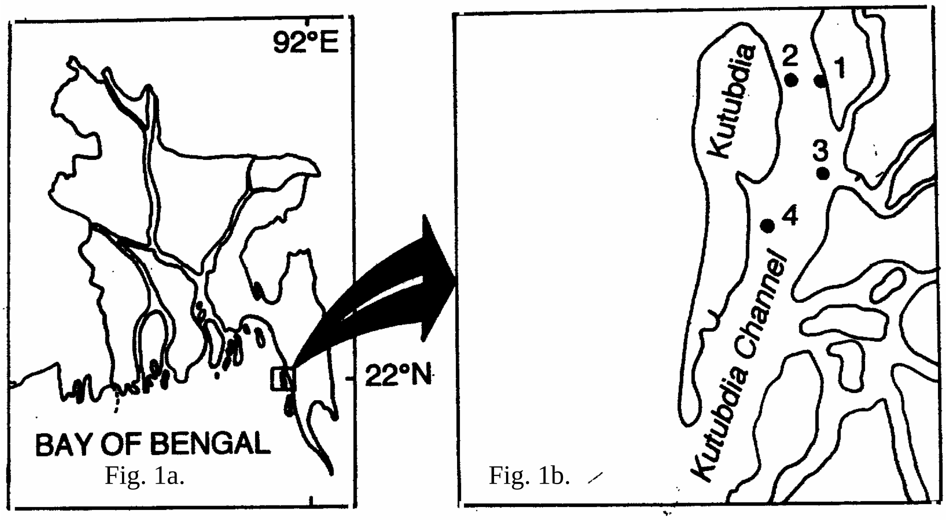

Fig.1a. Bangladesh showing sampling area; Fig.1b. Geographical location of four sampling stations in the Kutubdia Channel

Phytoplankton samples were collected from the surface water at each station using a plastic container. Two litres of water were taken and preserved in 3% neutral formalin and brought to the laboratory.

The preserved phytoplankton samples were taken in cylindrical measuring jars and allowed to settle for 16-20 hours. Then the samples were concentrated 10 ml by careful filtration and decantation (Boyd 1979). After preparing a homogeneous mixture by stirring the concentrated sample, an aliquot of 1 ml was removed with a stempell pipette and taken on a Sedgwick Rafter cell under a compound microscope for counting. The number of phytoplankton population was determined by cells.l^{-1} of water

Zooplankton samples were collected at monthly intervals during full moon and high tide periods from the four stations in the Kutubdia channel with a passenger ship of BIWTC (Bangladesh Inland Water Transport Corporation).

A (1.5 m) zooplankton net similar to that described by Mahmood and Khan (1982) was used, having 0.5 m^2 mouth opening, made of Hydro-bios nylon meshes 353 μm fitted with a plastic bucket at the cod end. A Karl Kolb digital flow meter was used to record the quality of water filtered through that net during sampling. All the zooplankton samples were immediately preserved in 5% neutralized formalin in the field. In the laboratory, zooplankton samples were sorted and enumerated following standard procedures by APHA (1976) and Lind (1979). Major taxonomic groups of zooplankton were separated using the method described by Davis (1955), Omari and Ikeda (1984) and Schram (1986). Zooplankton numbers were expressed as individuals / 100 m^3 of water.

Results and Discussion

Hydrological parameters

Statistical analysis Kruskal-Wallis (Sokal and Rohlf 1981) showed no significant difference in result at 1 or 5% among the hydrological factors of four different stations, so only the average of these parameters has been recorded (Table 1), which showed seasonal variations. Atmospheric temperature ranged from 25.15^{0}C to 33.25^{0}C. The minimum (25.15^{0}C) was recorded in December and maximum (33.25^{0}C) in September. Water temperature varied between 23.18^{0}C and 31.08^{0}C, the lowest was recorded in January and the highest in September. The concentration of dissolved oxygen varied from 3.87 ml.l^{-1} to 8.51 ml.l^{-1} with the highest value in May and the lowest in November. Salinity ranged between 9.15‰ and 29.2‰, with the maximum in February and the minimum in July. Secchi-depth varied from 11.50 cm (June) to 37.67 cm (January). The suspended particles varied from 0.22 to 3.34 (ml.l^{-1}), maximum was recorded in April and the minimum in December. The effective rainfall was confined in the monsoon season, with the maximum in June (768 mm). The maximum fresh water discharge occurred during monsoon months (May to October), with the maximum in August (166397.70 m^3.sec^{-1}) and minimum in January (8254.30 m^3.sec^{-1}).

