LIMNOLOGICAL ASPECTS OF ATRAI RIVER IN DINAJPUR, BANGLADESH

A THESIS

BY

TARIKUL HAQUE SARDER

Examination Roll No.: 1605199

Registration No.: 1605199

Session: 2016-2017

Semester: January-June, 2017

MASTER OF SCIENCE
IN
FISHERIES MANAGEMENT

DEPARTMENT OF FISHERIES MANAGEMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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Submitted to the
Department of Fisheries Management
In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
FISHERIES MANAGEMENT

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June 2017

DEDICATED

TO MY

BELOVED PARENTS,

ELDER BROTHER

AND

AFFECTIONATE

NEPHEW AL RAFI

DECLARATION

I declare that this MS thesis entitled **LIMNOLOGICAL ASPECTS OF ATRAI RIVER IN DINAJPUR, BANGLADESH**, which I submit to Department of Fisheries Management was carried out by me for the degree of Masters in Fisheries management under the guidance and supervision of Professor Dr. Zannatul Ferdoushi, Department of Fisheries Management, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

Furthermore, I took reasonable care to ensure that the work is original, and has not been taken from other sources except where such work has been cited and acknowledged within the text.

The Author

ACKNOWLEDGEMENTS

All the praises are belongs to the almighty Allah, the merciful, the beneficent, who enabled the author to complete as well as to submit the thesis for the degree of Master of Science (M.S.) in Fisheries Management.

The author feels proud to express his deepest sense of gratitude, sincere appreciation, profound respect, immense indebtedness and endless regards to his honorable teacher, research supervisor and Department Chairman, ***Professor Dr. Zannatul Ferdoushi****, Department of Fisheries Management, Faculty of Fisheries, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur for her sincere and scholastic guidance, valuable suggestions, sympathetic supervision and constant encouragement during the entire period of research work and preparation of this thesis.*

The author is ever grateful and immensely indebted to his honorable and respected teacher and research co-supervisor, ***Dr. Md. Afzal Hossain****, Associate Professor ,Department of Fisheries Management, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur for his constructive suggestions, providing certain facilities and continuous inspiration throughout the whole study period.*

The author feels a great pleasure to express his gratitude and regards to his all honorable teachers of the Department of Fisheries Management, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur for their innovative suggestion and heartfelt cooperation during the study period.

The author also grateful to the University Grants Commission (UGC), Bangladesh authority through Institute of Research and Training (IRT) for providing financial support in materializing this study.

The author also extends thanks to laboratory personnel and all staffs of Department of Fisheries Management, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur for their help and friendly behavior.

The author expresses his cordial thanks to Md. Harun-Or-Rashid, Sitara-E-Jahan, Komol Chandra Roy and other labmates, M.S. students, Department of Fisheries Management, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur for their friendly inspiration and help during this study.

Most sincere appreciation is also due to the author's parents, and elder brother and other family members for their endless patience, support, sacrifice and encouragement during the study.

The Author

ABSTRACT

Plankton functions the key role by transferring the food energy to higher trophic level in the ecosystem and often influenced by the environmental variability in inland waterbodies. A study was carried out to investigate plankton diversity and associated physico-chemical parameters of Atrai river from Dinajpur district in Bangladesh. Fortnight water sampling was performed at three sites namely Poromeshpur, Rubber dam and Mohonpur from Atrai river during July 2016 - February 2017. Collected samples were analyzed in the laboratory of Department of Fisheries Management, Faculty of Fisheries, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur. Shannon-Wiener index and Evenness index were used to calculate the diversity indices of plankton. ANOVA showed a significant variation ($P < 0.05$) in physico-chemical parameters among the sites. Mean value (±SD) of water temperature, pH and DO were 25.52±4.63^{0}C, 25.19±4.63^{0}C and 25.89±4.62^{0}C; 7.64±0.31, 7.81±0.31 and 7.47±0.35 and 7. 7.45±0.96, 7.91±0.98 and 7.06±1.06 mg/l in site 1, 2 and 3 respectively. Higher dissolved oxygen concentration was observed in site 1 while, pH was significantly variable among the sites during the study period. Moreover, there were significant variations in plankton abundance among the sites in Atrai river. However, the abundance of copepod and crustacean larvae did not show significant variation among the sites. A total of 57 genera of plankton were identified composed of 43 genera of phytoplankton and 14 genera of zooplankton. The abundance of chlorophyceae was higher (13.5×10^3 cells/l) followed by cyanophyceae (5.40×10^3 cells/l) at site 1 in January 2017. Total zooplankton found higher at site 1 in January 2017. Comparatively lower abundance of plankton (10.88×10^3 cells/l) was observed at site 3 in July 2016. Phytoplankton showed a Shannon-Wiener index value between 2.503 and 3.520 where, the Evenness index was from 0.884 to 0.941. In case of zooplankton Shannon-Wiener index showed the value from 1.468 to 2.295 and Evenness index value was 0.898-0.966. Overall, the diversity of plankton indicates variable biological productivity in the Atrai river of Dinajpur.

Keywords: Water quality, Plankton diversity, Atrai river.

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LIST OF ABBREVIATIONS

^{0}C	=	Degree centigrade
ANOVA	=	Analysis of Variance
APHA	=	American Public Health Association
BWDB	=	Bangladesh Water Development Board
$CaCO_3$	=	Calcium Carbonate
cm	=	centimeter
DO	=	Dissolved Oxygen
DOE	=	Department of Environment
DoF	=	Department of Fisheries
FAO	=	Food and Agriculture Organization of the United Nations
GDP	=	Gross Domestic Product
HSTU	=	Hajee Mohammad Danesh Science and Technology University
m	=	meter
mg/l	=	milligram per liter
ml	=	milliter
mm	=	milimeter
NTU	=	Nephelometric Turbidity Unit
pH	=	Hydrogen ion concentration
SD	=	Standard Deviation
SPSS	=	Statistical Package for Social science
S-R cell	=	Sedgwick-Rafter cell
UNEP	=	United Nations Environment Programme.
USGS	=	United States Geological Survey
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Bangladesh is located in the delta of the Ganges-Brahmaputra-Meghna river system. The country is traversed by a vast network, approximately 24 thousand kilometers of huge rivers with their tributaries and distributaries, mountain streams, winding seasonal creeks and canals. Moreover, a wide portion of land of Bangladesh is covered by large rivers such as the Padma, the Jamuna, the Teesta, the Meghna, the Brahmaputra and the Surma river. There are 405 rivers lying across the country, of which 57 are trans-boundary. All of these rivers are connected to the Bay of Bengal. The total area of inland water is about 39, 07,488 hectares of which the area of river and estuaries is about 85, 38, 63 hectares.

Fish and fisheries of those waterbody are integral part of social and national life of the people and playing a vital role in national economy of Bangladesh. It has become an important sector that contributes a significant role in the economy in terms of nutrition, revenue, employment generation and earning foreign currency in Bangladesh. About 17.80 million people approximately 11% of total population involved in fishing activities for their livelihood (DoF 2015). Along with male, 8.50% of women are involved in the fishing and fisheries activities (DoF 2015). This sector also contributing the major portion of the demand of protein. The aquatic biomass, fishing and aquaculture industries play a significant role in contributing fish protein to a large population of Bangladesh, many of whom suffer from chronic malnutrition (Ravenholt 1982). It is estimated that fisheries sector contributes about 60% of animal protein to the common people in Bangladesh (DoF 2015).

However, it is estimated that 40 % of the world population will live in water scarce regions by the year 2025 (UNEP 2004). Moreover, due to rapid growth of population and expansion of agricultural irrigation, domestic and industrial activities and municipal waste, an imbalanced heavy pressure has been put on the fishery resources of the river over the decades (Jhingran 1991). Nevertheless, unlike standing waters, primary production can be remarkably low in rivers. Again lack of proper management policy, over-exploitation and unplanned establishment of flood control and drainage projects (FCD) and flood control, drainage and irrigation projects (FCDI) are also responsible for the degradation of the natural resources. Thus, production of fish is decreasing from the capture fishery. In the year of 1963, total fish production from capture fishery of inland water was 89.2 % (DoF 1963), while in 2015 the production declined by 27.79% (DoF 2015).

In general aspects, productivity of a waterbody depends on the availability of presences of natural food item mainly, phytoplankton and zooplankton in the area. The state of productivity of any waterbody is determined by the amount of plankton it contains as they are major primary producers (Davies *et al.* 2009). In addition, the physical and chemical characteristics of water are important parameters as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Swingle 1969).

All plankton ecosystems are driven by the input of solar energy, confining primary production to surface waters and to geographical regions and seasons having abundant light. Plankton is an important food item of fishes and indicator for the productivity of a waterbody. Plankton (singular plankter) are a diverse group of organisms that live in the water column of large bodies of water and that cannot swim against a current. The name plankton is adopted from the Greek adjective (planktos), which means errant and by extension wanderer or drifter (Thurman 1997).

Plankton perform a significant role in the food chain of fishes (Chowdhury *et al*. 2007). They provide a crucial source of food to many large aquatic organisms and fish. Contribution of some organism is high and some are low. But contribution of no organism is negligible. Phytoplankton is the major contributor in the aquatic food web providing food for zooplankton. Local abundance of plankton varies horizontally, vertically and seasonally. The primary cause of this variability is also varied with the availability of temperature (Annalakshmi and Amsath 2012).

Phytoplankton serves as the base of the aquatic food web, providing an essential ecological function for all aquatic life. Like land plants, phytoplankton have chlorophyll to capture sunlight and they use photosynthesis to turn it into chemical energy. They consume carbon dioxide and release oxygen. All phytoplankton photosynthesize, but some get additional energy by consuming other organisms. In terms of numbers, the most important groups of phytoplankton include the diatoms, cyanobacteria and dinoflagellates, although many other groups of algae. Primary productivity by phytoplankton comprises trapping of radiant energy and its transformation into high potential biochemical energy by photosynthesis, using inorganic materials of low potential energy in fresh water ecosystem (Misra *et al.*2008).

The distributions, abundance, species diversity and species composition of the phytoplankton are used to assess the biological integrity of the water body (Townsend *et al.* 2000). Phytoplankton communities are major producers of organic carbon in large rivers, a food source for planktonic consumers and may represent the primary oxygen source in low-gradient rivers. Phytoplanktons are of great importance in bio-monitoring of pollution (Davies *et al.* 2009). Phytoplankton also reflects the nutrient status of the environment. They do not have control over their movements, thus they cannot escape pollution in the environment. In the aquatic ecosystem, the phytoplankton are the foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shellfish and finfish (Emmanuel and Onyema 2007).

The growth and existence of different groups of plankton vary from season to season. Certain species becomes dominant at a certain period of time, after this they disappear and another group comes to take their place which called succession. In a water body, there is a seasonal progression in the plankton, such that first one species is dominant and then another, at rather frequent intervals during the year. Certain plankton populations apparently disappear at specific periods and reappear during others. Such temporary disappearances are due to the fact that the species concerned either become too scarce or occur as spores. Some researcher recommended that the maximum development of phytoplankton take place during summer and minimum in winter (Anjana and Kanhera 1980; Philipose 1960). In smaller river there is generally a complicated succession of maxima and minima throughout the year.

The relationship between the physico-chemical parameters and plankton production of a waterbodies are of great importance in aquatic ecosystem. Size, structure and biomass of phytoplankton population and production are closely related to physico-chemical conditions of the water body (Mitchell-Innes and Pitcher 1992). The existence of various littoral and floodplain habitats, along with various recruitment processes, may explain the high taxonomic diversity recorded in the river and the dynamics of the main phytoplankton groups depend primarily on physical factors (Descy *et al.* 2012).

Study of water quality parameters is a basic tool that plays a vital role in making up of the ecosystems and determine the tropic dynamics of the water body. The change in water quality tends to change the living conditions especially in the number, diversity and distribution of the living organism of the ecosystem (Sharma and Singh 2013). The physico-chemical factors and nutrient status of water play the important role in governing the production of planktonic biomass.

Considering the importance of the planktonic community and the relationship between the abundance of plankton with the physico-chemical factors of a waterbody, several studies had been conducted in different part of Bangladesh. A number of experiments in many river of Dinajpur district were also studied by some researchers. As for example, Rakiba and Ferdoushi (2013) worked on physico-chemical properties of Dhepa river in Dinajpur district of Bangladesh. Ara (2015) studied on seasonal planktonic distribution of Dhepa river. Study on Atrai river was also performed by some investigators. For example Quader (1995) studied the stage-discharge relationship of Atrai river at four sampling points Panchagarh, Bushirbandar, Mohadebpur and Atrai. Ahmed *et al.* (2013) conducted a case study giving priority on the river water quality parameters of Atrai river in Naogaon. Manon and Hossain (2011) carried out a research on ecology of *Cyprinus carpio* var. *specularis* in Atrai river of Naogaon. Chaki *et al.* (2014) investigated the environment and fish fauna of the Atrai river and the status of fish diversity and the correlation of the fish with some physico-chemical parameters in Atrai Upazilla (sub-district) of Naogaon district. However, the diversity indices and effects of different physico-chemical parameters on planktonic community were not focused by them.

Due to insufficient data about the planktonic community with the diversity indices and considering the importance of water quality parameters the present study was undertaken with the following specific objectives to fulfill the experimental goal. On the other hand, the findings of this research will provide some valuable information about biological productivity of Atrai river in Dinajpur which could help in formation of some future policy to protect the environment from degradation and for sustainable livelihood of the local fisherman.

- Observation of some physical and chemical parameters of the Atrai river water
- Study on plankton communities in the Atrai river
- Determination of plankton diversity indices
- Exploration on the effects of different parameters on plankton abundance

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with literature review on physico-chemical and plankton communities of river, conducted by different researchers in Bangladesh as well as some other works conducted in abroad. Efforts have been given to collect and summarized review of different study related to the topics.

2.1 Water Quality

2.1.1 Physical parameters

2.1.1.1 Water Temperature

Temperature is defined as the degree of hotness or coldness in the body of a living organism either in water or on land (Lucinda and Martin 1999). Most lotic species are poikilotherms whose internal temperature varies with their environment, thus temperature is a key abiotic factor for them. Water can be heated or cooled through radiation at the surface and conduction to or from the air and surrounding substrate. Some works related to temperature are cited below:

Ahmed *et al.* (2015) observed the impact on aquatic environment for water pollution in the Vahirab river. They observed the highest value of temperature (31.5^0C) was during the month of August and September and whereas the lowest temperature (28^0C) was in October.

Abroampah *et al.* (2015) showed the impact of sofokrom quarry on river Anankwari in Ghana. They stated that the mean water temperature of Anankwari river proved that the downstream water sample recorded the highest mean water temperature values in river Anankwari. The water temperatures of the upstream site was in the range of 25.2^0C – 25.5^0C whereas, the downstream water temperature recorded an average range of 26.5^0C - 29.5^0C.

Ekwu and Udo (2014) investigated the water temperature in Ikpa river, South east of Nigeria. They found that water temperature was between 23.9^0C -32.5^0C.

Meme *et al.* (2014) analyzed physical and chemical parameters Oinyi river, Kogi State, Nigeria. They recorded temperature of within a range from 24^0C to 27^0C. During the study, highest value of water temperature was 27^0C in upstream region of the river.

