THE SEASONAL CYCLE OF THE PHYTOPLANKTON IN THE COASTAL WATERS OF COX'S BAZAR

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Roll no.: 0119/04

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A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Science in Marine Bioresource Science

Department of Marine Bioresource Science

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Chattogram- 4225, Bangladesh

April, 2021

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This is to certify that we have examined the above Master's thesis and have found that is complete and satisfactory in all respects, and that all revisions required by the thesis examination committee have been made

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Abstract

The study was conducted to investigate the seasonal distribution of phytoplankton in Teknaf, Cox' s bazar located at latitude 20°50′48″ N and longitude 92°16′24″ E. Water samples were collected from Teknaf during monsoon and winter seasons. The water samples were taken in sample bottle, later brought in laboratory for further analysis. Water temperature, pH and salinity were measured at the site. Alkalinity, EC, Chl-a, TDS, TSS, NH_4, NO_2-N, PO_4-P and SiO_3-Si were measured in laboratory. There were variations found among these physico-chemical parameters between monsoon and winter period. The result of water temperature, Chl-a, NH_4, NO_2-N and SiO_3-Si were higher in monsoon period than winter period. But the result of salinity, alkalinity, pH, EC, TDS, TSS, PO_4-P were found lower in monsoon period (August) than winter period (January). The variations could be occurred by rainfall or rain runoff flowing into it total phytoplankton abundance was 1620 cells/L in monsoon (August) and 912 cells/L in winter (January). Overall, 25 genera under 5 classes were observed during monsoon period and 18 genera under 3 classes were found during winter period. The most dominant group of phytoplankton was Bacillariophyceae in both season. In total 5 classes (Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae and Pyrrophyceae) of phytoplankton were found in monsoon, whereas in winter, 3 classes (Bacillariophyceae, Chlorophyceae and Pyrrophyceae) were recorded. Small phytoplankton taxa like *Aserionella, Coscinodisus, Thalassiothrix, Chlorella, Oscillatoria, Ulotthrix, Protoperidinium, Ceratium* were found dominant in Teknaf during both seasons. The seasonal variation in phytoplankton controlled by the wide range of physico-chemical parameters. Maximum species of phytoplankton were found in monsoon period due to freshwater influx and local geomorphology. These result suggested that monsoon is the favorable period for phytoplankton abundance in this coastal region. The findings also help to know the ecological status of the area in different seasons.

Keywords: phytoplankton, seasonal distribution, abundance, coastal water, Cox's Bazar, monsoon, winter, physico-chemical parameters, genera, class.

CHAPTER-1

INTRODUCTION

1.1 Background of the study

Phytoplanktons are the autotrophic (primary producer) components of the plankton community and an important part of oceans, seas and freshwater ecosystems. The suspended particular matters in the aquatic environment consist of living organism, otherwise called plankton and dead particles commonly referred as detritus. Plankton contains all organisms, plants and animals that are passively "drifting" along with water actions. While considering this, it must be remembered that, considering their small size, many planktons are strong swimmers and are capable of moving through comparatively long distances over a period of time, particularly in a vertical way.The seas form somewhat71percent of the world's surface and have an average depth of about 3800 meters. Plankton can be found in the three dimensions of the sea; the length,the breadth and the depth (Wickstead,1962).

When plankton bloom occurs, some diversities might be noticeable as coloured covers on the water surface due to the chlorophyll present within their cells and accessory pigments (such as phycobiliproteins or xanthophylls) in some species. About 1% of the global biomass is due to phytoplankton.

Planktons can be divided into three broad divisions (1) phytoplankton (2) zooplankton and (3)nano plankton,sometimes called micro plankton, composed of both plants and animals. The plant component of plankton is called phytoplankton comprising of unicellular (in some exceptional cases;multicellular) algae that produce their food by photosynthesis process , using light, carbon dioxide (CO_2),nutrients and trace metals. All these autotrophs have photosynthetic pigments such as chlorophylls and carotenoids. Some phytoplankton organism, mainly some species considered as dinoflagellates, can be temporarily or permanently heterotrophic all form up organic particulate substance from dissolved organic substances or even particulate organic substance. Their movement depends mostly on tides, currents and winds, because they are too small and weak to swim against the currents. Significant algal groups in the phytoplankton include diatoms, golden algae and cyanobacteria (formerly known as blue-green algae). The phytoplankton includes three main groups, via diatoms (e.g. *Coscinodiscus,Skeletonema),*dinoflagellates (e.g. *Noctiluca,Perdinium),*and the nanoplankton or µ-falgellates (e.g. *Isochrysis, Monochrysis*)(Perkins,1960).

The cell covering of phytoplankton can vary between and within taxonomic groups. These coverings might consist of either sample plasma membranes,protective and ornamented thecae frustules, lubricated or slimy structures and siliceous frustules or cellulose.Genus identification are based on morphological features,cellular structure, colour, size and cell division, which are all visible under the light microscope. Preserved or living specimens can be identified ; taxonomy can be enhanced with electron microscopy, especially for taxa that have external, recognizable, cell characteristics such as diatoms, chrysophytes and desmids.

Temperature, the most important factor in controlling the growth of phytoplankton was emphasized by many researchers (Goldinan, 1977).Similarity exists among the phytoplankton population structures of all estuaries especially those with a stable salinity structure, and in general there is a decrease in species diversity with increasing distance moving toward upstream. Each estuary, in common with all inshore waters, has a characteristic phytoplankton profile. The ultimate survival of which depends on individual reproduction rates and the water circulation, degree of mixing, exchange ratio and interactions with outside waters, which may include oceanic incursions (Perkins, 1960).Biological diversity of phytoplankton refers to the range of surface microscopic organisms in an environment. It is the range of organisms present in a given ecological community or system. Biodiversity of phytoplankton can be measured by counting their numbers and types of different species or by the genetic variations within and between species on the sampling site.

Phytoplanktons are the primary producer of an aquatic ecosystem. So they form their vital source of energy at the first tropic level and also serve to contribute in species diversity, distribution, seasonal succession and decomposition that act as significant components of the food web.

Tropical water is very rich with a variety of aquatic life and coastal water of Bangladesh is not an exception (West, 1973). Many planktons move over the period of a long distance (Wickstead,1978). Two maximum areas of plankton density was observed on the continental shelf of Bangladesh, one along the eastern coast of Cox's bazar to St. Martin island and another in the northern part of Swatch of no ground (Saetre,1981).

The diversity of phytoplankton differs from season to season. As the water parameters vary seasonally. These diversities of temporal patterns suggest that different mechanisms may control phytoplankton dynamics and productivity among estuaries, a fact that complicates the development of paradigms of estuarine phytoplankton ecology (Boynton et al., 1982). Rahman(1997) identified 25 species of phytoplankton under 22 genera from the Naf River estuary of which Bacillariophyta was the dominant group (64%) followed by the Chlorophyta (20%). Taimur (2006) studied on abundance and distribution of phytoplankton in the vicinity of St. Martin's Island during monsoon and post-monsoon. Seasonal difference of phytoplankton biomass, species composition and production vary markedly among the estuarine habitation types (Cloern et al.,1985). A level of knowledge is needed to recognize about seasonal variation of water quality parameters and the relation of seasonal phytoplankton abundance with the variation of parameters. A comparative study between them is also required. This study will highlight the pattern of the seasonal cycle in the coastal region in Bangladesh.

1.2 Objectives of the present study:

The objective of the study is to identify the seasonal variation of phytoplankton abundance, distribution with different water quality parameters along the pattern of seasonal cycle.

1.3. Main Objectives:

- To identify the various species of phytoplankton with the pattern of seasonal cycle
- To identify the relation of seasonal abundance with different water quality parameters.

CHAPTER-2

LITERATURE REVIEW

Although a good number of research works have been conducted on phytoplankton in different parts of the world. Reviews of some notable works conducted adjacent of Bangladesh have been include here.

Liyod (1925) made a thorough investigation on the nature of phytoplankton with special reference to the temporal distribution of phytoplankton and environmental conditions affecting the same.The studies by Allen (1936 and 1939) mentioned that the fluctuation and distribution of phytoplankton is related to hydrological parameters (Hulbert and Galliard, 1968).

Hulbert and Corwin (1970), Carpenter(1971), Lenz (1968),Nazneen (1980) worked on the influences of hydrological factors and the seasonal abundance of phytoplankton in Kinjhir lake, Pakistan which shows the influences of different physico chemical parameters on pond fertility such as temperature, pH,O_2,CO_2,NO_2,NO_3etc on phytoplankton growth and abundance as well as lake productivity.