Phytoplankton

The average total number of phytoplankton showed strong seasonal variation. The highest abundance of phytoplankton was recorded in autumn, winter, and early spring seasons (September - February) and the

Table 1. Monthly hydrological factors (average) in the Kutubdia channel of Bangladesh coastal water, Bay of Bengal

Environmental Factors		1988										1989	
		Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Air temperature (°C)		28.94	27.49	30.68	27.65	30.50	29.85	33.25	25.55	28.40	25.15	26.61	28.03
Water temperature (°C)		26.73	28.33	29.85	27.68	29.95	29.93	31.08	27.63	27.89	25.21	23.19	25.00
Dissolved oxygen ($ml.l^{-1}$)		5.37	7.52	8.51	4.31	4.04	4.74	3.94	5.64	3.90	4.34	5.08	5.50
Salinity (‰)		28.13	25.13	24.65	20.18	9.12	10.68	10.47	13.25	24.51	26.49	29.00	29.20
pH		8.30	7.92	7.29	7.13	7.14	7.13	7.10	7.10	7.96	7.94	8.32	8.27
Water trans-parency (cm)		40.75	34.43	38.43	36.43	42.08	32.25	47.30	49.95	41.28	43.75	43.05	41.30
Settling volume of suspended particles ($ml.l^{-1}$)		1.11	3.43	2.18	2.76	0.55	3.11	0.39	0.23	0.93	0.22	0.32	0.90
Total rainfall (cm)		2.6	10.7	31.0	76.8	51.6	53.1	55.9	19.2	11.4	0.7	0.0	6.1
Monthly bright sunshine	Total	301.9	253.8	213.7	133.3	129.8	117.8	214.0	227.7	222.4	269.0	288.0	261.8
	Mean	9.7	8.5	6.9	4.4	4.2	3.8	7.1	7.3	7.4	8.7	9.3	9.0

minimum in summer and rainy season (mid April - August). The peak occurrence of phytoplankton (Fig. 2) was recorded in January (3332.5 cells.l^{-1}) and the minimum in August (1295 cells.l^{-1}). Significant negative correlation was found between suspended particles of water and average phytoplankton population at four sampling stations in the Kutubdia channel (S_1, $r = -0.887$, $P < 0.1$; S_2, $r = -0.920$; $P < 0.001$; S_3, $r = -0.807$, $P < 0.01$; S_4, $r = -0.920$, $P < 0.001$); and it was positively correlated with Secchi-depth ($r = 0.868$, $P < 0.001$), No significant correlation was found between phytoplankton and zooplankton abundance in the investigated channel ($r = 0.24$, $P > 0.05$) and no significant variation of phytoplankton population among four stations PCA (Fig. 3).