Jackson *et al.* (2013) assessed the upstream and downstream water qualities of river Tano in Ghana. They found higher average temperatures in the upstream than downstream. In the upstream, water temperature was between 23.8^0C to 27.1^0C where, it was between 24.8^0C to 26^0C in downstream.

Al-Badaii *et al.* (2013) conducted a research on water quality assessment of the Semenyih river, Selangor, Malaysia. They noticed that the temperature was increased progressively from upstream to downstream. A statistically significant differences was found between stations. Highest value of temperature recorded in downstream site during rainy season and dry season was 27.36^0C and 27.55^0C respectively.

Mahazar *et al.* (2013) performed a research on monitoring urban river water quality using macro-invertebrate and physico-chemical parameters: case study of penchala river, Malaysia. They found that water temperature increase, as it goes down from the upstream to downstream.

Sunkad (2013) conducted an experiment on water quality of Malaprabha river with reference to physico-chemical factors near Khanapur town of Belgaum district in India. He found that water temperature was ranged from 22^0C to 31^0C.

Rahman and Huda (2012) observed that the average water temperature of Padma river in Bangladesh was 27.5^0C during their study on the seasonal variations in physicochemical and biological aspects of the Padma river at Paturia Ghat, Manikganj.

Manon and Hossain (2011) conducted a study on ecology of *Cyprinus carpio var. specularis* (physico-chemical conditions of the habitat) on Atrai river of Naogaon district. They found that the average water temperature was 26.39^0C.

Jafari and Alavi (2010) carried out a research on physico-chemical characteristics of the Talar river, Iran polluted by industrial effluents and domestic sewage. They observed that the water temperature was highest in the month of July (29.7^0C) and lowest in January (10.10^0C).

Kamal *et al.* (2007) carried out a research on the study on the physico-chemical properties of water of Mouri river, Khulna, Bangladesh. They observed that the water temperature was between 21.6^0C and 32.2^0C.

Dhakal (2006) discussed the physico-chemical parameters and benthic macroinvertibrates of Balkhu Khola in Kathmandu Valley in Nepal. She found that water temperature was maximum (25.5^0C) in the month of July at downstream and minimum (18^0C) was in the month of February at upstream.

Bhouyain *et al.* (1988) investigated the effects of domestic and factory waste on some water quality characteristics of Karnafully river estuary of Bangladesh. They stated that average temperature varied from 22.85^0C-31.25^0C and with increasing water temperature, dissolved oxygen concentration found to decrease.

2.1.1.2 Transparency

Transparency is a measurement of the suspended particulate matter in a water body which interferes with the passage of a beam of light through the water. Materials that contribute to turbidity are silt, clay, organic material or microorganisms. Transparency is important because it can influence biological communities such as submerged aquatic vegetation and algae and affect their ability to photosynthesize. Some works related to transparency are cited below:

Charles (2016) conducted a research comparative limnological studies of nnamdi azikiwe university (Unizik) and Amansea Streams in Awka South L.G.A., Anambra State, Nigeria. Secchi disk transparency of Unizik stream was between 36.22cm to 57.00 cm. Highest transparency value was in the upstream with 57.00 cm and lower in 36.22 cm. In the Amansea stream the range of transparency was between 30.01 cm to 39.10 cm.

Abroampah *et al.* (2015) showed the impact of Sofokrom quarry on river Anankwari in Ghana. They found that the turbidity for the water from the respective locations indicated that the downstream untreated water recorded the highest mean values than upstream. Data indicated that the downstream untreated water recorded the highest mean values of 7.90, 16.62 and 6.66 against upstream of mean values of 7.45, 12.83, and 5.26 during the three months period.

Fayissa (2015) investigated the biomass and photosynthetic productivity of phytoplankton in lake Kuriftu, Ethiopia. He observed that the lakes transparency was always less than 0.6 m with smaller values coincident with periods of rainfall and negatively correlated with phytoplankton biomass.

Al-Badaii *et al.* (2013) assessed the water quality of the Semenyih river in Malaysia. They observed that turbidity values varied between 8 and 46 NTU (Nephelometric Turbidity Unit). Highest turbidity was recorded 46 NTU (Nephelometric Turbidity Unit) in the downstream while, the lowest value was 8 NTU (Nephelometric Turbidity Unit) recorded in the upstream.

Rakiba and Ferdoushi (2013) recorded the transparency of Dhepa river in Dinajpur district of Bangladesh. They found that the transparency value of Dhepa river was between 8.10cm to 48.70cm.

Manon and Hossain (2011) conducted a research work on ecology of *Cyprinus carpio* var. *specularis* (physico-chemical conditions of the habitat) of Atrai river in Naogaon. They stated that the average transparency of Atrai river in Naogaon district was 57.25cm.

Razak *et al.* (2009) recorded turbidity values and found that turbidity were higher in upstream than down-stream during their study on the assessment of the water quality of the Oti river in Ghana. Turbidity values ranged from a minimum of 9.62 NTU (Nephelometric Turbidity Unit) in May to a maximum of 31.90 NTU (Nephelometric Turbidity Unit)in December. This is because most of the anthropogenic activities take place between upstream and downstream.

Olele and Ekelemu (2008) studied the physico-chemical and periphyton/phytoplankton study of Onah lake, Asaba, Nigeria. They noticed that mean transparency value at the three sampling streams was 32.33cm, 36.79 cm and 38.3 cm respectively.

Kamal *et al.* (2007) carried out a research on physico-chemical properties of water of Mouri river, Khulna, Bangladesh. They observed that the transparency was ranged between 15 and 66 cm.

2.1.1.3 Water level

Water level determines the temperature, circulation pattern of water and the extent of photosynthetic activity. If depth of water body is very low then more sunlight will penetrate in water. As a result, water temperature will be extremely high which is very harmful for primary producers. On the other hand if the depth of water body is very high then sunlight cannot penetrate into deeper region of water and causes the decrease in biological production. Some works related to water level are cited below:

Charles (2016) conducted a research on comparative limnological studies of Nnamdi Azikiwe University (unizik) and Amansea streams in awka south L.G.A., Anambra state, Nigeria. The water level in the stream was ranged between 0.54m and 0.63m. The lowest water level was recorded at in the downstream and the highest water level was recorded in the midstream.

Ekwu and Udo (2014) carried out an experiment on plankton community of Ikpa river, South east Nigeria. They noticed that water level was between 7.51-15.2m with the highest water level during the wet season.

Meme *et al.* (2014) measured the water level of Oinyi river nearby a cement factory in north central, Nigeria. During their study on analyses of physical and chemical parameters in surface waters nearby a cement factory in north central, Nigeria. The water level of the river during the sampling period was between 0.23 and 0.35 m.

Joadder (2012) observed the ecological aspects of a beel Joshi in the Rajshahi district. He noticed that the water level fluctuate between 0.3 and 2.29 m. The highest water level was recorded in the month of September where the lowest was in May.

Singh *et al.* (2010) monitored the physico-chemical properties of water samples from Manipur river system in India. The mean water level in the two sampling sites of Iril river were 0.23-1.36m and 0.30-1.65m.

2.1.2 Chemical parameters

Dissolved oxygen

Dissolved oxygen (DO) is a basic requirement for a healthy aquatic ecosystem. Most fish and aquatic insects "breathe" oxygen dissolved in the water column. The amount of oxygen available for aquatic life depends on the factors that affect how it dissolves in water. Mixing of water allows exchanges of oxygen with the air.

Ahmed *et al.* (2015) recorded dissolved oxygen in different months were 1.22 mg/l to 5.51 mg/l during their study on the impact on aquatic environment for water pollution in the Vahirab river.

Meme *et al.* (2014) assessed the physical and chemical parameters of in water course of Oinyi river, Kogi State, Nigeria. They showed that dissolved oxygen was between 6.02

mg/l and 7.01 mg/l with a highest value in station 1 having agricultural activities including fishing and other human activities include laundry works and bathing.

Al-Badaii *et al.* (2013) measure the dissolved oxygen of the Semenyih river in Malaysia while assessing water quality of the river. They stated that the maximum value of dissolved oxygen during rainy season and dry season was 7.07 mg/l and 7.44 mg/l respectively in upstream. Minimum value of dissolved oxygen in rainy season and dry season was 5.58 mg/l and 4.13 mg/l respectively in downstream.

Teshita and Wondie (2012) carried out a study on the impact of impoundment on downstream macro-invertebrate communities at Koga irrigation dam, West Gojam, Ethiopia. The mean dissolved oxygen concentration during the sampling period ranged from 8. 48 - 8. 76 mg/l. There was no significant difference in dissolved oxygen between reference and impaired sites.

Rahman and Huda (2012) measured dissolved oxygen concentration during their study on the seasonal variations in physicochemical and biological aspects of the Padma river at Paturia Ghat, Manikganj, Bangladesh. They found the average dissolved oxygen concentration was 7.79 mg/l.

Razak *et al.* (2009) measured dissolved oxygen values at Oti river in Ghana was ranged from a minimum of 7.90 mg/l in February and May to a maximum of 8.90 mg/l in December and February.

Dhakal (2006) observed that dissolved oxygen concentration was found high in July and it showed the decreasing trend till February in all sampling sites in Balkhu Khola of central Nepal. It was recorded less at downstream than at upstream part of the stream. Lowest DO value was 2.02 mg/l where highest value was 6 mg/l.

pH

pH is a measure of hydrogen ion concentration in water that is acidic, basic or neutral. It has direct effects on fish growth and survival of food organisms. Hence, to achieve good fish production pH of the water should be monitored regularly to ensure its optimum range of 6.5-8.5 (Banerjea 1967).

Islam *et al.* (2015) carried out an experiment on alteration of water pollution level with the seasonal changes in mean daily discharge in three main rivers Shitalakkhya, Buriganga and Turag river around Dhaka City, Bangladesh. They found that the average pH values in the three rivers ranged from 6.5 to 9.8 throughout the year.

Abroampah *et al.* (2015) measured the highest values of pH at downstream for the water samples for the entire period than the upstream during their study on the impact of sofokrom quarry on river Anankwari in Ghana. Recorded value of pH within the three month period were 7.80, 6.60 and 6.80 for up streams and 9.20, 8.9 and 9.9 for down streams respectively.

Ekwu and Udo (2014) found the pH value of Ikpa river water in Nigeria was between 6.5 and 9.8. They performed their research on plankton community of Ikpa river, South east of Nigeria.

Meme *et al.* (2014) analyzed the physical and chemical parameters in water course of Oinyi river, Kogi State, Nigeria. They showed that pH value was between 6.8 and 7.26. Highest value of pH 7.26 was found in that point having agricultural activities including fishing and other human activities include laundry works and bathing.

Nagarsekar and Kakde (2014) studied on physico-chemical parameters of Mithi river water in Mumbai metropolis. They found the average concentration levels at each of the four sampling point's S1, S2, S3 and S4 in the post monsoon season were 7.42, 7.35, 7.27 & 8.04. In the pre-monsoon season the values at S1, S2, S3 and S4 were 6.18, 6.26, 6.57 & 7.63 respectively. In the monsoon season the values were 7.25, 7.05, 7.08 and 7.62 at the four sampling stations.

Jackson *et al.* (2013) recorded pH during their research on comparative assessment of the upstream and downstream water qualities of river Tano in Ghana. They noticed that downstream values were generally higher than upstream in all the sampling periods. pH value in the upstream was between 6.34 and 7.43 where it was 6.82 to 8.31 in downstream.

Al-Badaii *et al.* (2013) recorded the highest pH at the upstream with a value of 8.4, whereas the lowest value was obtained at the downstream with the value of 7.07 in the dry season. They assessed the water quality of the Semenyih river, Selangor, Malaysia.

Teshita and Wondie (2012) showed the impact of impoundment on downstream macro-invertebrate communities at Koga Irrigation Dam, West Gojam, Ethiopia. The mean pH concentration along the Koga riverine system was ranged from 7. 06-7. 15.

Razak *et al.(*2009) noticed the variations of pH among the sampling months and along the course of the Oti river in Ghana (between upstream and downstream) were statistically insignificant at the 5% level Downstream values were lower than upstream values in all the sampling periods. The pH for the water samples ranged from a minimum of 7.87 in February to a maximum of 8.29 in December and May.

Dhakal (2006) recorded pH at Balkhu Khola at Kathmandu Valley in Nepal. The recorded value of pH was ranged from 7.9 to 8.6 at upstream and 8.5 to 9.5 at downstream.

Alkalinity

Alkalinity is a total measure of the substances in water that have "acid-neutralizing" ability. It is important characteristics of water that affect its suitability for biota and influence chemical reactions.

Joadder (2012) found that total alkalinity of beel Joshi in Rajshahi district to be varied from 12.0 mg/l to 34.9 mg/l. The highest and lowest value were recorded in January and June, respectively.

Jafari and Alavi (2010) showed a definite trend in seasonal fluctuation of total alkalinity to be varied from 52.36 mg/l to 98.12 mg/l in Talar river of Iran.

Olele and Ekelemu (2008) performed the physico-chemical and periphyton/ phytoplankton study of Onah lake, Asaba, Nigeria. They recorded the alkalinity value 24.0 mg/l, 26.30 mg/l and 28.59 mg/l in the three sampling sites.

Dhakal (2006) measured the alkalinity between 1.2 to 3.8 mg/l at upstream and 1.8 to 4.2 mg/l at downstream course of stream. Highest value was recorded in February and the minimum was recorded in September.

Mairs (1996) stated that waterbodies having alkalinity 40.0 mg/l more productive than waterbodies of lower alkalinity during the study conducted on a total alkalinity atlas for Maine lake waters.

2.1.3 Biological parameters

2.1.3.1 Plankton population

In natural waterbodies like oceans, lakes, rivers and swamps, the highest amount of biological production is due to the smallest organisms, named plankton. Quantity and quality of phytoplankton is a good indicator of water quality. High relative abundance of chlorophyta is an indicator of productive water (Ali *et al.* 2003). The good river system can be determined by its plankton composition that gives more information if there is any changes in water quality. Plankton studies and monitoring are valuable to control the physico-chemical and biological conditions of the water.

Belkhode and Sitre (2016) examined phytoplankton diversity of Dham river in wardha district of Maharashtra state, India. They found that there were 36 different species of phytoplankton of which 16 represented by chlorophyceae, while minimum only one was represented by euglenophyceae, desmidaceae and hydrocharitaceae.

Sharma *et al.* (2016) conducted a research work on the influence of physico-chemical parameters on phytoplankton distribution at Baldi river in India. They recorded 34 species of phytoplankton representing three major group bacillariophyceae, chlorophyceae and cyanophyceae. Maximum density was recorded during the winter months of the year (January-February) and lowest was during monsoon month (July-August). Zooplanktons were reported to be maximum (147 unit/l) during summer and minimum (3 unit/l) during monsoon. Green algae and blue green algae were reported to be maximum during winter and minimum during summer.

Nyakweba and Migiro (2014) found a total of 31 genera of phytoplankton from three sampling stations. Among the identified phytoplankton, 13 genera were of class chlorophyceae, 9 genera were from class of cyanophyceae, 6 genera from class of bacillariophyceae, 2 genera of class euglenophyceae and 1 genus of class dinophyceae.

Sarwade and Kamble (2014) worked on Plankton diversity in Krishna river, Sangli, Maharashtra in India. They stated that Phytoplankton diversity was observed in five groups, that is, cyanophyceae, bacillariophyceae, chlorophyceae, hydrocharitaceae and desmidiceae including 53 species. Among them, chlorophyceae was dominating with 22 species. Diversity of zooplanktons included, cladocera, rotifera, protozoa, nematoda, aostraca, schizopyrenida and copepoda as major groups with 25 genera. Rotifers were dominating with 9 diversified species.