Mahakam delta is one of the watershed regions in East Kalimantan, Indonesia and made through sedimentation process. Those are zones linking fresh and marine system and are so characterized by gradients of chemical, physical and biological parts within the water column. The spatial mapping of phytoplankton assist to determine hotspots area based on abundance and diversity. The knowledge of phytoplankton distribution with reference to spatial pattern is important to determine the status of the ecosystem structure.

Ahmed et al. (2004) investigated ecological studies on primary productivity, phytoplankton standing crops and diversity of the river Padma at Mawaghat, Munshigong.Salam (1977) studied on the phytoplankton of the Karnafuli river estuary and documented 111 species beneath 57 genera of that division Chlorophyta was the leading group(48.46%) followed by class Bacillariophyceae(35.24%) and he additionally studied the occurrence and regularity ofthe phytoplankton and benthic algae .

Sharif (2002) completed an analysis on quantitative distribution of plankton and benthos at 5 totally different stations of the Meghna river estuary throughout monsoon and 21 genera of phytoplankton were recognized in post monsoon .Subramanyan (1946) delivered an account of 170 forms of diatoms from Bay of Bengal near madras coast. He also documented 336 species of phytoplankton from the Arabian sea of the west coast of India and indicated their frequency of occurrence. In the St. Martin island, Islam (1970) investigated physiographic, ecological conditions, vertical distribution of algal vegetation, coastal distribution and association of algae. The studies by Yamazi (1972-1974) on different aspects of phytoplankton emphasis on the qualitative and quantitative estimation along with ecological factors.

In Bangladesh an extensive work on marine phytoplankton was done by Islam and Aziz (1975). They have presented the inverse relationship between phytoplankton and zooplankton growth of the northern– eastern part of the Bay of Bengal and quantitative relation between them were roughly 8:1 in summer, 3:1 in monsoon and 6:1 in autumn. They reported 29 genera and 76 species of phytoplankton from northern eastern part of Bay of Bengal belonging to different classes eg. Bacillariophyceae (64 species of 23 genera), Dinophyceae (10 species of 4 genera) and Cyanophyceae (2 species of 2 genera).

Islam and Haroon(1975) along with Islam and zaman (1975) studied on physical, chemical and biological aspects of Burigangariver where they showed typical freshwater phytoplankton. Morshed (1976),Chowdhury (1980 and 1992) and Shamsuddin (1995) worked on culture system of phytoplankton for use in hatchery.

On estuarine phytoplankton a descriptive research was completed by Salam (1977). The research reported that the benthic algae and plankton of the Karnafully river estuary and documented 111 species under 57 genera of which Chlorophyta was the leading group (48.46%) followed by the Bacillariophyta (35.24%). The previous two investigator Islam and Aziz (1977) identified 42 species of the phytoplankton from the Karnafully river estuary belonging to different classes. Chlorophyceae (12 species of 6 genera), Euglenophyceae (1 species of 1 genera), Chrysophyceae (1 species of 1 genera), Bacillariophyceae (17 species of 9 genera), Dinophyceae (5 species of 2 genera) and Cyanophyceae (6 species of 4 genera).

Chowdhury (1980) studied on phytoplankton along with some physico chemical factors of Kaptailake. Islam (1981) studied on phytoplankton and their distributional variations between Foy' s lake and Karnafully river estuary.

Many species of phytoplankton are found in the coastal water of cox’s bazar . The variation of phytoplankton abundance occur in different season Phytoplankton biomass was found to be seasonally maximal during autumn in the Patuxent River,Stross and Stottlemeyer(1965). These diversities of temporal patterns proposed that different mechanisms may regulate phytoplankton dynamics and productivity among estuaries, a indisputable fact that complicates the event of paradigms of body of phytoplankton ecology, Boynton et al. (1982). Rahman(1997) identified 25 species of phytoplankton under 22 genera from the Naf River estuary of which Bacillariophyta was the dominant group (645) followed by the Chlorophyta (20%).

Taimur (2006) studied on abundance and distribution of phytoplankton in the vicinity of St. Martin’s Island during monsoon and post-monsoon. Seasonal difference of phytoplankton biomass, species arrangement and productivity differ markedly among the estuarine habitat types (Cloern et a11985). The studies by Yamazi(1972-1974) on different aspects of phytoplankton emphasis on the qualitative and quantitative estimation along with ecological factors.

CHAPTER-3

MATERIALS AND METHODS

3.1 Study area

The study was conducted in Teknaf, Cox' s Bazar located at latitude 20°50′48″ N and longitude 92°16′24″ E. Samples were collected in monsoon and winter period.

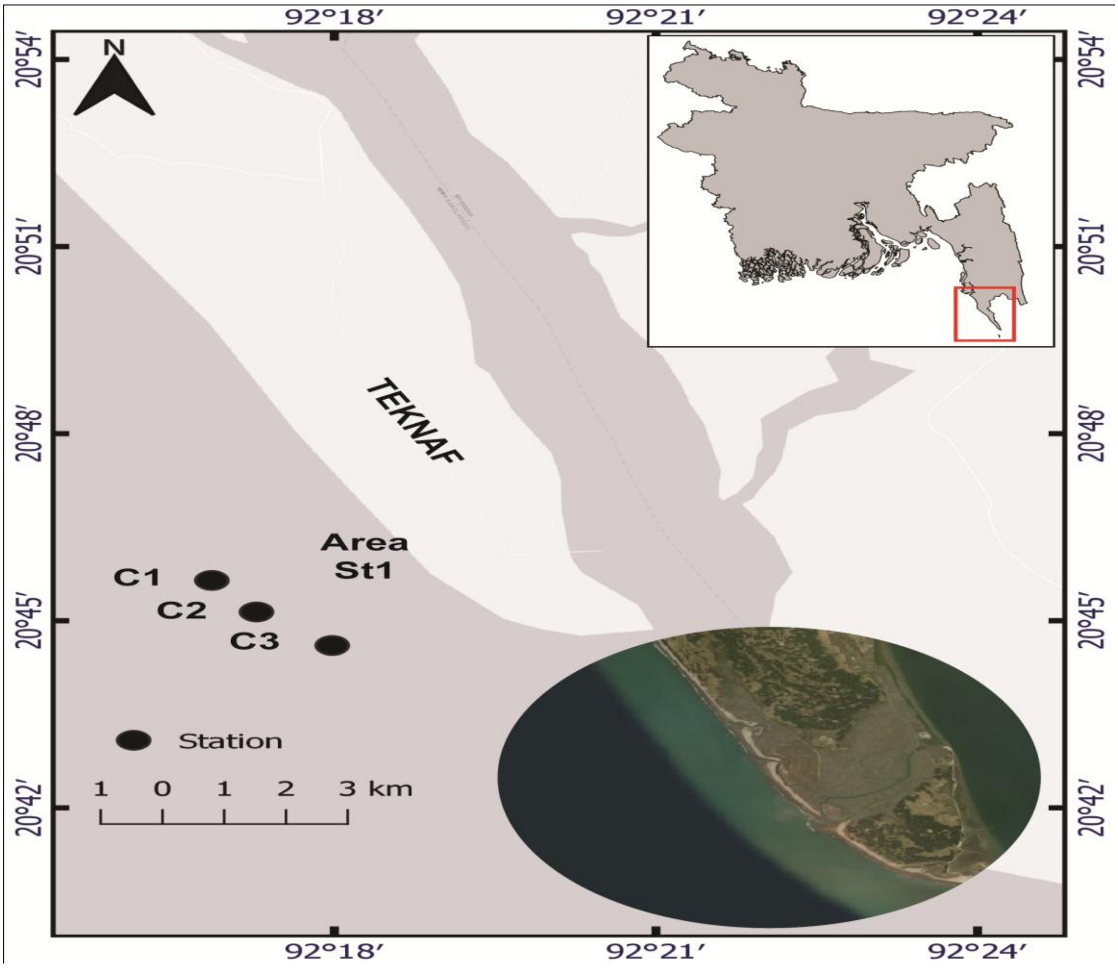

Figure -1: Location of study area (Station- Teknaf)

3.2 Study of phytoplanktons in sampling site

3.2.1 In situ determination of environmental factor

A) Water temperature

Water temperature was measured by using standard mercury filled centigrade thermometer having a range from 0^0C to 100^0C (Prabu, 2008).

B) pH

pH was determined by using digital pen pH meter (HANNA Instruments, model HI 98107). Water pH meter was calibrated before every measurement.

C)Salinity

Salinity was determined by using Hand-Held Refractometer (ATAGO, S/Mill, Salinity 0-100 ppt, Japan).