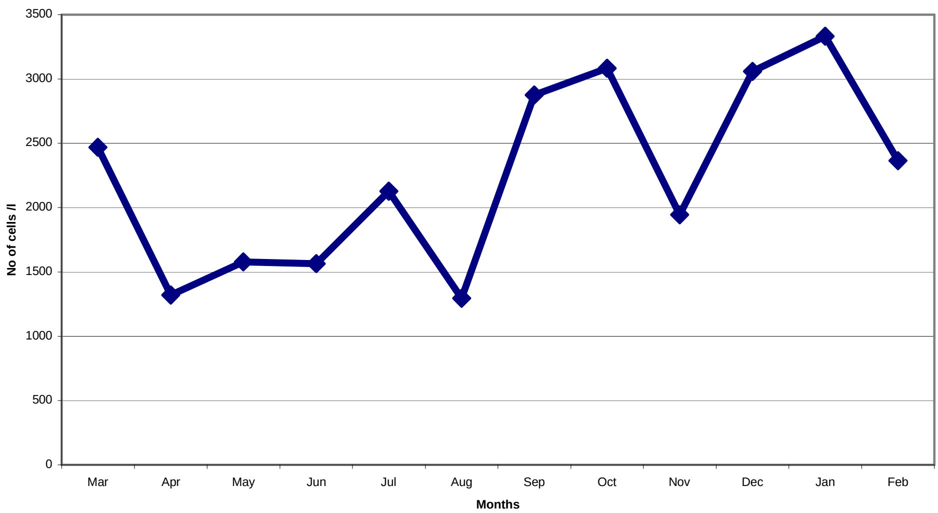

Fig. 2. Monthly occurrence of phytoplankton in the Kutubdia Channel

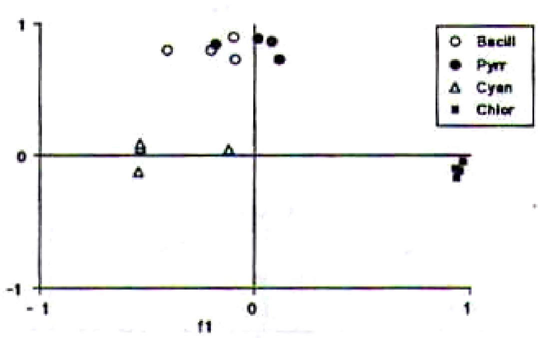

Fig. 3. PCA for spatial difference for phytoplankton group distribution at four sampling stations

Four major groups of phytoplankton were counted. The yearly average percentage composition of these groups in order of abundance were Bacillariophyta (64.42%), Chlorophyta (18.15%), Pyrrophyta (9.20%), and Cyanophyta (7.60%).

The maximum total density of phytoplankton was found at station 1 (2,613.33 cells.l^{-1}); it was probably related to monsoon wind speed and direction. Dickson and Reid (1983) reported that phytoplankton abundance was influenced by local effects of wind speed and direction.

Bacillariophyta and Pyrrophyta showed same seasonal succession, peak abundance in the post-monsoon, and lowest in monsoon season. Cyanophyta and Chlorophyta indicated opposite seasonal succession (Table 2). The highest abundance of Cyanophyta in the rainy-monsoon season was due to river discharge. But the minimum Chlororphyta was recorded in the rainy-monsoon season when the lowest salinity regime was recorded.

Chandran (1985) stated that during monsoon season, the estuary was enriched with nutrients due to heavy rainfall and the consequent land run-off. In spite of higher concentration of nutrients, the species composition, bloom formation and population density were low because of the higher seaward flushing and low light penetration due to high turbidity. In the present study, phytoplankton population was low in abundance due to turbidity caused by constant pouring of land run-off and tidal interference.

Tarzwell and Gaufin (1953) found that turbid waters might transport the byproducts of bacterial action on organic wastes and the effluent of sewage treatment plants to considerable distances. Corfitzen (1939) found that the greatest loss in light intensity was due to light absorption by silt with some additional loss by reflection and refraction. The present study area was turbid due to suspended particles and at the same time the density of phytoplankton population was low; these findings were in agreement with the results of above-mentioned authors.

No work is available to determine the effect of turbidity on phytoplankton production in Bangladesh. The European Inland Fisheries Advisory Commission and Food and Agricultural Organization of the United Nations, prepared water quality criteria on finely divided solids (chemically inert solids) for the maintenance of freshwater fishes and concluded that waters normally containing more than 400 ppm suspended solids would likely support only the poor fisheries (Anon 1965). In the present findings, overall suspended solid particles ranged from 20 ppm (0.02 m1.l^{-1}) to 6350 ppm (6.35 ml.l^{-1}). The phytoplankton abundance in the Kutubdia

Table 2. Phytoplankton abundance (cells.l^{-1}) in the Kutubdia channel of Bangladesh coastal water