Ekwu and Udo (2014) carried an experiment on plankton community of Ikpa River, South east Nigeria. They observed a total of 51 taxa of phytoplankton belonging to 48 genera and 8 taxa of zooplankton belonging to 4 genera in the river downstream.

Malik and Bharti (2012) reported a total of 40 taxa from different classes of plankton and zooplankton were reported. The phytoplankton (32 sp.) was found being the most abundant taxa than zooplankton (9 sp.) in Sahastradhara stream. Fluctuation in the phytoplankton density was recorded highest (1536 unit/l) during winter and lowest (20 unit/l) during monsoon. Zooplanktons were reported to be maximum (147 unit/l) during summer and minimum (3 unit/l) during monsoon. The total diatoms were reported highest (1022 unit/l) during starting the winter and lowest (4 unit/l) during monsoon. Green algae and blue green algae were reported to be maximum during winter and minimum during summer.

Joadder (2012) reported that phytoplankton diversity in the beel Joshi represented by 4 groups Viz. myxophyceae, chlorophyceae, bacellariophyceae, and euglenophyceae in order of abundance.

Jafari and Alavi (2010) determinate seasonal changes in phytoplankton and zooplankton populations and species abundance. The dominant phytoplanktonic algae determined were *Oscillatoria, Anabaena, Nostoc, Spirogyra, Pediastrum, Navicula* and *Nitzschia*. The dominant zooplanktonic organisms determined were *Paramecium, Daphnia, Cypris*, *Keratella* and *Arachinous*.

Shah *et al.* (2008) monitored the plankton community structure and productivity, its diurnal and seasonal variation in the Shibsha river. A total of 31 phytoplankton species were identified by them; 17 belong to bacillariophyceae, 7 to cyanophyceae, 5 to chlorophyceae and 2 to dynophyceae. Bacillariophyceae appeared to be the dominant group. The overall phytoplankton production attributed to low temperature was significantly high in June (175.8×10^3cells/l) and lower in September (12.0×10^3cells/l).

2.1.3.2 Diversity Indices

Sihombing *et al.* (2017) calculated the plankton diversity of Karangsong mangrove conservation areas in Indonesia. The Shannon-Wiener diversity index for the plankton was ranged between 1.040 and 1.462 across habitats, while the Evenness index ranged between 0.144 and 1.22.

Ikhuoriah *et al.* (2015) studied the zooplankton communities of the river Ossiomo at Ologbo, Niger Delta, Nigeria. They calculated the diversity indices of zooplankton communities. The value of calculated diversity indices using Shannon-Wiener index was

2.508, 1.592 and 2.116. Highest value of diversity index found at the station 1 and lowest was at station 3.

Sharma *et al.* (2015) carried out a study on phytoplanktonic diversity and its relation to physico-chemical parameters of water at Dogarwada Ghat of river Narmada. Evenness diversity index was from 0.9932 -0.7288 for phytoplankton in river Narmada.

Nyakweba and Migiro (2014) assessed the effects of selected water quality parameters on phytoplankton abundance and diversity in river Chepkoilel, Eldoret, Kenya. They recorded the highest Shannon-Wiener diversity index of phytoplankton at the Bridge in the month of November (2.573) and the lowest Shannon index was recorded in Matemo in the month of October (1.1700).

Descy *et al.* (2012) noticed the value of Shannon-Wiener diversity index varied from 0.34 to 5.78 during their experiment on phytoplankton of the river Loire, France: a biodiversity and modelling study which is extremely high.

Malik and Bharti (2012) calculated the Shannon-Wiener diversity index for the density of bacillariophyceae, chlorophyceae and cyanophyceae in Sahastradhara stream at Uttarakhand, India. The value of Shannon-Wiener diversity index for bacillariophyceae, chlorophyceae and cyanophyceae was 0.2180-0.366, 0.208-0.367 and 0.391-0.366 respectively.

Mukherjee *et al.* (2010) conducted a research work on plankton diversity and dynamics in a polluted eutrophic lake, Ranchi. Species diversity calculated by the Shannon – Wiener diversity index showed that the maximum diversity (2.5) was in October decreasing slightly in November but, increasing again in the month of December. The minimum diversity (0.5) occurred in August.

2.2 Correlation of different physico-chemical parameters on plankton community

Sharma *et al.* (2016) showed influence of physico-chemical parameters on phytoplankton distribution at Baldi river in India. They found positive correlation among turbidity, pH and alkalinity with water temperature, however negative relationship with bacillariophyceae, chlorophyceae and cyanophyceae.

Bera *et al.* (2014) carried out a research on correlation study on zooplankton availability and physico-chemical parameters of Kangsabati reservoir, West Bengal, India. Positive relationship among water temperature, pH, DO, transparency and alkalinity in Kangsabati reservoir were observed.

Sharma and Singh (2013) assessed the correlation between physico-chemical parameters and phytoplanktons of Tighra reservoir, Gwalior, Madhya Pradesh. pH , alkalinity and phytoplankton found to increase with increasing water temperature but, decrease in dissolved oxygen.

Araoye (2009) recoded that with increasing dissolved oxygen, pH also increased in Asa lake of Nigeria.

Bhouyain *et al.* (1988) investigated the effects of domestic and factory waste on some water quality characteristics of Karnafully river estuary and they noticed that with increasing water temperature, dissolved oxygen concentration decreased.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 Study area

Atrai river is the westernmost distributary of Brahmaputra river. It is originated about 10 km northeast of Shiliguri town of West Bengal (India).The river Atrai enters in Bangladesh in the north-east of near the villages of Joyganj and flowing southwards passes through the thanas of Debiganj, Birganj, Khanshama and Chirir Bandar, from north to the south. From a short distance to the east of Kantanagar, the Atrai throws out from its western bank a branch called the Gabura or Garveswari which passing close to the town of Dinajpur rejoins the main stream near Kawgaon after a course of about 15 miles. According to the data of Bangladesh Water Development Board (BWDB) the total length of Atrai river in Dinajpur district is about 30 km and highest width is about 193m where lowest width is about 60m with an average 96m. The overall shape of the river is meandering. The highest discharge of water in Atrai river found in from July-September during rainy season. The river serves as a perennial source of fishing. The river Atrai serves as a fishing, feeding, breeding and spawning ground for a lot of indigenous fish species and fish related aquatic organisms and also serves as a sources of earning for some of the local fisherman.

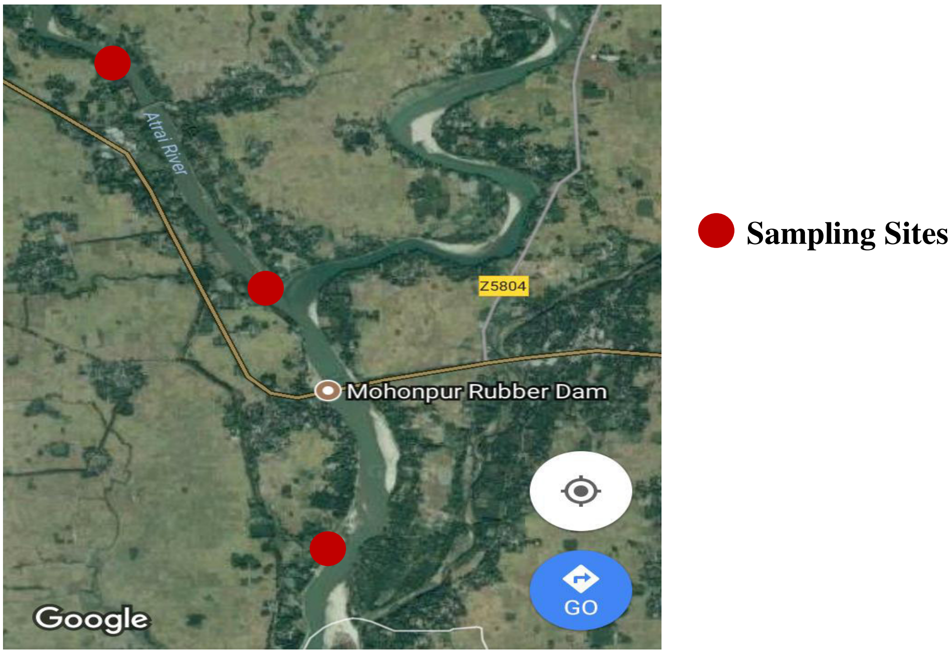


Figure 3.1 Satellite image indicating sampling sites of Atrai river in Dinajpur

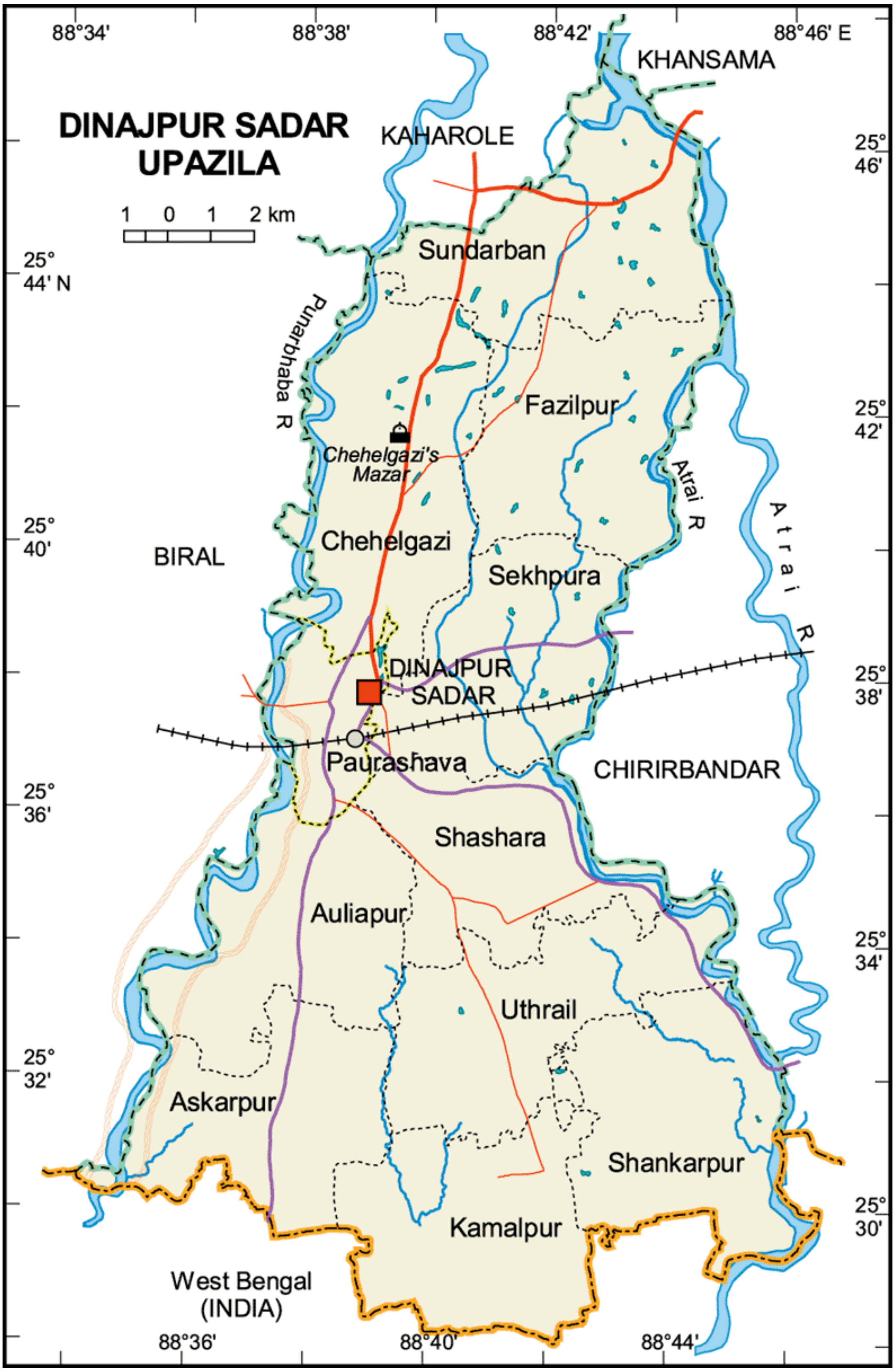


Figure 3.2 Map of Dinajpur Sadar Upazilla, Dinajpur indicating the major rivers including Atrai.

Site 1 Poromeshpur (25.557^{0}N 88.748^{0}E)

Site 2 Rubber dam ((25.545^{0}N 88.756^{0}E)

Site 3 Mohonpur (25.529^{0}N 88.760^{0}E)

Figure 3.3 Sampling sites of Atrai river in Dinajpur

3.2 Experimental design and sampling duration

Three sampling sites were selected for the research purpose (Figure 3.1 and Figure 3.3). Sites were chosen in such a manner to provide for even distance for effective sampling. The distance between each site was 2 km. Samples were taken fortnightly with three horizontal replicates. The total duration of the study period was eight months. The field samplings were started from July 2016 and completed in February 2017.

3.3 Field sampling

The sampling was done between 07 to 08 hours in every sampling period. For the determination of some physico-chemical parameters, samples were collected from the selected sites of the river and kept into separate bottles of 250 ml capacity. Bottles were then labeled with sampling site name, replication number and date of sampling. Water temperature (^{0}C), water level (m), dissolved oxygen (mg/l), pH and transparency (cm) were recorded in field level. Some samples were taken to the laboratory of the Department of Fisheries Management, Faculty of Fisheries, HSTU, Dinajpur for further analysis.

3.4 Physical parameters

Water temperature

Temperature of the river water was taken by using a Digital Celsius Thermometer and recorded during sampling period (Plate 3.1)

Transparency of water

Transparency of water or light penetration in water was measured by using Secchi disk (Plate 3.2). It was dipped into the water on a calibrated line until it disappear. The depth at which it disappear and also the depth at which it reappeared was recorded. The average of these two readings is called Secchi dish reading which is determined by the following formula (Lind 1979)

$$\text{Secchi disk reading (cm)} = \frac{A + B}{2}$$

Where,

A= Depth at which Secchi disk disappears

B= Depth at which Secchi disk reappears

2= Standard value of equation

Water level

Water level were measured at the study site by using 8 feet wooden measuring scale. Then the measured value was converted into meter value (Plate 3.3).

3.5 Chemical parameters

Different chemicals and equipment was used for the determination of chemical parameters of water.

Dissolved Oxygen

A digital dissolved oxygen meter (Model DO-5509) was used for the determination of dissolved oxygen in water. The DO meter was also calibrated by using specific user manual provided with it. Electrolyte liquid availability was also checked at a regular basis before sampling (Plate 3.4).

pH

A manually adjusted pH meter (HANNA Instruments, model HI 8014) was used to determine the pH of water of the study site (Plate 3.5). Prior to use, it was calibrated according to the user manual provided by the manufacturer.

Total alkalinity

Alkalinity was measured by trimetric method using 0.02N Sulfuric Acid and Methyl-orange indicator (APHA 1992) (Plate 3.6).