3.2.2 Laboratory analysis

A)Chlorophyll a measurement

500 ml water samples were filtered through membrane filter with the help of a vacuum pump. The filtered membrane was taken into 10 ml of 90% acetone and kept overnight. The filtered paper was mixed thoroughly with acetone using glass rod. Then centrifugation at 3500 RPM for 2:30 minutes was performed. The supernatant contents (extract) were taken into corvettes the absorbance of extract was determined at 664, 647, 630 nm comparing with blank acetone. The chlorophyll- a concentration was calculated by following equation :

Chlorophyll a= (11.85* A664- 1.54 *A647- 0.08 *A630)*V/S*1000

A664 = Absorbance at 664 nm

A647 = Absorbance at 647 nm

A630= Absorbance at 630 nm

V= Volume of acetone used

S= Volume of sampled filter (ml)

B)Electro-conductivity, TDS

Electro-conductivity was determined by using a digital Electro-conductivity meter (HANNA Instruments, model EC 98107). In the meantime the water TDS and Salinity can be known by this EC meter.

C)Total suspended solid (TSS):

Total suspended solids were measured by applying filtration procedure followed standard methods (APHA, 1995). Total suspended solids were measured by applying filtration procedure followed standard methods. For determination of turbidity (TSS) water samples were filtered through glass fiber filters which were dried at 105°C (>1 hr.) and weighted to obtain the quantity of suspended solids.

Equipments:

Filter paper, oven, Desiccator, Electrical Balance.

Method:

At first filter paper dried in the oven and placed into desiccator (at least 30 min at both stage). Then oven dried filter paper weighted. 50 ml water sample taken and filtered using filter paper. After filtration filter paper dried in oven at 104^{o}c and placed at Desiccator. Then measured the weight of filter paper with solid remaining. The value of TSS in water sample was calculated using following formula.

Calculation:

$$TSS = \frac{B-A}{50} \times 1000$$

Where,

A= Weight of the oven dried filter paper.

B = Weight of the filter paper with reaming solid.

D)Nitrite-nitrogen (NO_2-N):

Nitrite-nitrogen (NO_2-N) was determined following the methods described by Bendschneider and Robinson (1952).

Equipments:

Spectrophotometer (Model: Osk-15745), funnel, conical flask, measuring cylinder, filter paper.

Reagents:

Sulphanilamide, N-(-1-Napthal)-ethylene diaminedihydrochloride (NNED)

Method:

50 ml water sample was filtered by Whatman filter paper (0.1µm). Then 50 ml filtered sample were taken in a conical flask. 1 ml sulphanilamide added and mixed. Allowed to react for 2-8 min. Then 1ml NNED added and mixed. Measured the extinction after 10 minutes but before 2hrs at 543 nm.

Calculation:

(µg at NO_2-N/L): Factor (19.84) X (Absorbance of samples – abs. of blank).

E)Phosphate-phosphorus (PO_4-P):

Phosphate-Phosphorus (PO_4-P) was determined following the methods described by Murphy and Riley (1962).

Equipments:

Spectrophotometer (Model: Osk-15745), funnel, conical flask, measuring cylinder, filter paper.

Reagents:

Acid ammonium molybdate, stannous chloride.

Method:

50 ml water sample was filtered by Whatman filter paper (0.1µm). Then 50 ml filtered sample were taken in a conical flask. 2 ml acid ammonium molybdate and shake. Then 5 drops of stannous chloride added. At last the lack of developed color measured at 690 nm.

Calculation:

(µg at PO_4-P/L): Factor (45.93) x (Absorbance of sample − abs. of blank).

F)Silicate-silicon (SiO_3-Si):

Silicate-Silicon (SiO_3-Si) was determined following the methods described by Mullin and Riley (1955).

Equipments:

Spectrophotometer (Model: Osk-15745), funnel, conical flask, measuring cylinder, filter paper.

Reagents:

10% Acid ammonium molybdate, 25% Sulphuric Acid.

Method:

50 ml water sample was filtered by using Whatman filter paper (0.1µm). Then 50 ml filtered water sample were taken in a conical flask, add 2 ml acid ammonium molybdate and shake. Then added 0.5 ml Sulphuric acid in the conical flask. At last the absence of developed color measured at 460 nm.

Calculation:

(µg at SiO_3-Si /L): Factor (5372.58) x (Absorbance of sample − abs. of blank).

G) Alkalinity measurement:

For alkalinity measurement 100 mL of sample water was taken into a conical flask. Then 2-4 drops of Phenolphthalein indicator were added in the sample. As the colour of the sample didn’t change, it indicated that phenolphthalein alkalinity was absent.After that fresh 100 mL water sample was taken into another flask and 2-4 drops of methyl orange indicator were added in the sample. The colour turned into yellow . Then the sample was titrated against standard H_2SO_4 (0.02N) .Titration was continued until the yellow colour turned into pink . The required amount of acid (H_2SO_4) was recorded and the result was calculated by the following formula :

$$\text{Alkalinity} = \frac{\text{Acid used (ml)}*0.02\text{N(Normality of acid}*50\text{(Gram equivalent weight of CaCO 3)}*1000}{\text{Sample volume (V)}}$$

H) Ammonia

For the determination of ammonia, the program 324 set in the photometer (pHoto Flex; WTW, Germany) and zero adjustment was done using distilled water.The pH value of the sample was also checked whereas, the desired value, approx. pH 7 VARIO AMMONIA Salicylate F10 powder pack and VARIO AMMONIA Cyanurate F10 powder pack needed to measure the ammonia in water sample. At first, 10 mL of sample water was taken in empty cell using pipette. The contents of VARIO AMMONIA Salicylate F10 powder packs were added and the cell was closed with screw cap.Then the cell was shaken and allowed to react for 3 minutes. After that the contents of VARIO AMMONIA Cyanurate F10 powder pack also added and the cell closed with screw cap. Then the cell was shaken and allowed to react for another 15 minutes . Then the cell was inserted in the photometer and the photometric reading recorded afterwards .

3.2.2 Qualitative and quantitative estimation of plankton

Samples were collected in 2.5 L plastic bottles for qualitative and quantitative analysis of phytoplankton. Sampling was done between 11 am to 1 pm from surface water by using phytoplankton net. Phytoplankton net have been towed just under the water surface for one minute at a speed of approximately 1m/s and samples were collected in sample bottle. Samples were preserved with 5% buffered formalin.

The quantitative enumeration of phytoplankton were carried out with the help of a Sedgewick – Rafter (S-R) counting cell under the microscope. This S-R cell was washed with water and dry properly. Then 1 ml sample was taken in S-R cell and left for 15 minutes undistributed to allow plankton settle. The plankton in 10 randomly selected cells were recognized up to family level and calculated under a binocular microscope with imaging facilities. The planktons were also observed under microscope to study the major plankton classes.

Plankton abundance was calculated by using this formula :

N=(P*C*100)/L

N=Number of plankton cells or units per litre of original water

P=The number of plankton counted in 10 fields

C=The volume if final concentration of the sample(ml)

L=The volume(L) of water sample.

CHAPTER-4

RESULTS

4.1Water temperature

Water temperature was 32^oC during monsoon season.Water temperature was 25.2^oC during winter season (Figure: 2a). The value of water temperature was higher in monsoon(August) and lower in winter(January).Water temperature has strongly positive correlation with NH_4, NO_2-N and moderately positive correlation with SiO_3-Si (Table-1).

4.2 Salinity

Water salinity was 25.8psu during monsoon season(August) and alinity was 32.7psu during winter season(January) (Figure: 2b). The value of salinity was lower in monsoon and higher in winter.Salinity has strongly positive relationship with alkalinity, pH, EC, TDS and PO_4-P (Table-1).

4.3 pH

pH of the investigated area was 6.3 during monsoon (August).In winter season(January), pH was 6.5 (Figure: 2a).The value of pH was lower in monsoon and higher in winter.pH has strongly positive correlation with EC, TDS and PO_4-P (Table-1).

4.4 Alkalinity

The value of alkalinity was 126.7 ppm in monsoon (August) and was134.3 ppm in winter(January) (Figure: 2e). The value of alkalinity was lower in monsoon and higher in winter.Alkalinity has strongly positive relationship with pH, EC, TDS and PO_4-P (Table-1).

4.5 EC

EC value of the investigated area was 49.2mS/cm in monsoon season(August) and 61.1mS/cmin winter season(January) (Figure: 2b). The value of EC was lower in monsoon and higher in winter. EC has strongly positive correlation with TDS and PO_4-P (Table-1).

4.6 Chlorophyll- a

The Chlorophyll- avalue was 1.63 µg/L during monsoon period . In winter period the value was1.30 µg/L(Figure: 2g). The value of chlorophyll a was higher in monsoon and lower in winter. Chlorophyll-a has strongly positive correlation with NH_4, NO_2-N and moderately positive correlation with SiO_3-Si (Table-1).