Phytoplankton division	1988										1989		Yearly average	% composition
	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb		
Bacillariophyta	1525.0	487.5	775.0	700.0	1675.0	875.0	2275.0	2425.0	1250.0	2087.5	2150.0	1350.0	1464.58	65.05
Pyrrophyta	125.0	87.5	168.8	50.0	150.0	75.0	275.0	275.0	275.0	392.5	375.0	237.5	207.19	9.20
Cynophyta	187.5	73.8	67.5	152.5	202.5	300.0	280.0	127.5	107.5	142.5	237.5	175.0	171.15	7.60
Chlorophyta	632.5	671.2	566.3	662.5	100.0	45.0	45.0	257.5	312.5	437.5	570.0	602.5	408.54	18.15
Monthly total of phyto-plankton	2470.0	1320.0	1577.6	1565.0	2127.5	1295.0	2875.0	3085.0	1945.0	3060.0	3332.5	2365.0	2251.46	100

channel was strongly negatively correlated with turbidity. High densities of total phytoplankton population were recorded during low rate of turbidity. In the present investigation, the results coincided with Anon (1965). In the opposite, highest densities of Cyanophyta occurred during rainy-monsoon months (June - September) when suspended particles were high.

Zooplankton

The maximum number of zooplankton was recorded during monsoon (Table 3) with a peak in September (326,146.3 individuals per l00 m^3). Kruskal-Wallis one way ANOVA showed ($P = 0.604$) no significant difference in distribution of zooplankton among the four sampling stations. The abundance of zooplankton in the Kutubdia channel was not significantly correlated with phytoplankton ($r = 0.29$, $P > 0.05$, $N=48$).

In the community, the yearly percentage composition of major groups in order of abundance were copepods 94.30%, chaetognaths 2.48%, *Acetes* 1.05%, lucifers 0.67%, crab larvae 0.33%, mollusc larvae 0.24%, fish larvae 0.21%, mysids 0.203%, shrimp PL 0.193%, *Squilla* 0.192 %, *Hydromedusae* 0.08%, polychaetes 0.008%, amphipods 0.004% and other groups represented 0.047%.

TWINSPAN analysis revealed that (Fig. 4) *Hydromedusae*, mysids and *Squilla* larvae were the major indicator groups and they represented only <1% of the zooplankton population. All the dominant groups (copepods, chaetognathus, crab larvae, fish larvae, shrimp PL. and mollusc larvae) showed similar seasonal variations, and their peak recruitment was during the southwest monsoon period: April to September (Fig. 5).

Dutta et al. (1954) stated that salinity affected the composition and density of the plankton. The results of the present investigation differed with the above results in this respect that maximum zooplankton was recorded in the three months (July - September) when rainfall was maximum and consequently, salinity was minimum. The rainfall and floodwater during the southwest monsoon abruptly lowered the salinity in the month of September. From October there was a steady increase in salinity values caused by dry conditions associated with the northeast monsoon. The density of total zooplankton was lower in the northeast monsoon than southwest monsoon season. Dutta et al (1954) observed that the density of zooplankton decreased with increasing turbidity, so, in the maximum turbid water zooplankton was consequently minimum. In the present study, maximum turbidity occurred in April and June, and in the same months zooplankton population was comparatively lower at all sampling stations.

Table 3. Monthly averages of zooplankton abundance (individuals/100m^3) in the Kutubdia channel of Bangladesh coastal water, Bay of Bengal