A 50 ml sample was taken with the help of pipette in the conical flask, 2-3 drops of methyl orange indicator solution was added and the sample was titrated with 0.02N Sulfuric Acid, until the color disappeared. The titration was continued until end point with change of color from orange to pink. The required volume was recorded and amount was calculated as total alkalinity, mg/l as $CaCO_3$.

$$\text{Alkalinity (mg/l)} = A \times N \times 50000/\text{ml of sample used.}$$

Where,

A=Total ml of titrant used

N= Normality of acid (0.02N)

Plate 3.1 Determination of Water Temperature

Plate 3.2 Determination of Transparency

Plate 3.3 Determination of Water Level

Plate 3.4 Determination of Dissolved Oxygen

Plate 3.5 Determination of Water pH

Plate 3.6 Determination of Alkalinity

Plate 3.7 Collection of plankton Sample

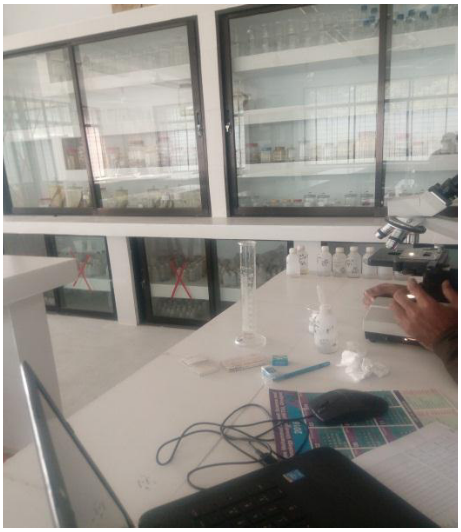


Plate 3.8 Identification and counting of plankton using a Sedgwick-Rafter cell and a binocular microcospe

3.5 Plankton observation

3.5.1 Collection of plankton sample and preservation

Plankton samples were collected from each sites of Atrai river by using plankton net (mesh size, 0.04 mm) for the qualitative and quantitative study of plankton (Plate 3.7). Ten liters of water samples were passed through the plankton net. Then the collected sample was preserved immediately in plastic bottles with 4% formalin solution for the further study. Each bottles was marked by using black colored permanent marker with site number, sample number and date of the data collection. At the laboratory each bottles of filtered plankton were measured by using measuring cylinder and carefully checked up the water level and put the data on the notebook for further analysis.

3.5.2 Analysis of plankton

(a) Qualitative analysis

Taxa of plankton were identified to genus level with the help of taxonomic keys from the text book of Babar and Haworth (1981), Bellinger (1992), Pontin (1978), Lind and Brook (1980) with magnification of 10 × 0.25 under binocular microscope (Plate 3.8).

(b) Quantitative analysis

For quantitative study of plankton, the sample containing bottles was shakes properly to evenly distribute the plankton in the bottle. Then 1 ml of concentrated plankton sample was taken by a dropper and placed on the counting chamber of S-R (Sedgwick-Rafter) cell. The Sedgwick-Rafter cell is approximately 50 mm long, 20mm wide and 1mm deep. The total volume is 1000 mm^3 or 1ml. The counting chamber is equally divided into 1000 fields each having a volume of 0.001 ml. Before counting the S-R cell was allowed to stand at least 15 minutes to settles the planktons. The cell was then set on an electric microscope. Planktonic organism present in 10 fields from the total 1000 fields was randomly chosen for counting. Then the abundance of plankton was calculated using the following formula (Rahman 1992).

$$N = \frac{A \times 1000 \times C}{V \times F \times L}$$

Where,

N= Number of plankton cells per liter

A=Total number of plankton counted

C= Volume of final concentration of samples in ml

V= Volume of field in cubic millimeter

F= Number of fields counted

L= Volume of original water in liter

The average number of plankton was recorded and expressed numerically as cells per liter of water (cells/l)

3.5.3 Diversity analysis

The following diversity indices were calculated in order to measure the status of water quality.

Shannon-weaver diversity index

Plankton diversity was calculated by Shannon-weaver diversity index (Washington 1984)

Shannon-weaver index, $H' = -\Sigma (Ni/N) \ln (Ni/N)$

Where,

Ni = abundance of species i, and

N= total number of individuals in the community.

The maximum diversity of the plankton community occurs when all species are equally abundant in numbers or contribute equally to the total number of individuals. Maximum diversity is given by:

$H_{max} = \ln S$

Where,

S= is the total number of species of the community.

Evenness diversity index

The Evenness-index (E) of the phytoplankton communities (Washington 1984) was calculated by comparing the actual diversity to the maximum diversity.

$E = H'/ H_{max}$

Where,

H'=represents the Shannon-Wiener index value

H_{max} = maximum diversity of the plankton community

3.6 Statistical analysis

The statistical analyses were performed using SPSS (Statistical Package for Social Science) software version 20. An analysis of variance (Two Way ANOVA) and Tukey's test were applied to data for determining significance and comparison between mean ± SD (standard deviation). The Pearson's correlation coefficient was accomplished using SPSS (Statistical Package for Social Science) to determine the relationship among the various physico-chemical parameters and different plankton abundance. A probably value $P<0.05$ was considered as statistically significant. Diversity indices were calculated by using PAST (Paleontological Statistics) version 3.0 software.

CHAPTER IV

RESULTS

CHAPTER IV

RESULTS

This chapter presents the findings and statistical analysis of different physical, chemical and biological parameters of Atrai river. The mean values of all the physical, chemical and biological parameters were calculated from the raw data obtained from the sampling sites. These mean values were presented in a tabular, ANOVA table forms and in graphs.

4.1 Physical parameters

4.1.1 Water temperature

The fortnightly variation of temperature among different sites in Atrai river during sampling is presented in Figure 4.1. The water temperature was highly variable (site 1: 18.28 ^{0}C to 32.51 ^{0}C; site 2:17.97 ^{0}C to 32 ^{0}C and site 3: 18.70 ^{0}C to 32.83 ^{0}C) during the study period (Table 4.1). Whereas, mean value (±SD) of water temperature were 25.52±4.63^{0}C, 25.19±4.63^{0}C and 25.89±4.61^{0}C in the site 1, site 2 and site 3 respectively (Table 4.1). Highest water temperature (32.77^{0}C) was found at site 3 in July-2016. On the other hand, lowest temperature (17.99^{0}C) were recoded from site 2 in January-2017. The difference in the water temperature among three sites were statistically significant (P<0.01) (Table 4.1).

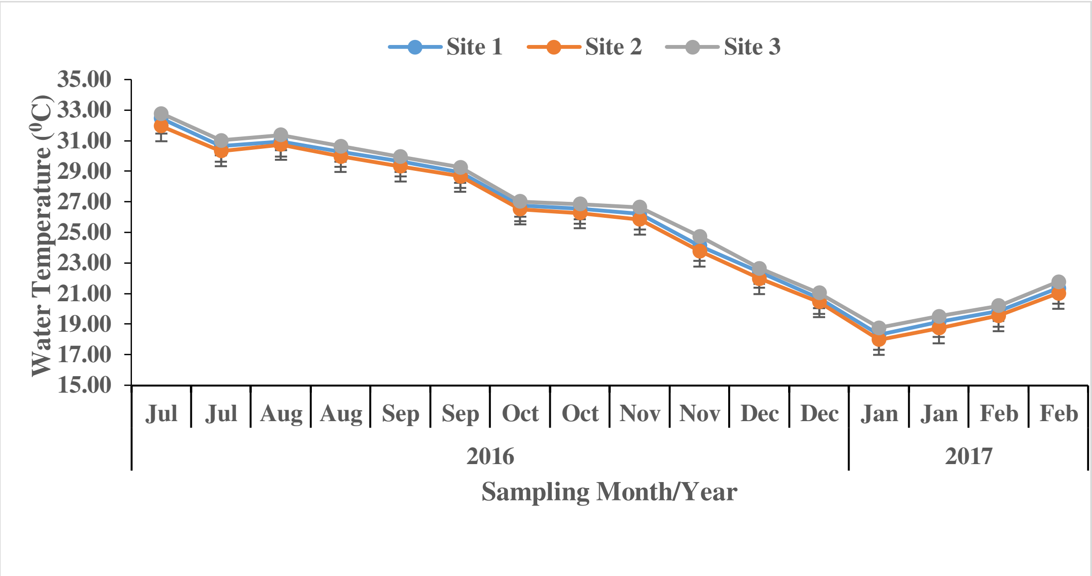


Figure 4.1 Fortnightly variation of water temperature (^{0}C) at three sampling sites

4.1.2 Transparency

The difference in transparency among three sampling sites were statistically significant (*P*<0.01) at 1% level of significance (Table 4.1). Highest value of transparency (74.67cm) was found in the site 3 in the month of August-2016 and lowest value (34.67cm) was in the site 1 in the month of January-2017 during the sampling period. Fortnightly variation in transparency shown in the following Figure 4.2.

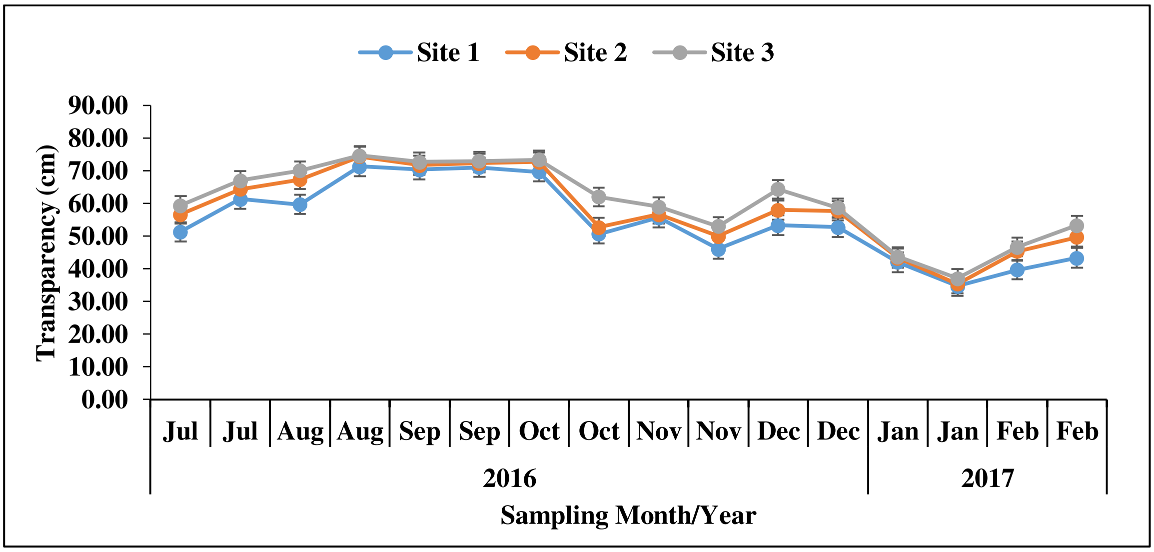


Figure 4.2 Fortnightly variation of transparency (cm) at three sampling sites

4.1.3 Water level

Mean value (±SD) of water level at site 1, 2 and 3 in the Atrai river during sampling period was 1.51±0.31m, 1.67±0.36 m and 1.32±0.23m respectively (Table 4.1). Fortnightly variation of water level among different sites is shown in Figure 4.3. Highest water level (2.36 m) found during sampling period was at site 2 having a dam in the month July-2016 and lowest (1.03 m) was at site 3 in the month of February-2017. The difference of water level was statistically significant (*P*<0.01) at 1% level of significance (Table 4.1).

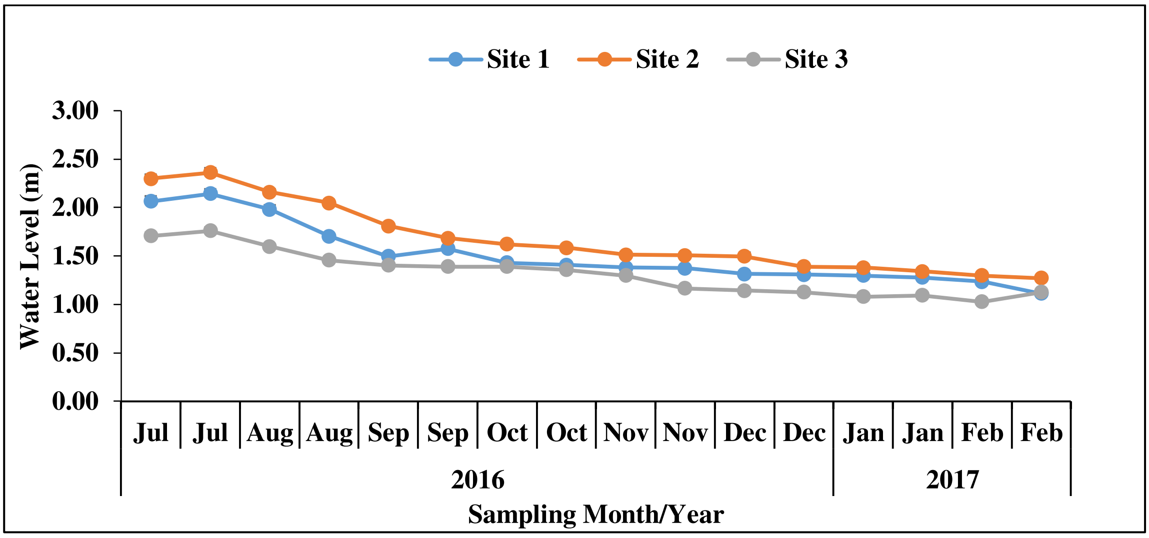


Figure 4.3 Fortnightly variation of water level (m) at three sampling sites

Table 4.1 Comparison of physical parameters (Mean±SD) recorded from three sampling sites using ANOVA

Parameters	Sampling Sites			F-value	ANOVA Significance of Difference
	Site 1	Site 2	Site 3		
Water Temperature (^{0}C)	25.52±4.63^b (18.28-32.51)	25.19±4.63^b (17.97-32.00)	25.89±4.61^a (18.70-32.83)	11.23	**
Transparency (cm)	54.54±11.77^b (32.00-73.00)	58.00±11.69^a (32.00-76.00)	60.48±11.38^a (33.00-76.00)	15.54	**
Water Level (m)	1.51±0.31^b (1.08-2.24)	1.67±0.36^a (1.24-2.54)	1.32±0.23^c (1.02-1.85)	240.82	**

NS= Values are not significantly different (P>0.05)

Data in parenthesis indicates the range values

**Values with different superscript letter in the same row indicate a significant difference at 1% significance level based on two way ANOVA followed by Tukey's test.

4.2 Chemical parameters

4.2.1 Dissolved Oxygen

Dissolved oxygen found to be varied from 5.30-8.60 mg/l, 5.60-9.30 mg/l and 4.90-8.60 mg/l respectively at site 1, site 2 and site 3 of Atrai river during the sampling period. Mean value (±SD) of dissolved oxygen at three sites were 7.45±0.96, 7.91±0.98 and 7.06±1.06 mg/l respectively (Table 4.2). Significant difference (*P*<0.01) in the value of dissolved oxygen among three sites were noticed in Table 4.2. Fortnightly variation in dissolved oxygen is shown in Figure 4.4. Highest dissolved oxygen concentration (9.17 mg/l) was found during the month of October-2016 at site 2 and lowest (5.03 mg/l) was at site 3 during the month of July-2016.