4.7 Total dissolved solids (TDS)

The value of Total Dissolved Solids (TDS) ranged from 24.7gm/L to 30.5gm/L. 24.7gm/L was found in monsoon (August)and 30.5gm/L was found in winter (January) (Figure: 2d).TDS has strongly positive correlation with PO_4-P and weakrelationship with TSS (Table-1).

4.8 Total suspended solid (TSS)

TSS varied from 1.3gm/L to 1.4gm/L. The minimum TSS value 1.3gm/L found during monsoon (August) and 1.4gm/L was found during winter (January) (Figure: 2d). The value of TSS was lower in monsoon and higher in winter.TSS has weak positive relationship with PO_4-P and SiO_3-Si (Table-1).

4.9 Ammonia(NH_4)

The value of $NH_4$was 171.3 µg/L in monsoon period and 140 µg/Lin winter period. The value of NH_4 was higher in monsoon(August) and lower in winter(January) (Figure: 2c). NH4 has strongly positive correlation with NO_2-N and moderately positive correlation with SiO_3-Si (Table-1).

4.10 Nitrite-nitrogen(NO_2-N)

The Nitrite Nitrogen (NO_2-N) value was 0.8 µg/L during monsoon period(August). In winter period(January), the value was 0.4 µg/L (Figure: 2c). The value of NO_2-N was higher in monsoon and lower in winter.NO_2-N has strongly positive relationship with SiO_3-Si (Table-1).

4.11 Phosphate-phosphorus(PO_4-P)

0.3 µg/L was the value of PO_4-P during monsoon period(August). 1.4 µg/L was the value of PO_4-P during winter period(January) (Figure: 2f). The value of PO_4-P was lower in monsoon and higher in winter.

4.12 Silicate-silicon (SiO_3-Si)

The value of Silicate-Silicon (SiO_3-Si) was 96.7 µg/L during monsoon period(August). 86 µg/L was during winter period(January) (Figure: 2f).The value of SiO_3-Si was higher in monsoon and lower in winter.

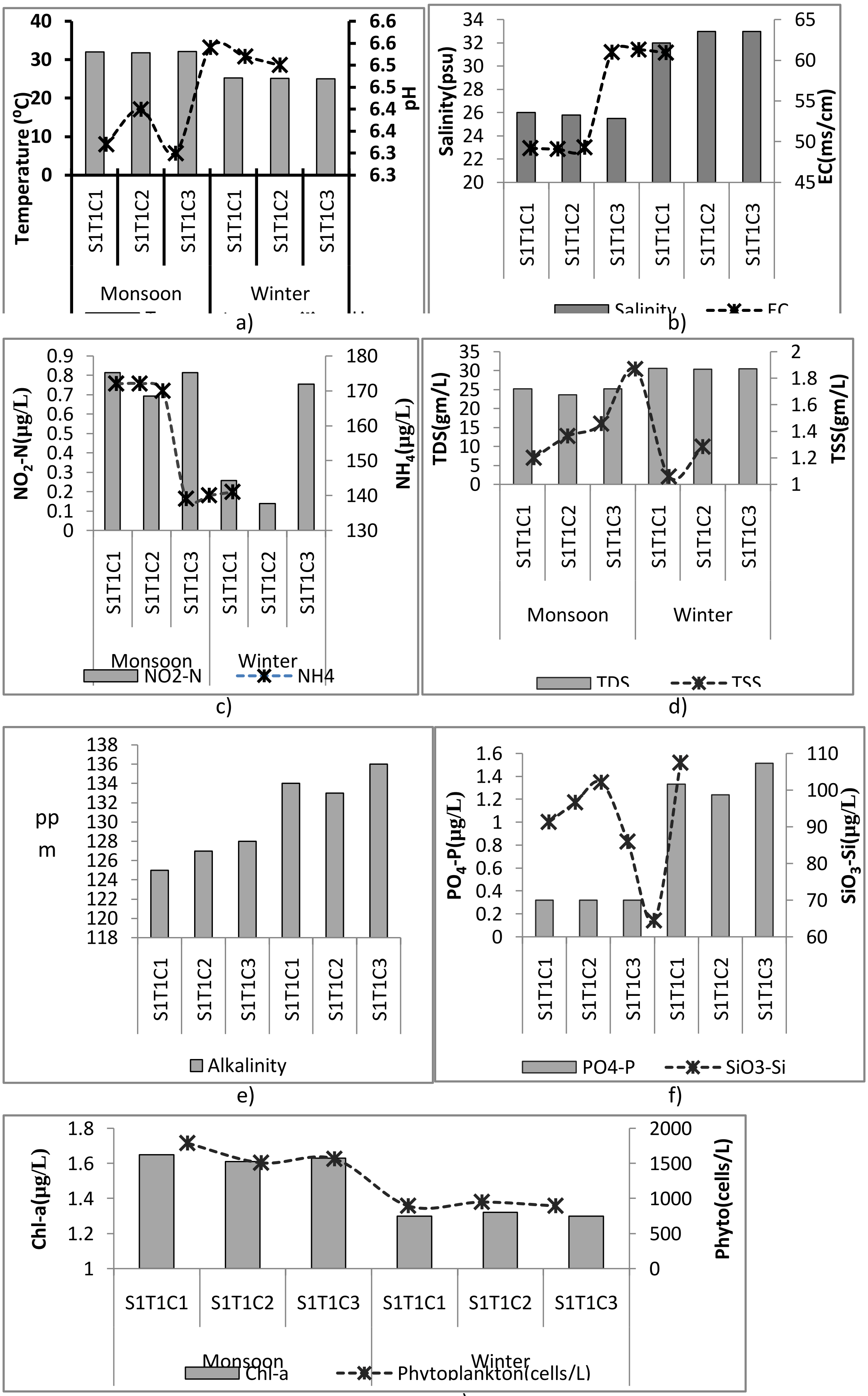

Figure-2 : Seasonal variations among parameters

4.13 Statistical analysis

4.13.1 Correlation among parameters

Table-1: Correlation among different physico chemical factors

	WT	Sal	Alka	pH	EC	Chl-a	TDS	TSS	NH_4	NO_2-N	PO_4-P	SiO_3-Si
WT	1											
Sal	-.99**	1										
Alka	-.95**	.94**	1									
pH	-.94**	.92**	.87*	1								
EC	-.99**	.99**	.94**	.93**	1							
Chl-a	.99**	-.98**	-.96**	-.95**	-.99**	1						
TDS	-.97**	.97**	.92**	.86*	.98**	-.97**	1					
TSS	-0.11	0.02	0.20	0.19	0.11	-0.16	0.13	1				
NH_4	.99**	-.98**	-.95**	-.93**	-.99**	.99**	-.98**	-0.16	1			
NO_2-N	0.69	-0.68	-0.53	-0.77	-0.72	0.7	-0.67	-0.13	0.72	1		
PO_4-P	-.99**	.98**	.97**	.91*	.98**	-.99**	.97**	0.13	-.98**	-0.59	1	
SiO_3-Si	0.37	-0.39	-0.12	-0.43	-0.40	0.34	-0.37	0.24	0.39	.85*	-0.24	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Water temperature has strongly positive correlation with NH_4, NO_2-N, Chl-a and moderately positive correlation with SiO_3-Si. Salinity has strongly positive relationship with alkalinity, pH, EC, TDS and PO_4-P.pH has strongly positive correlation with EC, TDS and PO_4-P. Alkalinity has strongly positive relationship with pH, EC,TDS and PO_4-P. EC has strongly positive correlation with TDS and PO_4-P. Chlorophyll-a has strongly positive correlation with NH_4, NO_2-N and moderately positive correlation with SiO_3-Si. TDS has strongly positive correlation with PO_4-P and less significant relationship with TSS. TSS has weakly positive relationship with PO_4-P and SiO_3-Si. NH4 has strongly positive correlation with NO_2-N andmoderately positive correlation with SiO_3-Si. NO_2-N has strongly positive relationship with SiO_3-Si.

4.13.2 Cluster analysis

Multivariate statistical analysis such as Cluster Analysis (CA), PrincipalComponent Analysis (PCA) act as an effective index for meaningful interpretation of spatio-temporal parametric data. Many researchers have used the techniques to assess and characterized the water chemistry. Talukder et al. (2016),Jiang-Qi et al. (2013), Qadir et al. (2007) and Kowalkowski et al. (2006) demonstrated that multivariate statistical methods (PCA, CA, FA) can be very effective to interpret the complex data sets, identifying pollution factors, assessing water quality with spatio-temporal deviation.