Major taxonomic groups of zooplankton	1988										1989		Yearly average	% composition
	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb		
Hydromedusae	197.93	87.65	1.65	-	87.43	1.75	-	-	-	-	-	9.48	32.16	0.08
Chaetognathus	2290.25	1060.4	2646.25	45.13	1312.75	905.95	814.95	13.58	234.23	49.60	108.33	2514.75	999.68	2.48
Polychaetes	-	5.23	11.55	-	-	-	-	-	12.08	5.40	6.43	-	3.39	0.008
Amphipods	-	-	-	-	-	4.45	-	-	-	-	-	16.95	1.78	0.004
Copepods	24515.85	7060.85	1655.15	1558.00	25666.55	10759.1	324954.5	270.8	5595.5	1151.63	1507.23	36704.28	38024.7	94.30
Mysids	1.63	0.70	105.83	73.58	677.35	103.25	8.20	-	12.08	-	-	1.68	82.02	0.203
Lucifers	1897.73	237.08	15.43	324.40	11.05	269.10	-	-	66.30	53.90	47.85	321.65	270.38	0.67
Acetes	705.10	1168.3	1118.15	265.93	967.85	41.60	179.28	21.98	375.93	9.80	-	205.35	421.61	1.05
Shrimp larvae	71.07	333.61	139.06	70.27	98.49	32.23	20.65	7.87	48.73	28.96	36.12	24.14	75.93	0.19
Crab larvae	551.75	69.45	208.33	5.55	355.75	169.50	98.18	-	4.28	-	49.73	102.13	134.55	0.33
Squilla larvae	846.50	57.30	-	0.93	-	-	-	-	-	4.40	6.78	11.15	77.26	0.192
Molluscs larvae	-	19.68	416.68	680.55	-	-	-	-	-	-	4.00	42.00	96.91	0.24
Fish larvae	169.08	7.33	534.48	20.65	126.53	50.28	67.65	-	25.65	-	6.78	26.75	86.27	0.21
Other zooplankton	31.25	14.53	104.18	6.48	6.83	16.68	2.95	-	-	-	-	-	15.24	0.04
Monthly total of zooplankton	31278.14	10122.11	21853.74	3051.47	29310.58	12353.89	326146.36	314.23	6374.78	1303.69	1773.25	39980.31	401321.88	100

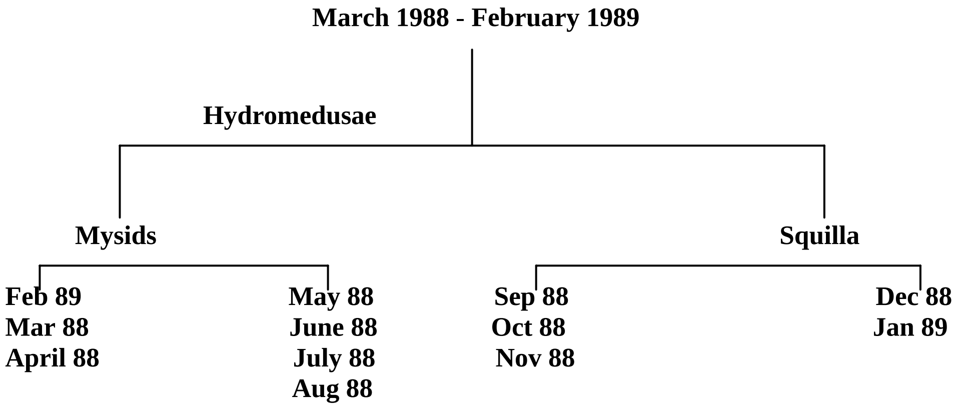

Fig. 4. Dendrogram for the temporal structure according to the TWINSPAN using 12 months fourth root transformed density data