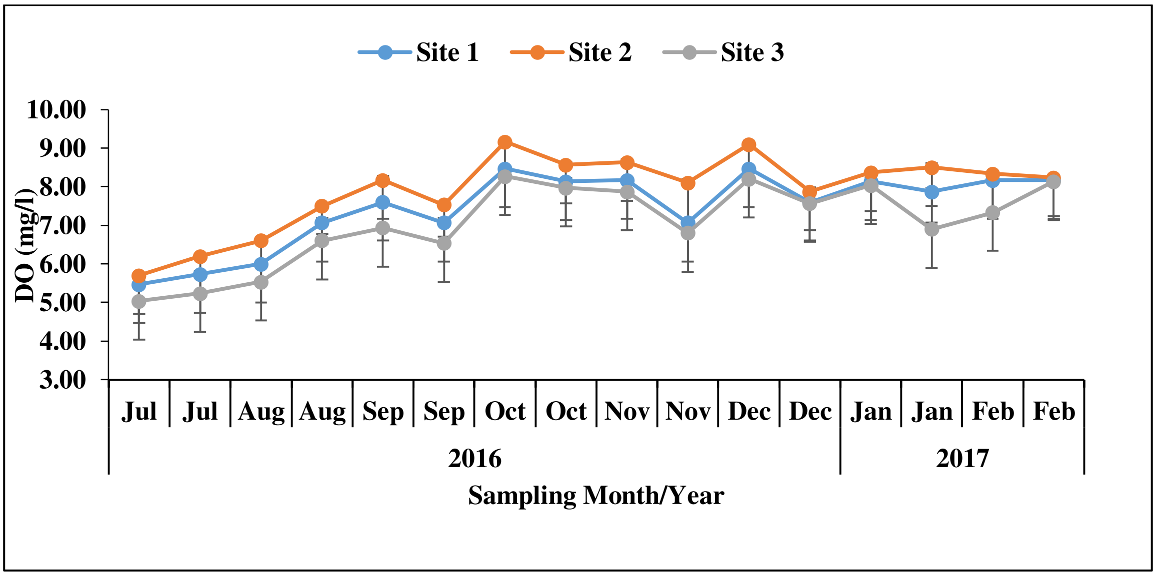


Figure 4.4 Fortnightly variation of dissolved oxygen (mg/l) at three sampling sites

4.2.2 pH

Significant variation of pH among the three sampling sites were found throughout the sampling period. Mean value (±SD) of pH among three sampling sites were 7.64±0.31, 7.81±0.31 and 7.47±0.35 respectively (Table 4.2). Highest value (8.56) was observed at site 1 during the month of February-2017 and lowest pH (6.97) was at site 3 during the month of October-2016.

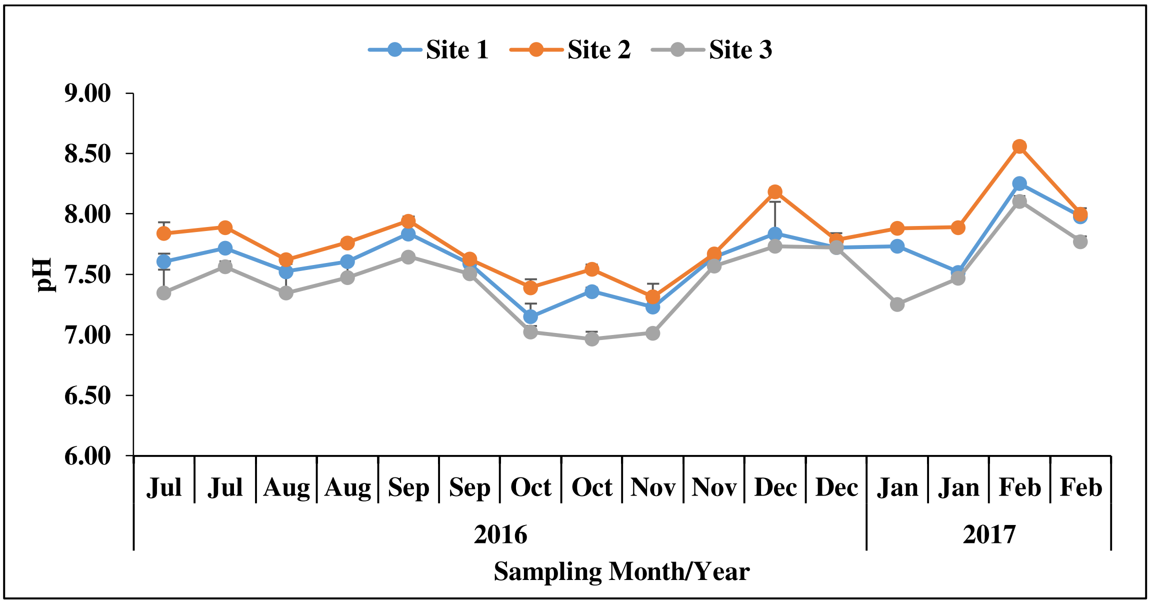


Figure 4.5 Fortnightly variation of pH at three sampling sites

4.2.3 Alkalinity

The difference in the value of alkalinity among three sampling sites were statistically significance ($P<0.01$) (Table 4.2). Highest value of alkalinity (60.67 mg/l) was found at site 1 in the month of January-2017 and lowest (15.33 mg/l) was recorded from site 3 in the month of July-2016. Fortnightly variation in alkalinity among three sites are shown in Figure 4.6.

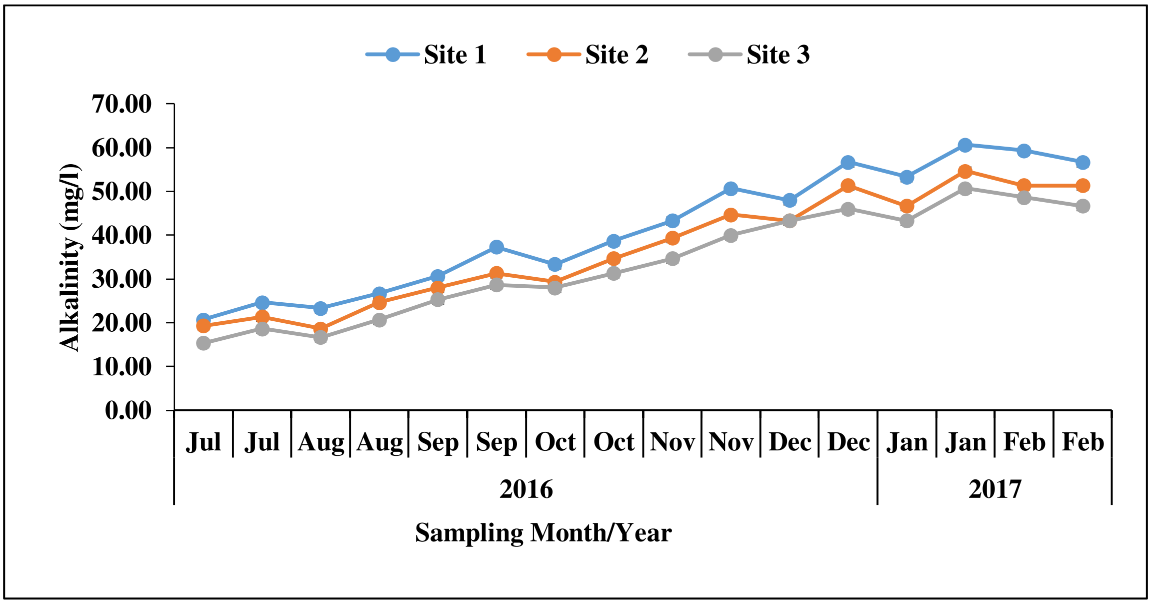


Figure 4.6 Fortnightly variation of alkalinity (mg/l) at three sampling sites

Table 4.2 Comparison of chemical parameters (Mean ±SD) recorded from three sampling sites using ANOVA

Parameters	**Sampling Sites**			**F-value**	**ANOVA Significance of Difference**
	Site 1	**Site 2**	**Site 3**		
DO (mg/l)	7.45±0.96^{b} (5.60-9.30)	7.91±0.98^{a} (5.30-8.60)	7.06±1.06^{c} (4.90-8.50)	48.16	**
pH	7.64±0.31^{b} (7.15-8.73)	7.81±0.31^{a} (6.93-8.58)	7.47±0.35^{c} (6.70-8.18)	29.45	**
Alkalinity(mg/l)	41.50±13.63^{a} (20.00-62.00)	36.88±12.30^{b} (18.00-56.00)	33.63±11.92^{c} (14.00-52.00)	77.95	**

NS= Values are not significantly different (P>0.05)

Data in parenthesis indicates the range values

**Values with different superscript letter in the same row indicate a significant difference at 1% significance level based on two way ANOVA followed by Tukey's test.

4.3 Biological parameters

4.3.1 Plankton population

Findings from the present study revealed that abundance of phytoplankton was extremely high compared to zooplankton. Total 57 genera of plankton were identified of which 43 genera was phytoplankton and 14 genera was zooplankton. Phytoplankton represent by 19 genera of chlorophyceae, 9 genera of cyanophyceae, 13 genera of bacillariophyceae and 2 genera of euglenophyceae where zooplankton represent by 3 genera of copepoda, 6 genera of rotifera, 4 genera of cladocera and 1 genera of crustacean larvae (Table 4.3). Generic status of different groups of plankton are shown in Table 4.3.On the other hand Table 4.4,4.5 and 4.6 representing mean (±SD) value and ranges of phytoplankton, zooplankton and total plankton ($\times 10^3$cells/l) value.

Table 4.3 Generic status of different groups of plankton identified from the sampling sites of Atrai river

Phytoplankton		Zooplankton
Cyanophyceae	**Chlorophyceae**	**Copepoda**
Anabaena	*Actinastrum*	*Cyclops*
Aphanizomenon	*Chlorella*	*Diaptomus*
Chrococcus	*Chodatella*	*Leptodorta*
Gleotrichia	*Closterium*	**Rotifera**
Merismopedia	*Coelastrum*	*Asplanchna*
Microcystis	*Cosmarium*	*Brachionus*
Nostoc	*Hydrodictyon*	*Filinia*
Oscillatoria	*Microspora*	*Keratella*
Synecococcus	*Oedogonium*	*Lecane*
Bacillariophyceae	*Pediastrum*	*Trichocera*
Actinella	*Planktospaeria*	**Cladocera**
Amphora	*Scenedesmus*	*Daphnia*
Cyclotella	*Sphaerocystis*	*Diaphanosoma*
Diatoma	*Spirogyra*	*Moina*
Fragillaria	*Staurastrum*	*Sida*
Melosira	*Stigeoclonium*	
Navicula	*Ulothrix*	**Crustacean Larvae**
Nitzschia	*Volvox*	Nauplius
Planktoniella	*Zygnema*	
Stephanodiscus	**Euglenophyceae**	
Surirella	*Euglena*	
Synedra	*Phacus*	
Tabellaria		

Table 4.4 Mean (±SD) value and ranges of phytoplankton (×10^3cells/l) value in the sampling sites during the sampling period

Parameters	Sampling Sites			F- value	ANOVA Significance of Difference
	Site 1	Site 2	Site 3		
Cyanophyceae	2.96±1.06^a (1.00-5.40)	2.67±1.13^{ab} (0.31-5.28)	2.51±1.09^b (0.78-4.92)	5.04	*
Bacillariophyceae	3.53±1.37^a (1.00-6.12)	3.02±1.26^b (1.05-6.16)	2.76±1.49^b (0.80-6.97)	10.75	**
Chlorophyceae	7.14±2.75^a (2.47-13.50)	6.38±2.73^a (2.08-12.18)	5.41±2.34^b (1.60-10.25)	11.86	**
Euglenophyceae	0.39±0.26^a (0.00-1.02)	0.38±0.20^a (0.00-0.90)	0.19±0.16^b (0.00-0.60)	10.04	**

Table 4.5 Mean (±SD) value and ranges of zooplankton (×10^3cells/l) value in the sampling sites during the sampling period

Parameters	Sampling Sites			F- value	ANOVA Significance of Difference
	Site 1	Site 2	Site 3		
Copepoda	0.88±0.52 (0.27-2.70)	0.82±0.44 (0.00-2.20)	0.78±0.49 (0.00-2.05)	1.31	NS
Rotifera	1.79±0.75^a (0.78-4.05)	1.60±0.64^{ab} (0.62-3.08)	1.42±0.73^b (0.30-3.28)	7.98	*
Cladocera	1.04±0.61^a (0.25-3.15)	0.89±0.47^{ab} (0.21-2.10)	0.78±0.42^b (0.00-2.05)	6.02	*
Crustacean Larvae	0.29±0.22 (0.00-0.74)	0.24±0.19 (0.00-0.68)	0.21±0.13 (0.00-0.41)	2.95	NS

Table 4.6 Mean (±SD) value and ranges of total plankton value (×10^3cells/l) in the sampling sites during the sampling period

Parameters	Sampling Sites			F- value	ANOVA Significance of Difference
	Site 1	Site 2	Site 3		
Total Phytoplankton	14.03±4.86^a (5.00-24.30)	12.45±4.97^b (4.94-22.88)	10.88±4.73^c (3.60-21.32)	13.38	**
Total Zooplankton	4.00±1.66^a (1.40-10.35)	3.55±1.45^{ab} (1.26-6.60)	3.18±1.49^b (0.80-6.97)	8.62	**
Total Plankton	18.03±6.29^a (7.00-34.65)	15.99±6.23^b (6.50-29.48)	14.06±6.02^c (4.40-28.29)	13.31	**

NS= Values are not significantly different (P>0.05)
**Values with different superscript letter in the same row indicate a significant difference at 5% significance level based on two way ANOVA followed by Tukey's test.*
*** Values with different superscript letter in the same row indicate a significant difference at 1% significance level based on two way ANOVA followed by Tukey's test.*

4.3.2 Cyanophyceae

Cyanophyceae represent by 9 genera and took the third position in number of genera. Most dominant species were *Microcystis*, *Nostoc*, *Oscillatoria* and *Synecococcus* etc. The abundance of cyanophyceae were 1.00-5.40×10^3, 0.31-5.28×10^3 and 0.78-4.92×10^3 cells/l in the site 1, site 2 and site 3 respectively (Table 4.4). Fortnightly variation of cyanophyceae is presented in Figure 4.7

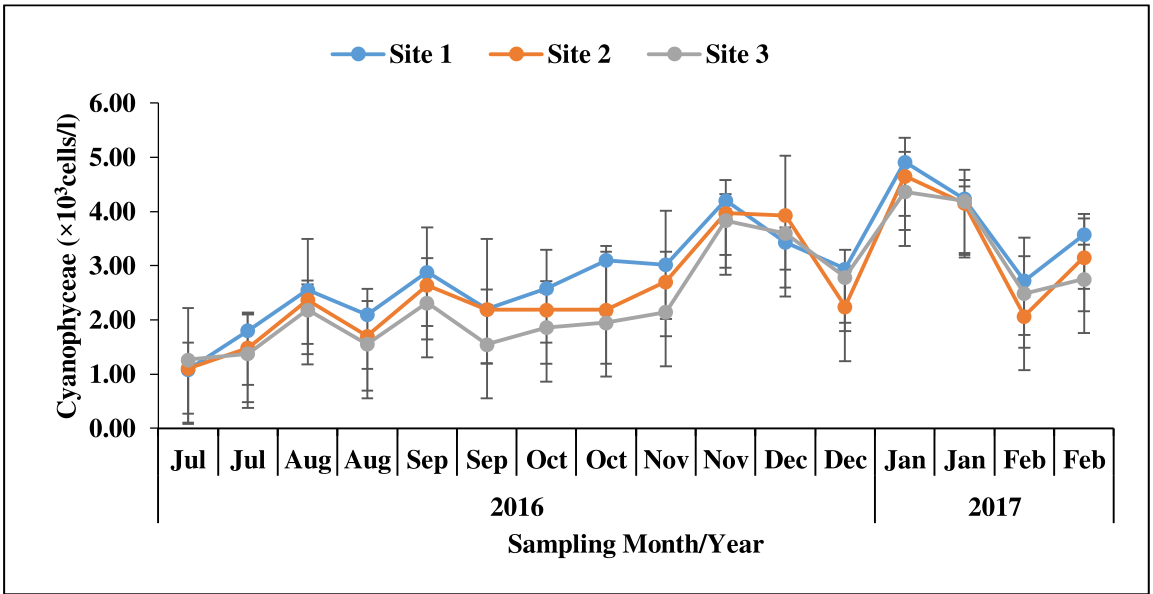


Figure 4.7 Fortnightly variation in the abundance of cyanophyceae (×10^3 cells/l) at three sampling sites

4.3.3 Bacillariophyceae

Both the highest and lowest abundance of bacillariophyceae was found in the month of January-2017 and July-2016 respectively at site 3 shown in Figure 4.8. The difference in the abundance of bacillariophyceae was statistically significant (P<0.01) at 1% level of significance (Table 4.4). Mean value (±SD) of bacillariophyceae was $3.53\pm1.37\times10^3$, $3.02\pm1.26\times10^3$ and $2.78\pm1.49\times10^3$ cells/l respectively in three sampling sites during the sampling period (Table 4.4). Dominant species were *Cyclotella*, *Fragillaria*, *Navicula*, *Surirella* and *Tabellaria* etc.