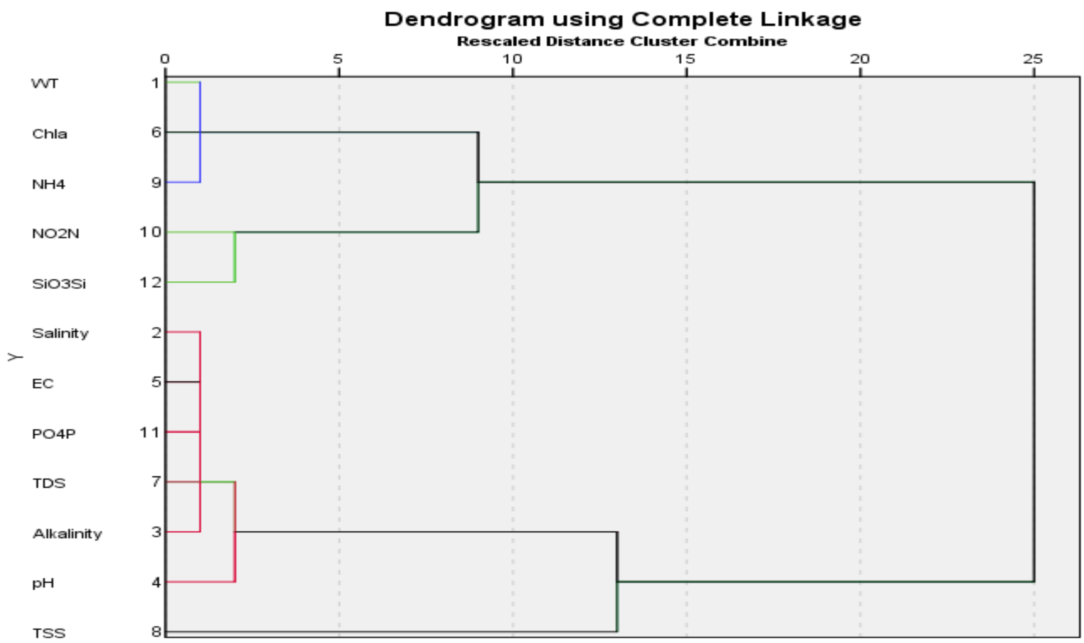

Figure- 3: Dendrogram of different physicochemical factors (Three colors are representing three clusters)

Amalgination steps of Cluster Analysis (CA) were performed using ward linkage with absolute correlation coefficient distance.Firstly CA was applied among the parameters,which brought out three significant cluster: Cluster 1: WT, Chl-a, NH_4, Cluster 2: NO_2 -N , SiO_3-Si, Cluster-3 salinity,EC, PO_4-P ,TDS , alkalinity and pH. Parameters are clustered in minimum distance have a high affinity with same identical behavior during seasonal changes and also have a potential influences with each other. It was observed that there was a close similarity among water temperature, chlorophyll-a and NH_4. There was also close similarity among salinity,EC, PO_4-P,TDS, alkalinity and pH. NO_2-N and SiO_3-Si had small similarity.

4.13.3Principal components analysis

Principal Component Analysis or PCA is a statistical procedure that allows to summarize the information content in large data tables by means of a smaller set of "summary indices" that can be more easily visualized and analyzed.

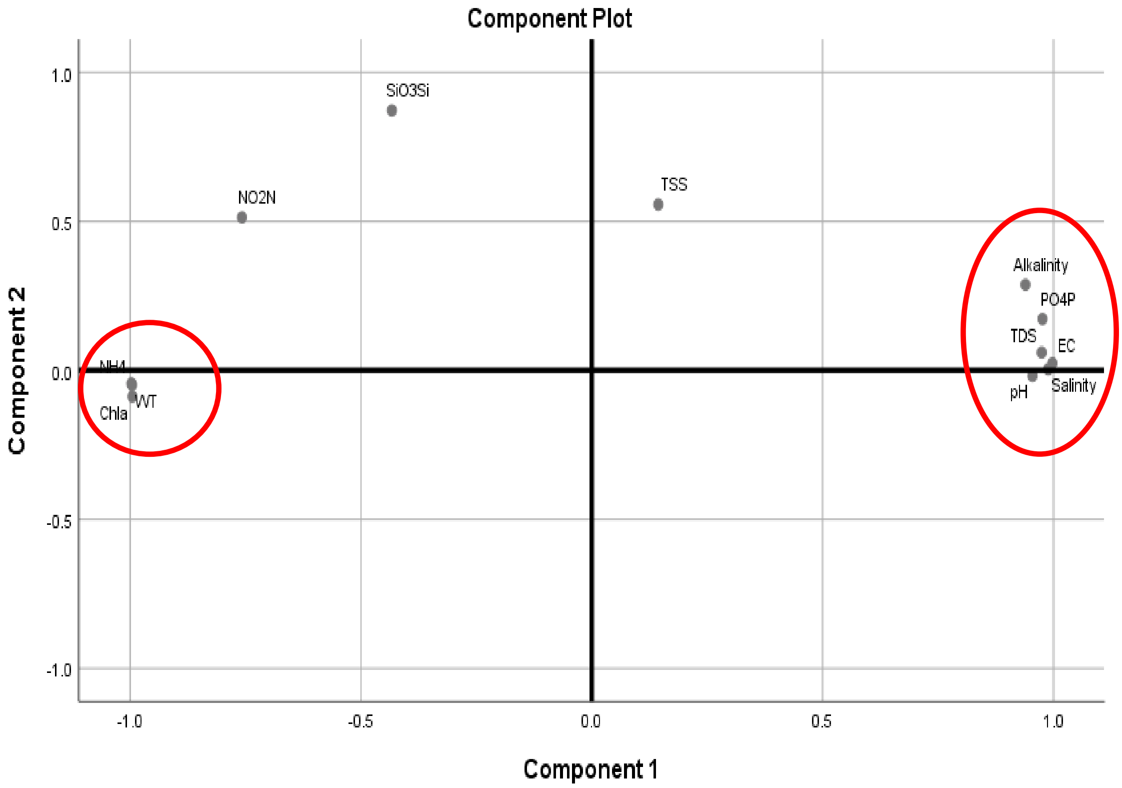

Figure-4: Principal Components Analysis

There is a close positive relationship among alkalinity, PO_4-P, TDS,EC, salinity andpH. There is also a close positive relationship among water temperature, Chl-a and NH_4.But NO_2-N, SiO_3-Si and TSS are not correlated with others.(Figure-4).

4.13.4 Correlation among parameters and phytoplankton

Table-2: Correlation among parameters and phytoplankton abundance(Cells/L)

Parameters	WT	Sal	Alk	pH	EC	Chl-a	TDS	TSS	NH_4	NO_2-N	PO_4-P	SiO_3-Si	Phyto
WT	1.0												
SAL	-0.9	1.0											
Alk	-0.8	0.7	1.0										
pH	-0.8	0.8	0.7	1.0									
EC	-0.6	0.7	0.7	0.7	1.0								
Chl-a	.8*	-0.7	-0.9	-0.8	-0.6	1.0							
TDS	-0.6	0.7	.8*	0.8	.8*	-0.8	1.0						
TSS	0.3	-0.5	0.2	0.0	-0.1	-0.2	0.2	1.0					
NH4	0.6	-0.6	-0.8	-0.8	-0.9	0.8	-0.9	-0.2	1.0				
NO_2-N	0.6	-0.6	-0.4	-0.9	-0.6	0.6	-0.4	0.1	0.7	1.0			
PO_4-P	-0.9	.8*	.9**	0.8	0.7	-0.9	.9*	0.0	-0.8	-0.5	1.0		
SiO_3-Si	0.1	-0.3	0.1	-0.5	-0.5	0.0	-0.2	0.3	0.4	0.7	0.0	1.0	
Phyto	.84*	-0.7	-0.9	-0.8	-0.6	1.0**	-0.8	-0.2	0.8	0.6	-0.9	0.0	1.0

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Phytoplankton abundance has strongly positive correlation with water temperature, Chl-a, NH_4, moderately positive correlation with NO_2-N and weakly positive correlation with SiO_3-Si. Phytoplankton abundance has negatively correlation with salinity, alkalinity, pH, EC, TDS, TSS, PO_4-P.