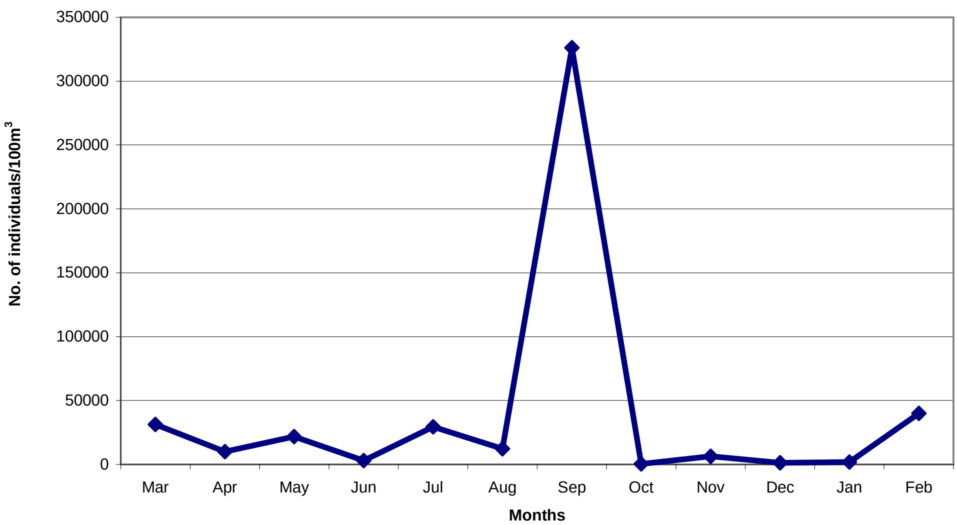

Fig 5. Monthly occurrence of zooplankton in the Kutubdia channel

So, the present investigation was close in agreement with the observation of Dutta et al. (1954).

Dutta et al. (1954) and Elias (1983) observed that the zooplankton abundance in the Hooghly and Mathamuhuri river estuaries was inversely related to turbidity, but reached maximum during the periods of low temperature and low turbidity. They also mentioned that the seasonal variation and succession in the zooplankton of these estuaries appear to be influenced by the physico-chemical factors, i.e. temperature, turbidity, salinity, dissolved oxygen, pH, etc., and biological factors like changes in the reproductive activity of the different organisms, but correlation of these factors became difficult when two or more of them were at work simultaneously. The findings of the present investigation were in agreement with the above-mentioned results. On the basis of the present ecosystem analysis, a general model (Fig. 6) was prepared, showing the role and ultimate effect of the Southwest monsoon on the production of plankton.