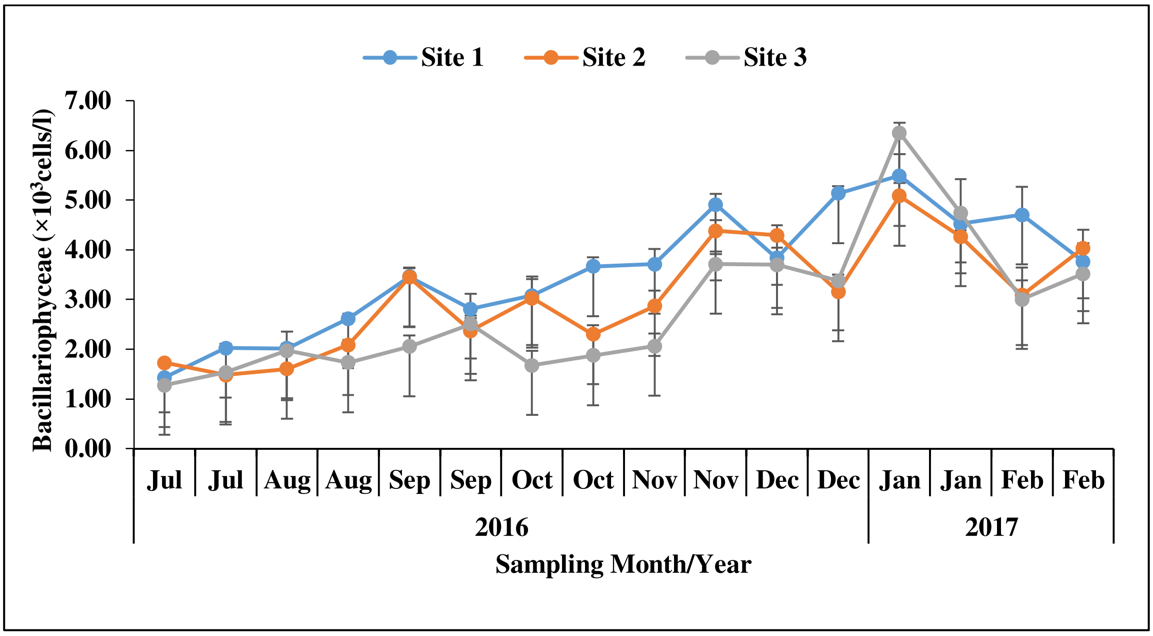


Figure 4.8 Fortnightly variation in the abundance of bacillariophyceae ($\times10^3$ cells/l) at three sampling sites

4.3.4 Chlorophyceae

Chlorophyceae noted as first position in abundance and number of genera during the sampling period represent by 19 species. This group showed the significant difference (P<0.01) among the sampling sites during sampling at 1% level of significance (Table 4.4). The abundance of chlorophyceae at site 1, site 2 and site 3 was 2.47-13.50×10^3, 2.08-12.18×10^3 and 1.60-10.25×10^3 cells/l respectively (Table 4.4). Most dominant species was *Chlorella*, *Cosmarium*, *Pediastrum* and *Scenedesmus* etc.

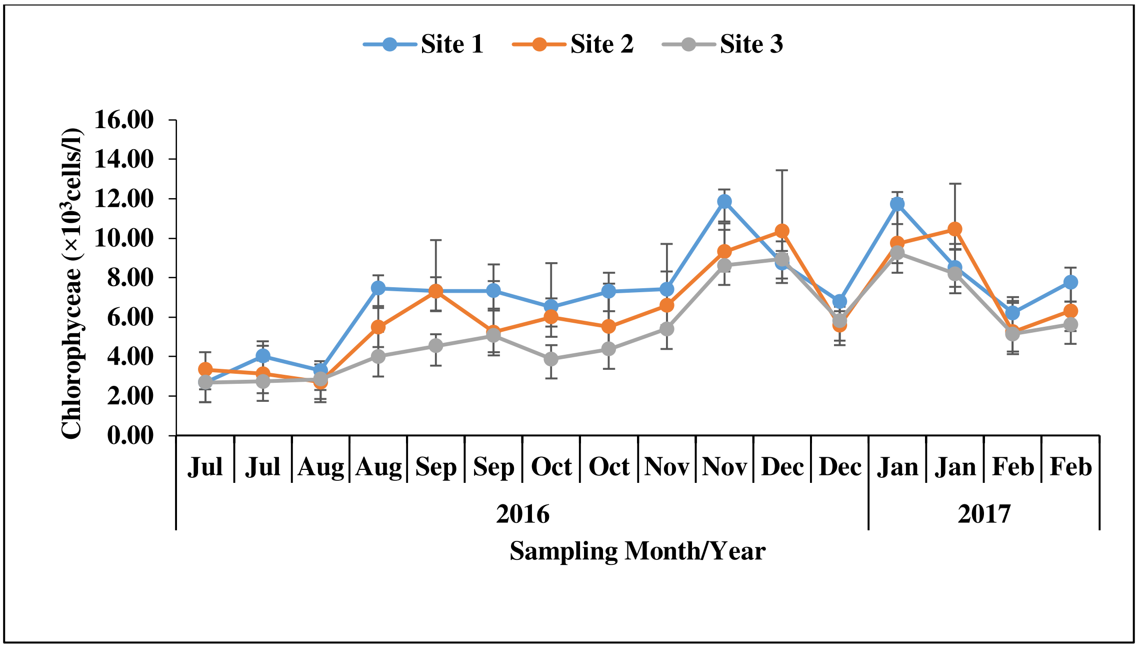


Figure 4.9 Fortnightly variation in the abundance of chlorophyceae (×10^3cells/l) at three sampling sites

4.3.5 Euglenophyceae

Two genera of euglenophyceae, namely *Euglena* and *Phacus* were identified during the study period. The abundance of euglenophyceae was ranged 0.00-1.02×10^3, 0.00-0.90×10^3 and 0.00-0.60×10^3 cells/l in site 1, 2 and 3 respectively during sampling (Table 4.4). The difference in the density of euglenophyceae among the sampling sites were statistically significant (P<0.01) at 1 % level of significance (Table 4.4). Fortnightly variation in the abundance of euglenophyceae is presented graphically in Figure 4.10

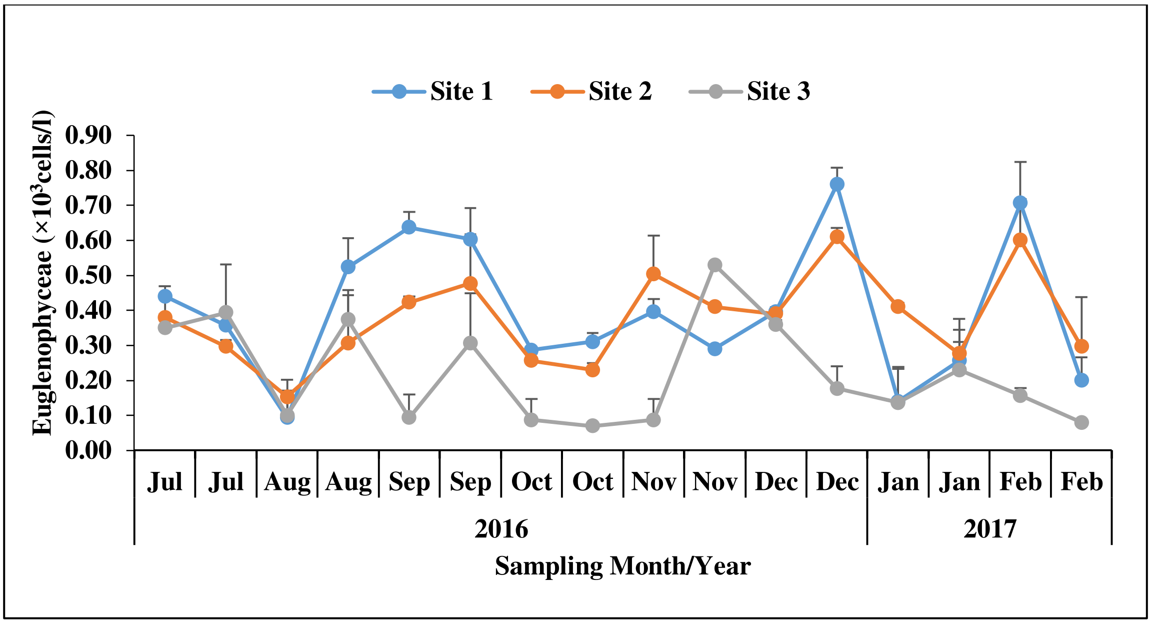


Figure 4.10 Fortnightly variation in the abundance of euglenophyceae (×10^3cells/l) at three sampling sites

4.3.6 Total phytoplankton

The difference in the abundance of total phytoplankton was statistically significant (*P*<0.01) at 1% level of significance (Table 4.6). Dominant group of phytoplankton was chlorophyceae and bacillariophyceae. Total 43 genera of phytoplankton was identified. Highest amount of phytoplankton 22.27×10^3 cells/l was identified from site 1 in the month of January-2017 where lowest 5.23 ×10^3cells/l were from site 3 in the month of July-2016 (Figure 4.11). Fortnightly variation in the abundance of total phytoplankton is shown in Figure 4.11.

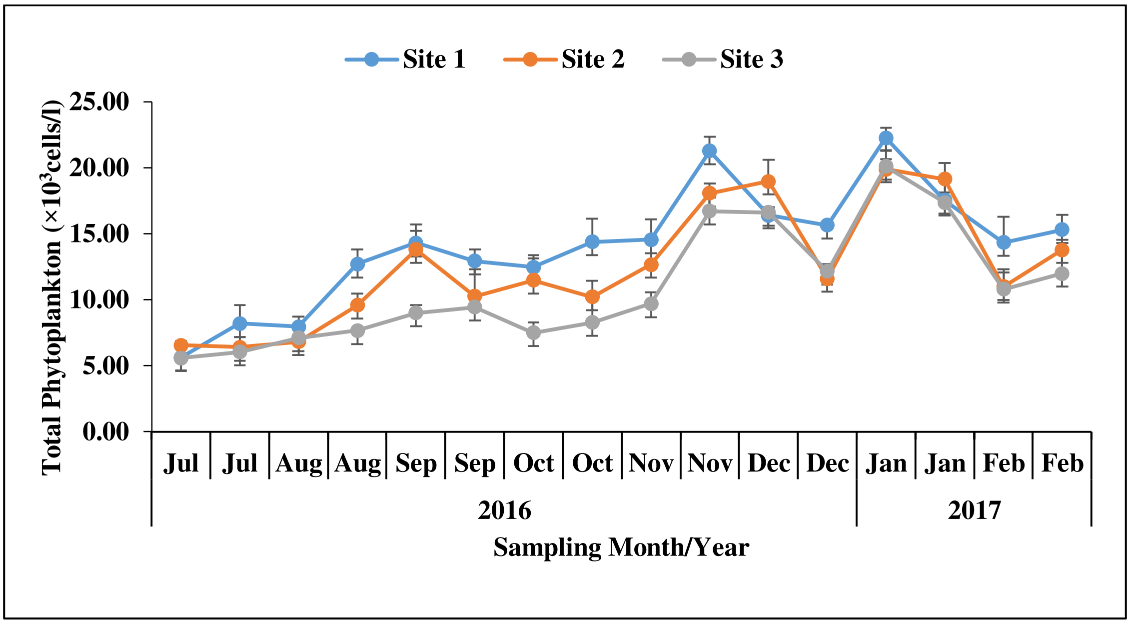


Figure 4.11 Fortnightly variation in the abundance of total phytoplankton (×10^3cells/l) at three sampling sites

4.3.7 Copepoda

Fortnightly variation in the abundance of copepod is shown in Figure 4.13. Most dominant genus was *Cyclops* and *Diaptomus.* Abundance of copepoda was found to vary from 0.27-2.70×10^3, 0.00-2.20×10^3 and 0.00-2.05×10^3cells/l in the three sampling sites respectively (Table 4.5). Highest abundance was found during the month of November-2016 and January-2017 and lowest was during the month of July-2016 to September-2016. No significant difference (P>0.05) in the abundance of copepoda were found in the sampling sites of Atrai river (Table 4.5).