4.14 Phytoplankton composition in Teknaf, Cox's Bazar during monsoon and winter season

Table-3 : Seasonal variations of phytoplankton abundance (%)

Phytoplankton	**Season -1(Monsoon)(%)**	**Season-2(Winter)(%)**
Amphora	9.70	10.74
Asterionellopsis	6.40	8.12
Asterionella	12.90	13.50
Biddulphia	6.40	5.37
Bacillaria	8.05	5.37
Coscinodiscus	9.70	10.74

Cyclotella	9.70	10.74
Chaetoceros	1.64	0
Diatoma	3.20	2.76
Diploneis	3.20	2.76
Fragilaria	1.65	0
Melosira	1.65	0
Navicula	3.20	5.37
Nitzschia	1.65	2.70
Odontella	3.20	5.41
Pseudo-nitzschia	1.65	0
Skeletonema	1.65	2.70
Thalassiothrix	14.55	13.50
Total Bacillariophyceae	**71.30**	**75.55**
Chlorella	56.92	66.07
Oscillatoria	14.32	33.93
Ulothrix	28.46	0
Total Chlorophyceae	**8.02**	**6.14**
Anabaena	100	0
Total Cyanophyceae	**1.17**	**0**
Amphidinium	100	0
Total Dinophyceae	**2.28**	**0**
Ceratium	46.60	55.36
Protoperidinium	53.40	44.34
Total Pyrrophyceae	**17.22**	**18.42**
Total Phytoplankton	**100**	**100**

4.15Phytoplankton composition

The water sample was collected for plankton observation. From the collected water sample of Teknaf, Cox's Bazar,phytoplanktons were observed . Total phytoplankton abundance was 1620 cells/L in monsoon(August) and 912 cells/L in winter(January). A total number of phytoplankton genera representatives of five classes were identified. The contributionof phytoplankton was of the total count of plankton.The observed five classes was Bacillariophyceae, Chlorophyceae,Dinophyceae,Pyrrophyceae andCyanophyceae .

A) Bacillariophyceae

The class Bacillariophyceae dominated the plankton community in Teknaf with 71.30 % in monsoon(August) and 75.55% in winter(January) consisting of 18 genera . The most dominated genus are *Thalassiothrix, Asterionella* , *Amphora, Coscinodiscus, Cyclotella ,Bacillaria, Asterionellopsis and Biddulphia*.The contribution of *Thalassiothrix*14.55%, *Asterionella*12.90%, *Amphora* 9.70%, *Coscinodiscus*9.70%, *Cyclotella*9.70%,*Bacillaria*8.05%,*Asterionellopsis*6.40% *and Biddulphia*6.40% in bacillariophyceae class in monsoon season. The contribution of *Thalassiothrix*13.50%, *Asterionella*13.50% , *Amphora* 10.74%, *Coscinodiscus*10.74%, *Cyclotella*10.74% ,*Bacillaria*5.37%,*Asterionellopsis*8.12% *and Biddulphia*5.37% in winter season. The variation inBacillariophyceae between seasons were significant (<0.05)(Table-4).

Table-4 : Significance of phytoplankton with season

Phytoplankton	Season
Amphora	0.64
Asterionellopsis	0.085
Asterionella	0.797
Biddulphia	0.016
Bacillaria	0.003
Coscinodiscus	0.056
Cyclotella	0.066
Chaetoceros	0.009
Diatoma	0.526
Diploneis	0.786
Fragilaria	0.009
Melosira	0.009
Navicula	0.03

Nitzschia	0.127
Odontella	0.039
Pseudo-nitzschia	0.008
Skeletonema	0.011
Thalassiothrix	0.936
Total Bacillariophyceae(%)	**0.001**
Chlorella(%)	0.003
Oscillatoria(%)	0
Ulothrix	0
Total Chlorophyceae(%)	**0.009**
Anabaena	0
Total Cyanophyceae(%)	**0**
Amphidinium	.
Total Dinophyceae(%)	**0.013**
Ceratium	0.001
Protoperidinium	0.001
Total Pyrrophyceae(%)	**0.271**

B) Chlorophyceae

8.02% phytoplankton were found in monsoon(August) and 6.14% in the Chlorophyceae class with 3 genera. The contribution of *Chlorella* was 56.92%, *Oscillatoria* 14.32% and *Ulothrix*28.46% in Chlorophyceae class in monsoon period(August). The contribution of *Chlorella* was 66.07%, *Oscillatoria* 33.93% and *Ulothrix*0% in winter (January). The variation in Chlorophyceae between seasons were significant (<0.05) (Table-4).

C)Cyanophyceae

The percentage of Cyanophyceae in total phytoplankton was 1.17% in monsoon(August) and 0% in winter(January).Only *Anabaena* was found. The variation in Cynophyceae between seasons were significant (<0.05) (Table-4).

D) Dinophyceae

Only *Amphidinium* was found from Dinophyceae class . The contribution of dinophyceae in total phytoplankton was 2.28% in monsoon(August) and 0% in winter(January). The variation in Dinophyceae between seasons were not significant (>0.05)(Table-4).

E) Pyrrophyceae

The contribution of Pyrrophyceaein total phytoplankton was 17.22% in monsoon(August) and 18.42% in winter(January).Only *Cerratium*and *Protoperidinium* were found. The variation in Pyrrophyceae between seasons were not significant (>0.05) (Table-4).

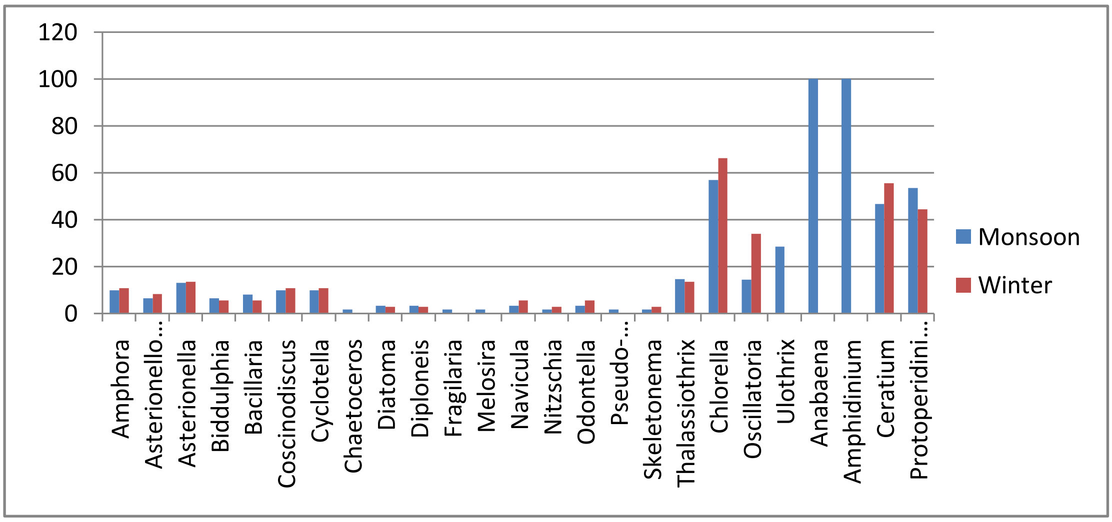

Figure-5: Seasonal distribution of different species of phytoplankton (%)

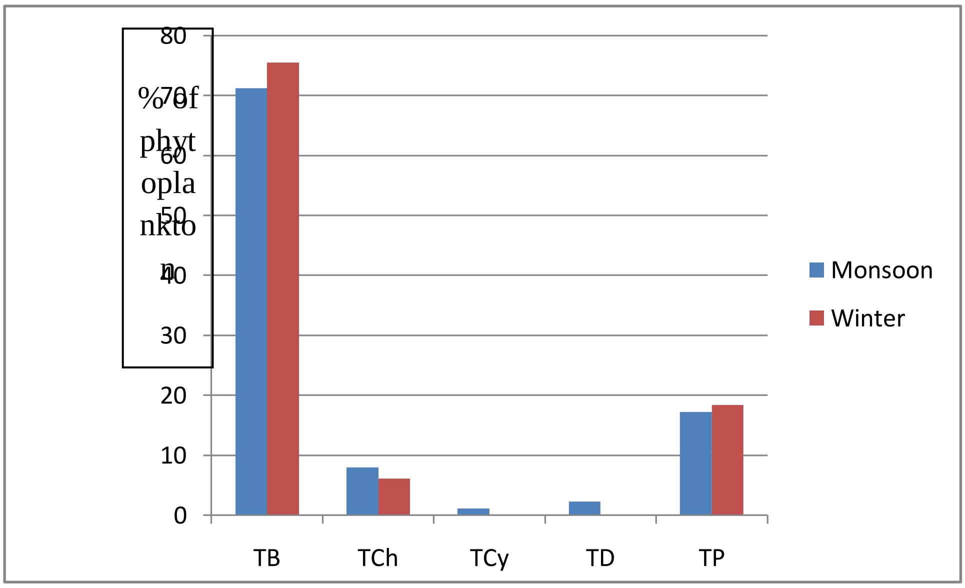

Figure-6 : Seasonal distribution of different classes of phytoplankton (%) (TB= Total Bacillariophyceae,TCh= Total ChlorophyceaeTCy= Total Cyanophyceae, TD= Total Dinophyceae, TP= Total Pyrrophyceae)

CHAPTER-5

DISCUSSION

Phytoplankton abundance indicates the productive status of a water body, because they are the primary source of food for most of the animals in an aquatic environment. Phytoplankton identification has been used as an important tool for environmental monitoring and received considerable attention in previous and ongoing researches. Seasonal variation in environmental parameters and plankton production shows that the favorable period for primary production in Teknaf is monsoon period when nutrients accumulate from freshwater run-off due to monsoon rainfall and due to more nutrient inflow in this time. Recent climate change has influenced worldwide phytoplankton productiontoo (Boyce *et al*.,2010).