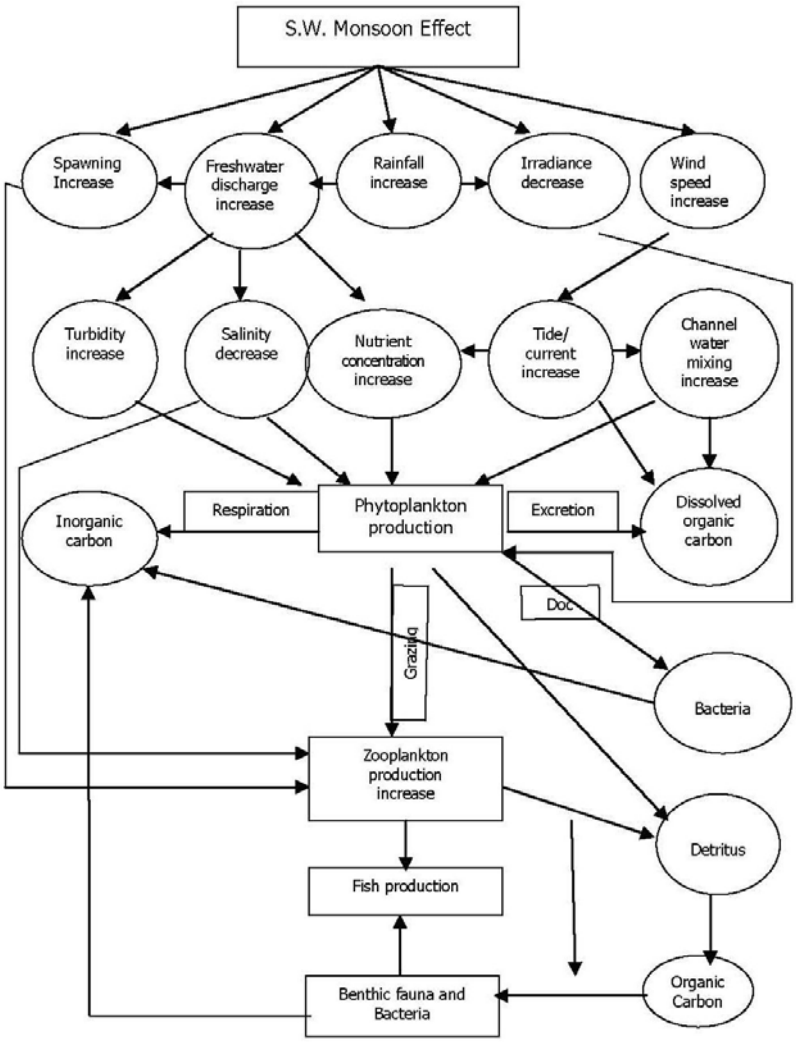

Fig. 6. An ecological model of the role and effect of the south west monsoon in a part of Bay of Bengal

Conclusion

The present findings showed the important role played by the Southwest monsoon in promoting productivity of zooplankton, which was subsequently correlated to the highest biological activities (breeding) or increase in nutrients by effect of seasonal upwelling.

References

Anon, 1965. Water quality criteria for European fresh water fish. Report on finely divided solids and inland fisheries. FAO (EIFAC Tech. pap. no. 1). Intl. Jour. Air and water poll. 9:151-168.

APHA, 1976. Standard Methods for the examination of water and waste water. American Public Health Association, Washington D. C. 1193 pp.

Barnes, H., 1959. Apparatus and methods of oceanography, Part 1. (chemical). Acad. press, London. pp. 178-183.

Boyd, C. E., 1979. Water quality in warm water fish ponds. Agricultural Experimental station. Auburn University Alabama, 359 pp.

Chandran, R., 1985. Seasonal and tidal variation of phytoplankton in the gradient zone of veller estuary. *Mahasagar Bull. Nat. Inst. Ocea*., 18 (10): 37-48 pp.

Corfitzen, W. E., 1939. *A study of the effect of silt on absorbing light which promotes the growth of algae and moss in canals*. Brureau of reclamintion, U.S. Dept. of the Interior, Washington D. C. 14 pp.

Davis, C. C., 1955. The marine and fresh water plankton. Michigan State Univ. Press. 562 pp.

Dickson, R R., and P. C. Reid, 1983. Local effects of wind speed and direction on the phytoplankton of the Southern Bight. Jour. plak. Res. 5 (4): 441-445.

Dutta, N., I. C. Malhatra and B. B. Bose, 1954. Hydrological and seasonal fluctuations of the plankton in the Hooghly estuary. Proceedings Indo-Pacific Fisheries council. Bangkok, 48-54.

Elias, M. S., 1983. Zooplankton of the Mathamuhuri estuary with special reference to shrimp and finfish larvae. M. Sc. Thesis. Institute of Marine Sciences, University of Chittagong, Bangladesh. 172pp.

Lambeuf, M. 1987. Bangladesh fish resources of the continental shelf, R/V ANUSANDHANI trawling survey results (Sept. 1984 - June, 1986) rept. prep for the FAO/UNDP project. Strengthing of the -- progm. for Mar. Fish resources Mangt., Res. and Devt. Fao, Rome, 1987, FI: DP/BGD/80/025, Field document 1: 26pp

Lind, O. T., 1979. Handbook of common methods in Limnology. C. V. Masby Company, Missouri, 199 pp.

Mahmood, N and Y. S. A. Khan, 1982. Desiging and feasibility studies on postlarval nets. University Grants Commission. Research Programme, Dhaka, Final Report, 14pp.

Omari, M. and I. Ikeda, 1984. Methods in Marine Zooplankton Ecology. john wiley & Sons, 332pp.

Schram, F.R. 1986. Crustacea. Orford University Press, New York, pp.606.

Sokal, R.R. and F.J. Rohlf, 1981. Biometry (2nd Edition), W.H. Freeman, San Francisco, 959pp.

Tarzwell, C. M. and A. R. Gaufin, 1953. Some important biological effects of pollution often discharged in stream. Surveys reprinted from Purdue Univ. Eng. Bull. Proc. 8th Ind. West Conf; 38pp.

Received October 20, 2004; Accepted September 11, 2006