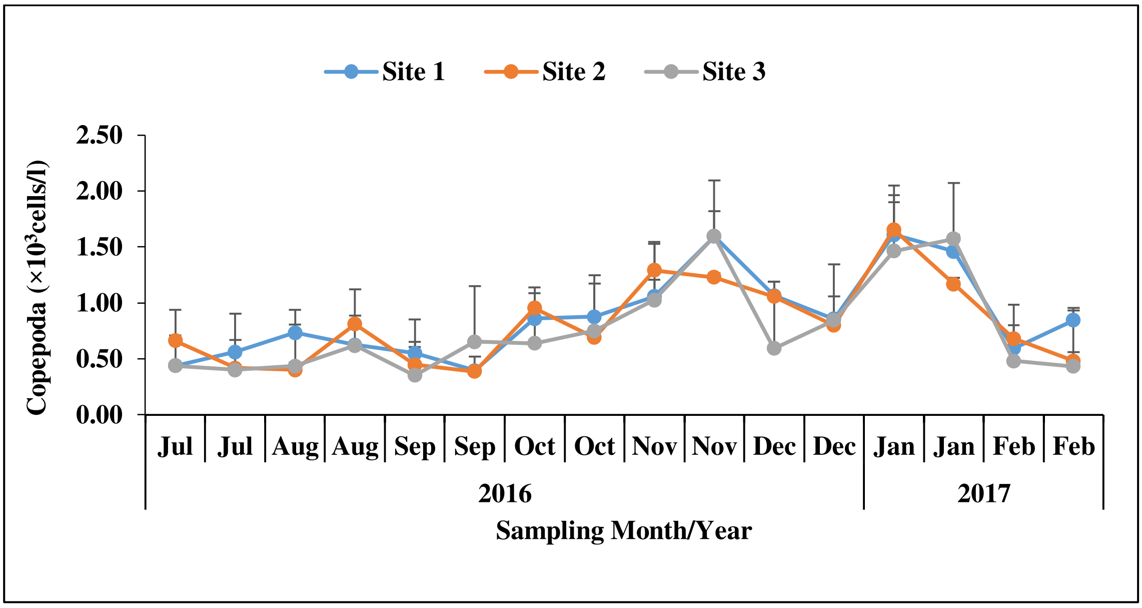


Figure 4.12 Fortnightly variation in the abundance of copepoda (×10^3 cells/l) at three sampling sites

4.3.8 Rotifera

Dominants genera of rotifera was *Asplanchna, Brachionus* and *Keratella.* Highest density of rotifera was found in the month of November-2016 and January-2017. Whereas lowest was during the month of September-2016 and February-2017. Mean value (±SD) of abundance in rotifera at the three sampling sites were $1.79 \pm 0.75 \times 10^3$, $1.60 \pm 0.64 \times 10^3$ and $1.42 \pm 0.73 \times 10^3$ cells/l respectively (Table 4.5). Significant difference ($P<0.05$) was found in the abundance of rotifera among the sampling sites (Table 4.5). Fortnightly variation in the abundance of rotifera is presented graphically in Figure 4.13.

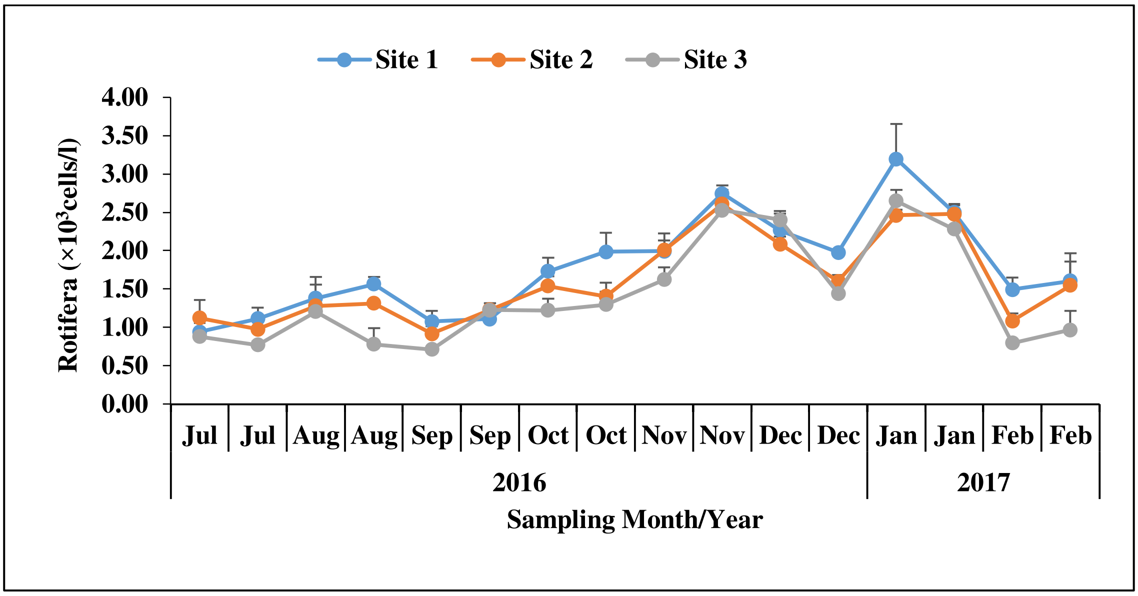


Figure 4.13 Fortnightly variation in the abundance of rotifera ($\times 10^3$ cells/l) at three sampling sites

4.3.9 Cladocera

Cladocera represent by 4 genera of which *Daphnia* and *Moina* was dominant throughout the study period. The abundance of cladocera in the three sampling sites were 0.25-3.15×10^3, 0.21-2.10×10^3 and 0.00-2.05×10^3 cells/l respectively (Table 4.5). Highest value was found in the month of January-2017 and lowest value found in the month of September-2016. Significant difference (P<0.05) found in the density of cladocera during sampling period (Table 4.5).

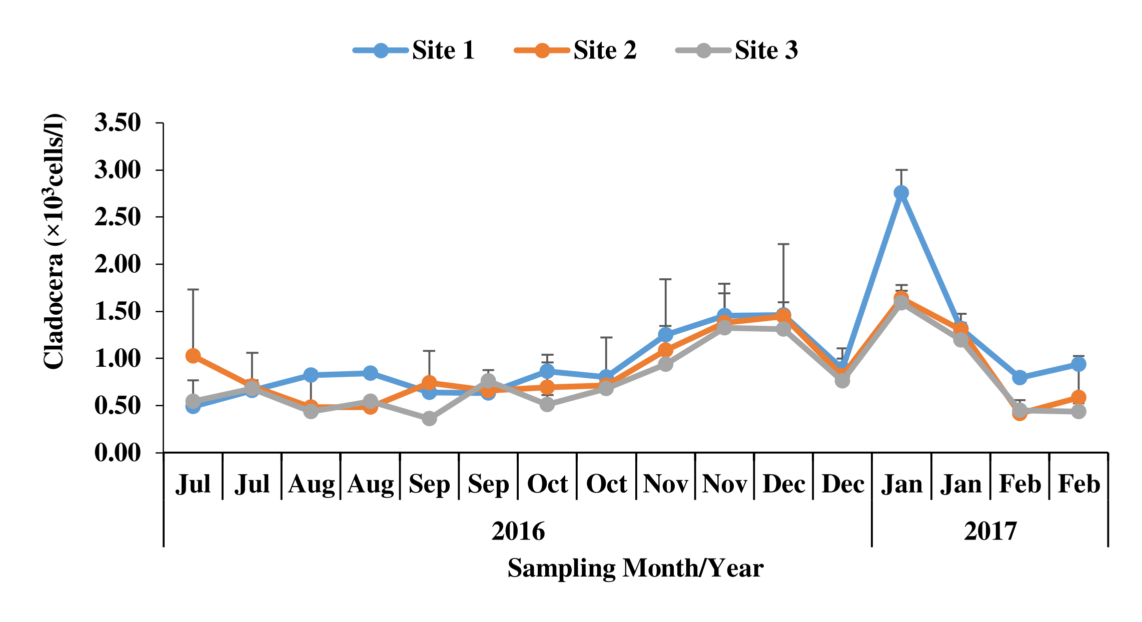


Figure 4.14 Fortnightly variation in the abundance of cladocera (×10^3cells/l) at three sampling sites

4.3.10 Crustacean larvae

No significant difference (*P*>0.05) in the abundance of crustacean larvae was found among the sampling site during the sampling period (Table 4.5). Mean value (±SD) in the abundance of crustacean larvae at the three sampling sites were $0.29 \pm 0.22 \times 10^3$, $0.24 \pm 0.19 \times 10^3$ and $0.21 \pm 0.13 \times 10^3$ cells/l respectively (Table 4.5).

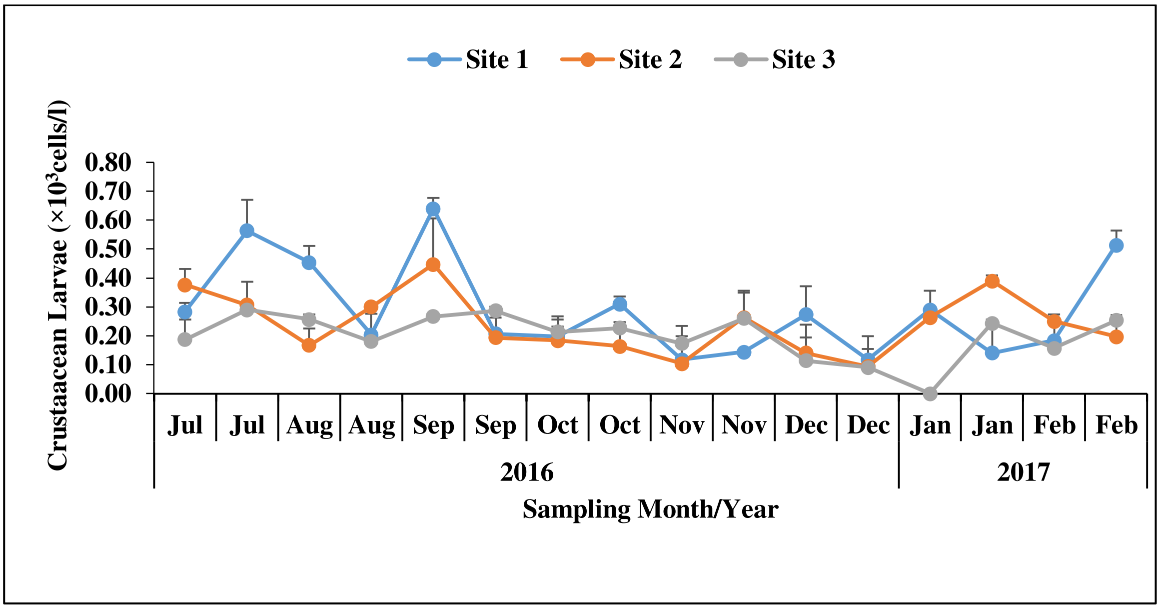


Figure 4.15 Fortnightly variation in the abundance of crustacean larvae ($\times 10^3$ cells/l) at three sampling sites

4.3.11 Total Zooplankton

Fortnightly abundance of total zooplankton shown in Figure 4.16. Dominant group was rotifera and cladocera. Abundance of total zooplankton varied from 1.40-10.35×10^3, 1.26-6.60×10^3 and 0.80-6.97×10^3 cells/l in site 1, 2 and 3 respectively. Mean value ± (SD) of total zooplankton in the sampling sites was were 4.00±1.66×10^3, 3.55±1.45×10^3 and 3.18±1.49×10^3 cells/l respectively (Table 4.6).

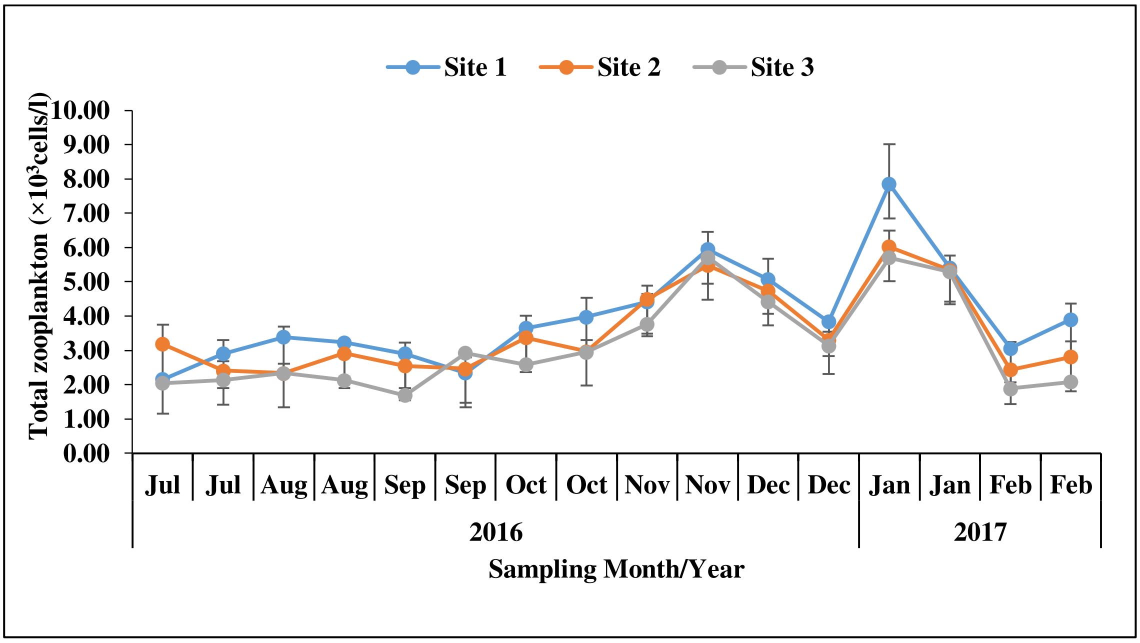


Figure 4.16 Fortnightly variation in the abundance of total zooplankton (×10^3cells/l) at three sampling sites

4.3.12 Total plankton

The difference in the abundance of total plankton was statistically significant ($P<0.01$) at 1% level of significance among the sampling site (Table 4.6). The density of total plankton was relatively low during the month of July-2016 and August-2016. It found to gradually increase with decrease in water temperature and reached at the highest value in November-2016 and January-2017. The abundance of total plankton in the three sampling sites were $7.00\text{-}34.65\times10^3$, $6.50\text{-}29.48\times10^3$ and $4.40\text{-}28.29\times10^3$ cells/l respectively (Table 4.6).

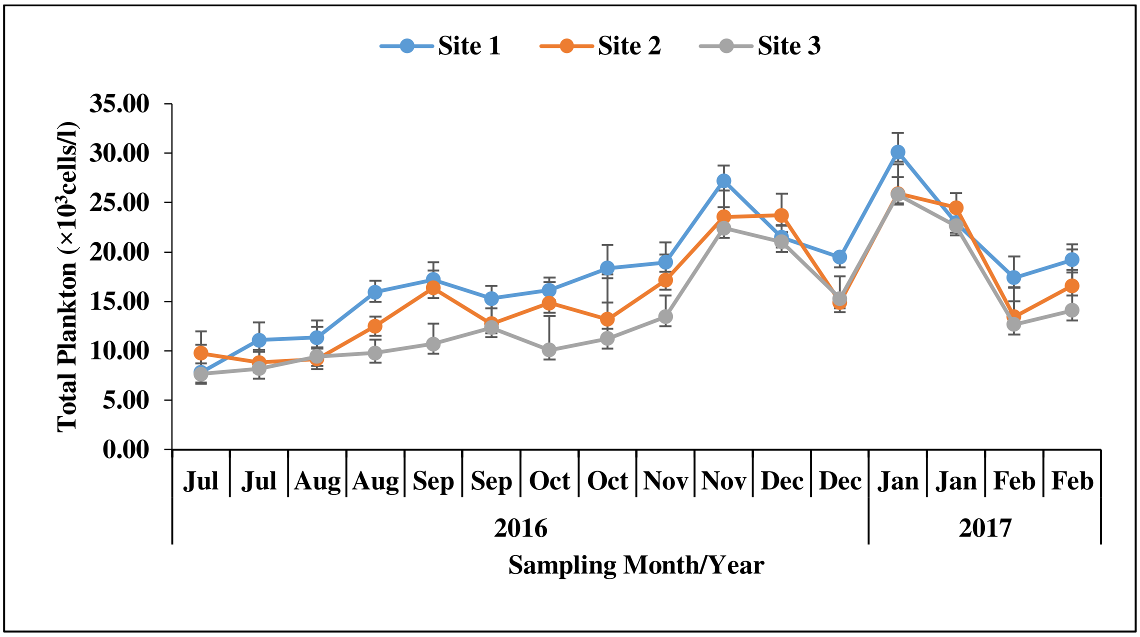


Figure 4.17 Fortnightly variation in the abundance of total plankton ($\times10^3$cells/l) at three sampling sites

4.3.13 Composition of plankton community

Phytoplankton was dominant over zooplankton throughout the sampling period in Atrai river. Among the plankton community 78% was phytoplankton and the rest 22% was zooplankton.