In Teknaf, a large amount of agricultural pollutant components from different sources have led to nutrient enrichment which induced phytoplankton bloom. Higher primary production was found in different estuarine and coastal waters during monsoon period (Lugomela,1995). The rain cycle seems to be the key reason controlling the seasonality of plankton groups in Teknaf. 480 tons of solid wastes and 2.5 million people's excreta were being dumped into the Karnafully river estuary each year which directly entered into the Bay of Bengal (Nuruddin*et al*., 1994).

Seasonal variations of phytoplankton are related to the difference of environmental factors in aquatic habitats (Cetin andSen,2004). Water temperature is one of the most important physical factor that affects the seasonal distribution of phytoplankton (Mosisch*et al*., 1999). Water temperature strongly influences the seasonal variations of phytoplankton (Richardson *et al*.,2000). In the present study, maximum species diversity was found in monsoon period(August) which had the highest degree of temperature.Phytoplankton activity tends to increase in response to increase temperature (Urrutia*et.al*., 2006, O'Connor,2009) which is related to the result of present study.

The salinity distribution indicated that it varies from time to time, depending on the effect of freshwater influx and the diffusion of sea water. In the present study, salinity level was low in monsoon(August) but high in winter(January). It may be noted that low salinity condition occurred through mixing of freshwater with brackish water in monsoon period. Salinity or the resultant water column stratification also created short term phytoplankton difference (George *et al*.,2012).

Electric conductivity has relationship with salinity and TDS. EC largely depend on the amount of ions or charged particles found in water. In the present study, EC was found low in monsoon(August), but high in winter(January). It could be occurred by rainfall or rain runoff flowing into it. There is also a connection between EC and TDS. The measurement of TDS is estimated from EC assuming dissolved solids are predominantly ionic species of low enough concentration to yield a linear TDS-EC relationship.

In the present study, pH was found low in monsoon (August) than winter(January). It could be occurred by natural geological conditions at the site and the changes in river flows. It also could be attributed to removal of CO_2 by photosynthesis through bicarbonate degradation.

In the study area, alkalinity was found low in monsoon(August) and high in winter(January). This could be due to high water level with its attendant salt concentration and the higher value in winter due to low water levels. There is also a relationship between pH and alkalinity. Low pH indicated low alkalinity and high pH indicated high alkalinity.

TDS and TSS value were found low in monsoon (August) and high in winter (January). TDS And TSS could be influenced by the change in pH. The change in pH could cause some of the solutes to precipitate or affect the solubility of the suspended matter. TSS could be settled down in water.

Ammonia is a biologically active component found in most water as normal biological degradation product of organic nitrogen. It can be utilized directly as nutrients by several phytoplankton species. In the study area, ammonia value was high in monsoon (August) and low in winter (January). It could be occurred by sewage and fishing vessels disposal at the site. Directly polluted water by sewage or river discharge, the ammonia concentration become high.

Phytoplankton abundance and taxonomic diversity can be influenced by the supply of nutrients in natural water. In the present study, the highest species diversity of phytoplankton was found in monsoon, when NO_2-N concentration was found to be highest. Nitrite nitrogen was found in traces and also showed a seasonal distribution pattern. Nitrite-nitrogen is one of the essential nutrients for phytoplankton in the Oman sea. The effect of nitrogen on the seasonal variation of phytoplankton was also documented in lakes in Wuhan, China (Lv*et al*.,2011).

Phytoplankton variations are dependent on total nitrogen and phosphorus (Sakamoto,1966). In the present study, phosphate level is low in monsoon period(August) which could be attributed to the rapid removal of reactive phosphate from the water caused by the silt content associated with freshwater discharge. Low phosphate noted during monsoon might be due to sudden breaking monsoon and subsequent removal of phosphate from the water by the silt brought into the water by heavy rains and to the biological removal of it by plankton population. The effect of nitrogen on the seasonal variation of phytoplankton was also documented in lakes in Wuhan, China (LV *et al*.,2011).

In the monsoon(August), the silicate value was higher than winter(January) caused by the silt content associated with freshwater discharge.In winter, the silicate may be attributed to the decrease of silt present in water and the low population of plankton. Silicate can affect the phytoplankton distribution. Blooms of *Gymnodinium* and *Cochlodinium* appear to occur in waters with high silicate(Kwon *et al*.,2014; Al-Hashimi*et al*.,2014).

25 genera under 5 classes of phytoplankton were observed during monsoon period(August) and 18 genera under 3 classes were found during winter period(January). The most dominant group of phytoplankton was Bacillariophyceae in both season. 5 classes (Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae and Pyrrophyceae) were found in monsoon. But in winter, 3 classes (Bacillariophyceae, Chlorophyceae and Pyrrophyceae) were found. Small phytoplankton taxa like *Aserionella, Coscinodisus, Thalassiothrix, Chlorella, Oscillatoria, Ulotthrix, Protoperidinium,Ceratium* were found dominant in Teknaf during both seasons. In contrast, huge amount of *Coscinodiscus spp*. was found as dominant species in the water of Sepanggar Bay, on the west coast of Sabah (Sidik*et al*.,2008).

In the present study, the seasonal variation in phytoplankton may be controlled by the wide range of physico-chemical parameters such as temperature, salinity, nitrite-nitrogen, phosphate-phosphorus. Seasonal variations of phytoplankton are complicated due to interactions among physico-chemical factors (El-Gindy, Dorgham, 1992) and it is related with the present investigation. In addition maximum taxonomic diversity was found during monsoon period in the present study.

CHAPTER-6

CONCLUSION

Teknaf, Cox's Bazar is an important coastal area of Bangladesh. Phytoplankton communities may be used as an indicator of ecological status. The present investigation summarizes the seasonal fluctuations in physico-chemical parameters and phytoplankton diversity at Teknaf, Cox's Bazar. According to the results of the study, both monsoon and winter seasons significantly affect phytoplankton assemblages and cause variation in diversity in Teknaf, Cox's Bazar. Different physico-chemical properties of waters are subjected to change during monsoon and winter season. As a result of these changes, variation in phytoplankton diversity is observed in both seasons. Maximum classes of phytoplankton were found in monsoon period. Bacillariophyceae is the most diverse class in both season. Seasonal diversity of phytoplankton communities is essential for reflecting the resource supply in the ecosystem. The overall study gives a good outline of the seasonal dynamic relationship between phytoplankton and environmental parameters.

CHAPTER-7

RECOMMENDATION AND FUTURE PERSPECTIVES

Phytoplankton is an important indicator which help to know the status of a habitat. The present study gave information about seasonal variation of different physic chemical parameters and their relations with the seasonal distribution of phytoplankton. The study also gave us information about ecological status of Teknaf in different seasons. This is helpful for sustainable management and conservation of ecology in Teknaf, Cox's Bazar region.

However, present studies had some limitation. If there were more time the study could become more informative and more fruitful. There were also the limitations of proper vessels for sampling. The result of the present study might be used as a guideline for further study with more samples and more time. Finally following points might be considered.

a) Proper vessels for sampling should be considered. If it is possible, sampling should be done in research vessel.
b) More time and seasons for sampling should be considered.
c) Weather during sampling should be considered.
d) Proper safety should be maintained.
e) Finally proper sampling method and plan should be followed.

Continuing this type of research effort may help to know about the physico chemical parameters, their relation with phytoplankton and the ecology of Teknaf, Cox's Bazar.

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Appendix I

The values of different physicochemical factors during monsoon and winter period

Station	Season	WT	Salinity	Alkalinity	pH	EC	Chl-a	TDS	TSS	NH4	NO2-N	PO4-P	SiO3-Si
1	1	32	26	125	6.32	49.2	1.65	25.2	1.2	172	0.813	0.321	91.33
1	1	31.8	25.8	127	6.4	49.1	1.61	23.6	1.362	172	0.694	0.321	96.706
1	1	32.1	25.5	128	6.3	49.3	1.63	25.2	1.456	170	0.813	0.321	102.079
1	2	25.3	32	134	6.54	61	1.3	30.6	1.868	139	0.258	1.332	85.961
1	2	25.2	33	133	6.52	61.3	1.32	30.4	1.058	140	0.139	1.24	64.471
1	2	25	33	136	6.5	60.9	1.3	30.5	1.284	141	0.754	1.516	107.452

Appendix II

Seasonal abundance of phytoplankton (Cells/L) in Teknaf, Cox's Bazar, recorded during monsoon and winter period

Phytoplankton	**Season-1(Monsoon)(Cells/L)**	**Season-2(Winter)(Cells/L)**
Amphora	112	74
Asterionellopsis	74	56
Asterionella	149	93
Biddulphia	74	37
Bacillaria	93	37
Coscinodiscus	112	74
Cyclotella	112	74
Chaetoceros	19	0
Diatoma	37	19
Diploneis	37	19
Fragilaria	19	0
Melosira	19	0
Navicula	37	37
Nitzschia	19	19
Odontella	37	37
Pseudo-nitzschia	19	0
Skeletonema	19	19
Thalassiothrix	168	93
Total Bacillariophyceae	**1155**	**689**
Chlorella	74	37
Oscillatoria	19	19
Ulothrix	37	0
Total Chlorophyceae	**130**	**56**
Anabaena	19	0
Total Cyanophyceae	**19**	**0**
Amphidinium	37	0
Total Dinophyceae	**37**	**0**
Ceratium	130	93
Protoperidinium	149	74
Total Pyrrophyceae	**279**	**168**
Total Phytoplankton	**1620**	**912**

Appendix III

Some observed phytoplankton under microscope

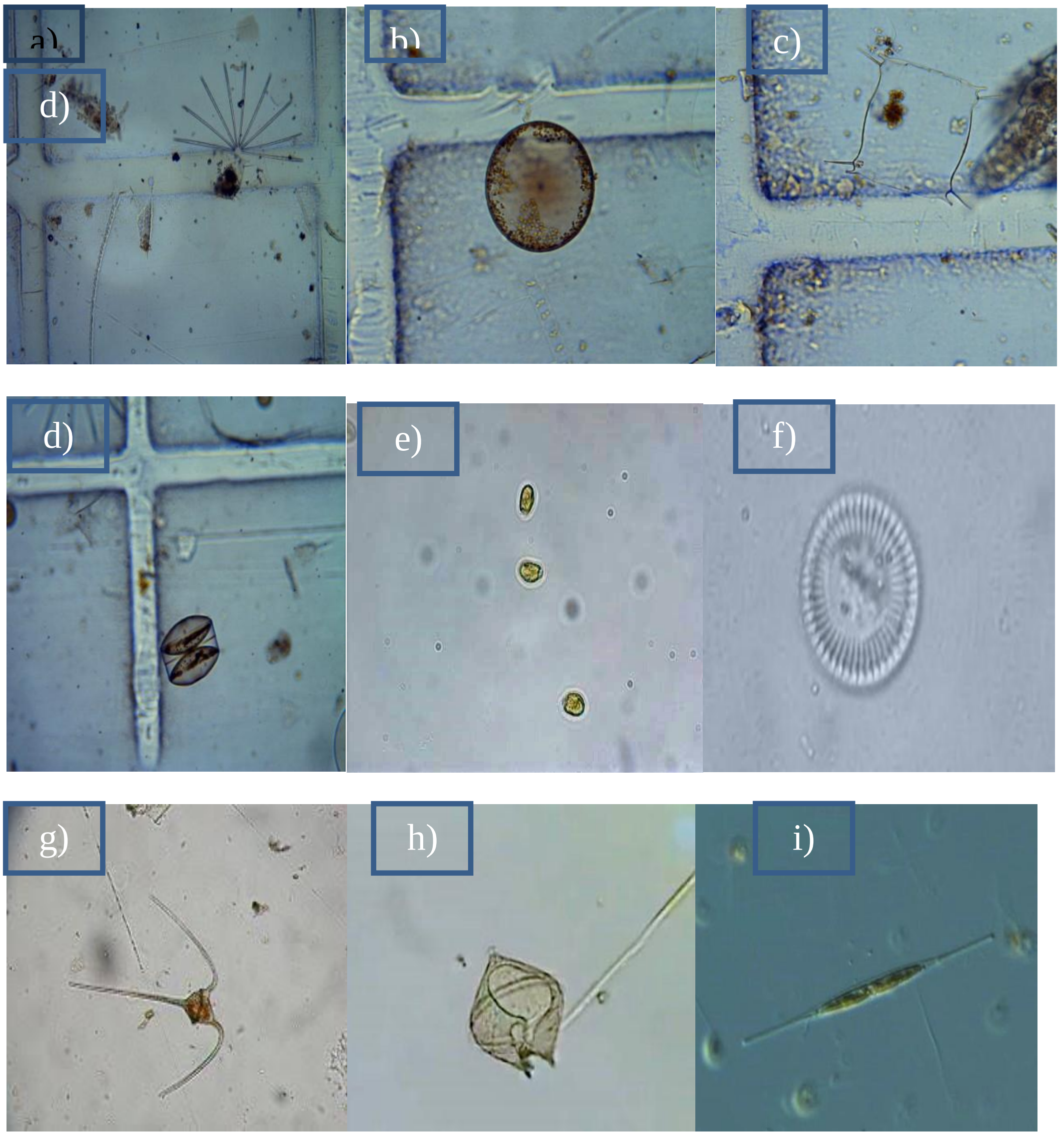

Figure- 7: Microscopic images of some species of phytoplankton; a)*Thalassiothrix,* *b) Coscinodiscus, c) Biddulphia, d) Amphora, e) Amphidinium, f) Cyclotella, g)Ceratium, h) Protoperidinium, i)Nitzschia*

Appendix IV

Some picture of laboratory work

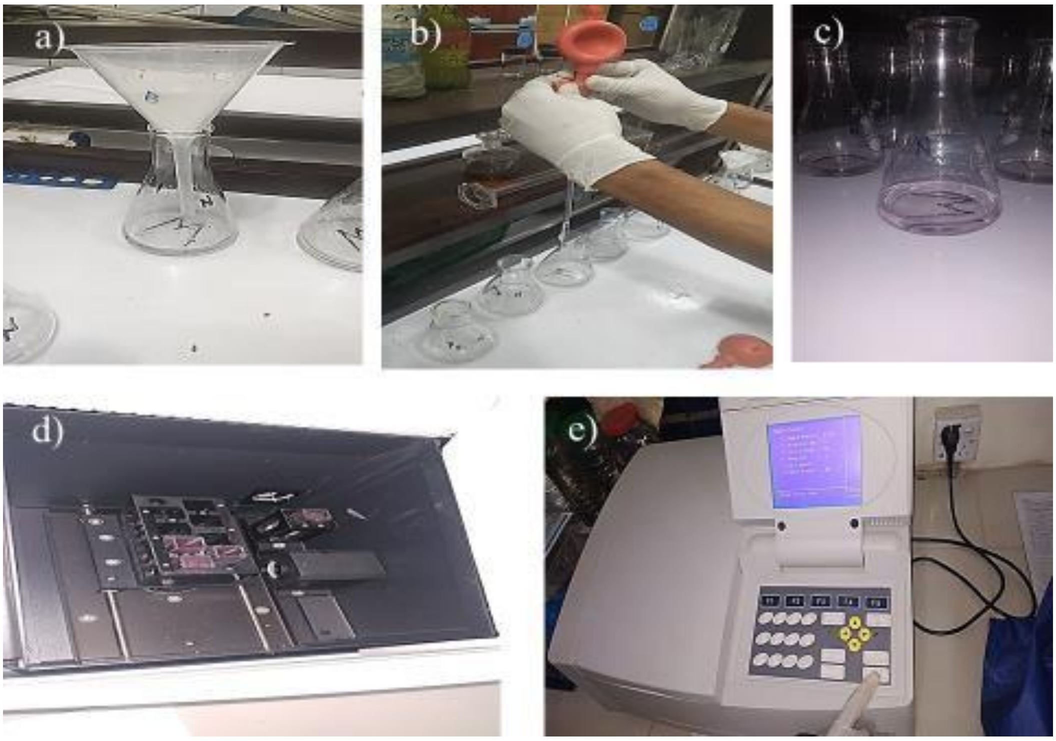

Figure-8: Determination of nitrite; a) Filtration of sample, b) Adding chemicals, d) Reaction, d) Insertion of vial, e) Photpmetric measurement

Figure-9 **:**Ammonia determination of sample; a) and b) Required reagents c) Adding reagents, d) Ongoing reaction, e) Inseting vial, f) Ammonia analysis

Figure-10 **:** Determination of phosphate; a) filtration of sample, b) Required chemicals, c) Adding chemicals, d) Reaction, e) Insertion of vial, f) Photometric measurement

Figure-11: Phytoplankton observation; a) Sedgewick-rafter cell, b) Observation and counting

Appendix V

Some pictures of field work

Figure-12: Phytoplankton sample collection by using plankton net

BIOGRAPHY

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