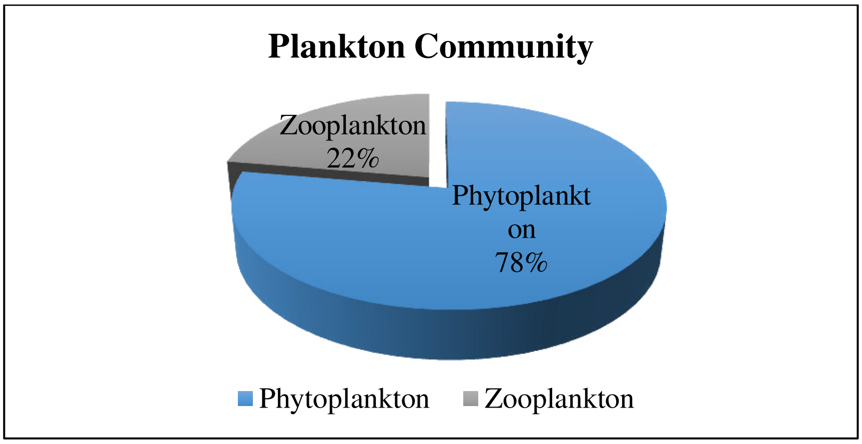


Figure 4.18 Percentage composition of plankton community at three sampling sites

4.3.14 Composition of phytoplankton community

Four major group of phytoplankton were identified from Atrai river during study period. Most dominant phytoplankton group was chlorophyceae and lowest was euglenophyceae. The order of dominant phytoplankton group was chlorophyceae (51%), bacillariophyceae (25%), cyanophyceae (22%) and euglenophyceae (2%).

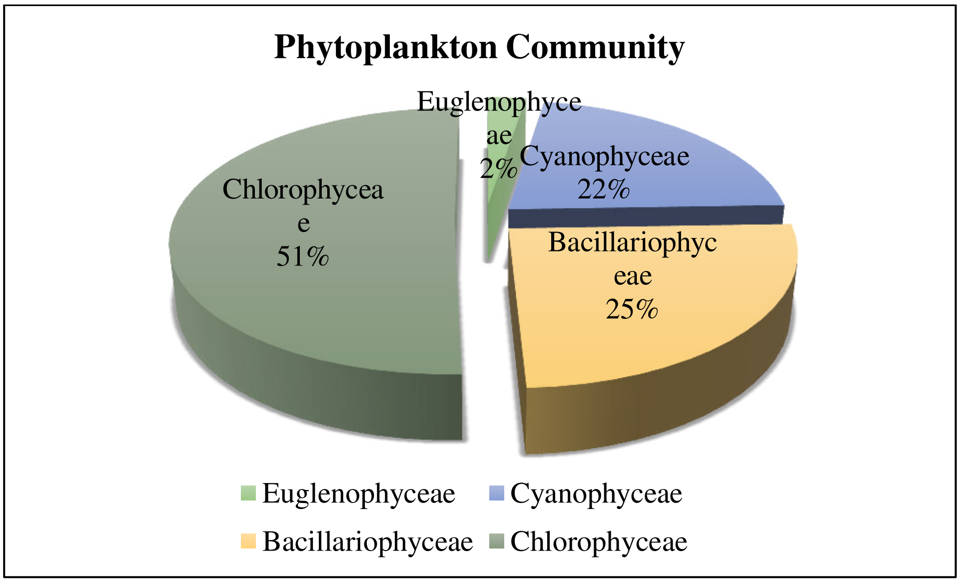


Figure 4.19 Percentage composition of phytoplankton community at three sampling sites

4.3.15 Composition of zooplankton community

Zooplankton community also composed of four groups named copepoda, rotifera, cladocera and crustacean larvae. The sequences of dominancy of zooplankton group was rotifera (45%)>cladocera (25%)> copepoda (23%) > crustacean larvae (7%).

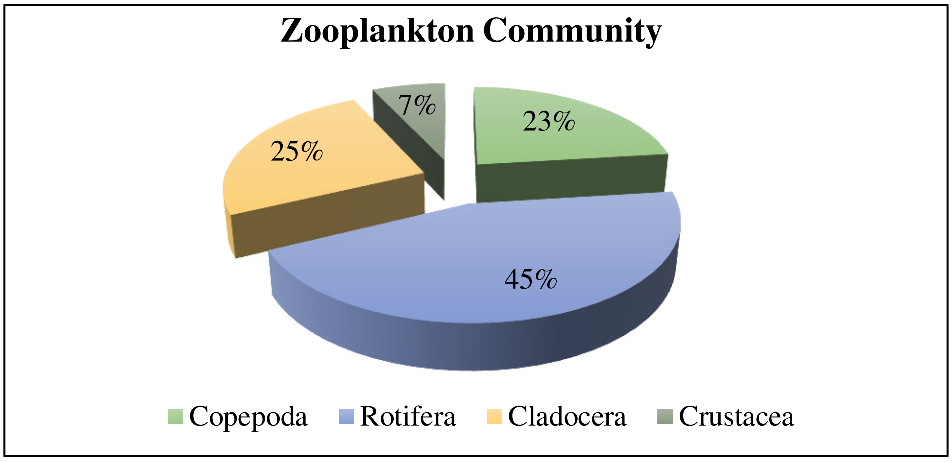
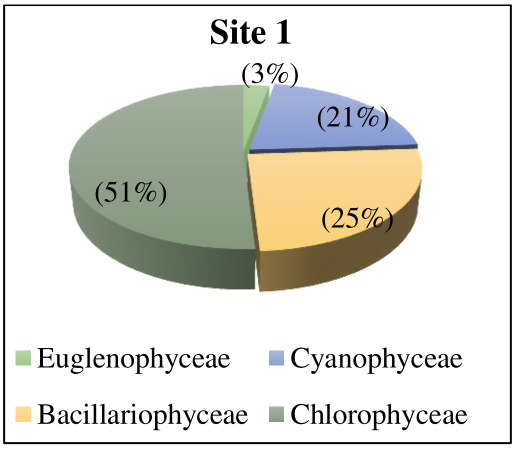
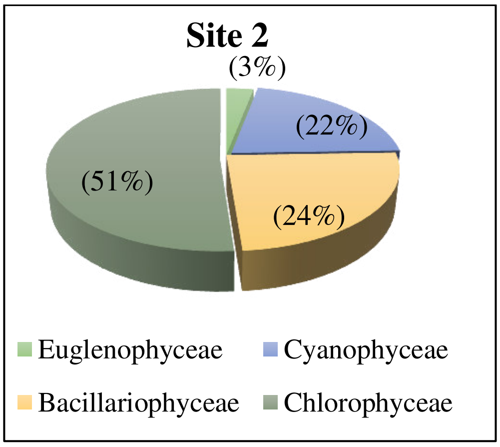


Figure 4.20 Percentage composition of zooplankton community at three sampling sites





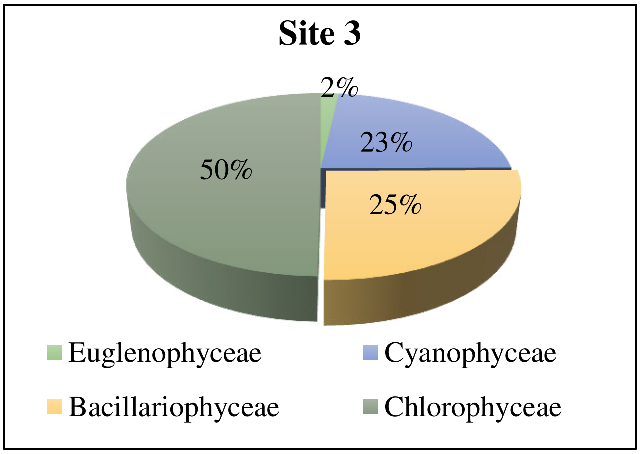


Figure 4.21 Percentage composition of different phytoplankton group at three sampling sites.

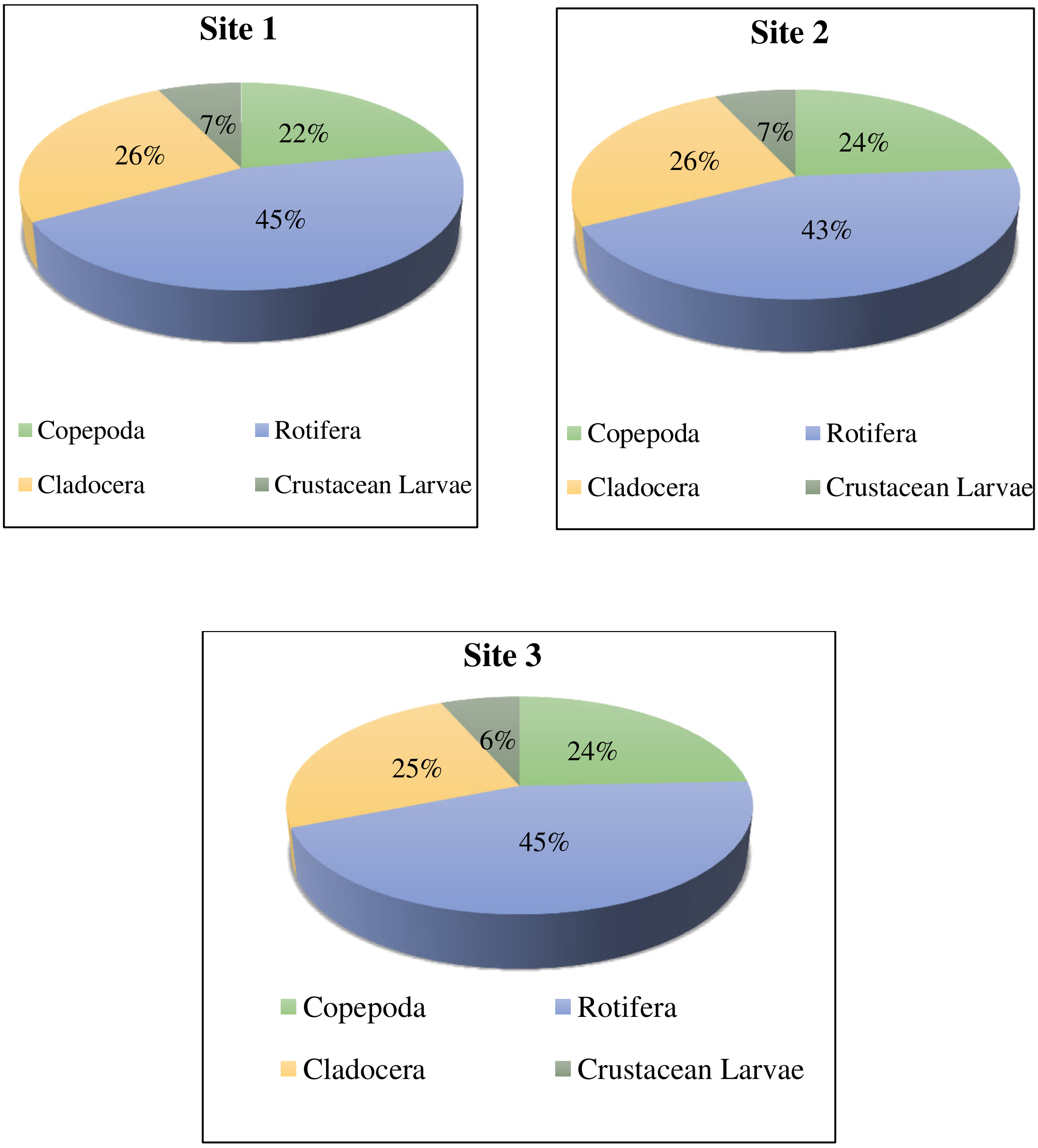


Figure 4.22 Percentage composition of different zooplankton group at three sampling sites.

4.4 Diversity Indices

4.4.1 Total phytoplankton

Shannon-Wiener Index

Fluctuation in the diversity of Shannon-Wiener index of total phytoplankton was observed throughout the sampling period. Little variation found among different sampling sites. Highest value of Shannon-Wiener index for total phytoplankton was 3.520 at site 3 during the month of February-2017 and lowest 2.503 in the month of July-2016 at site 2 (Figure 4.23). Fortnightly variation in the Shannon-Wiener index of total phytoplankton group at different sampling sites of Atrai river is shown in Figure 4.23.

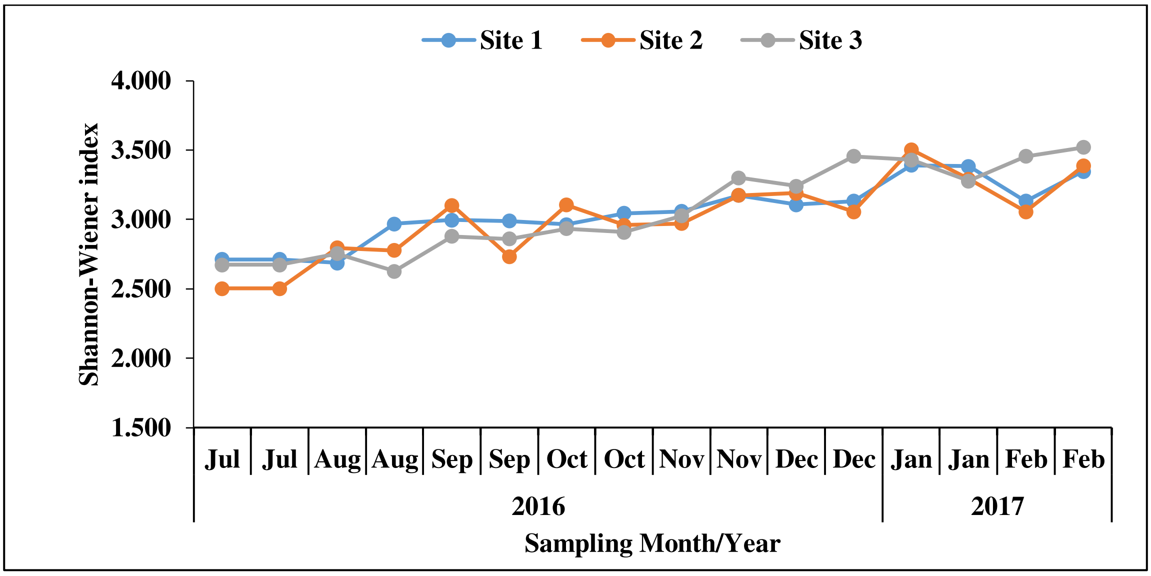


Figure 4.23 Fortnightly variation in the Shannon-Wiener index of total phytoplankton group at three sampling sites

Evenness index

Figure 4.24 representing the fortnightly variation in the Evenness index of total phytoplankton at different sampling sites of Atrai river. The value of Evenness index in the sampling sites was between 0.884-0.941. Highest value was found at site 1 during the month of January-2017 where the lowest was in July-2016 at site 2 (Figure 4.24).

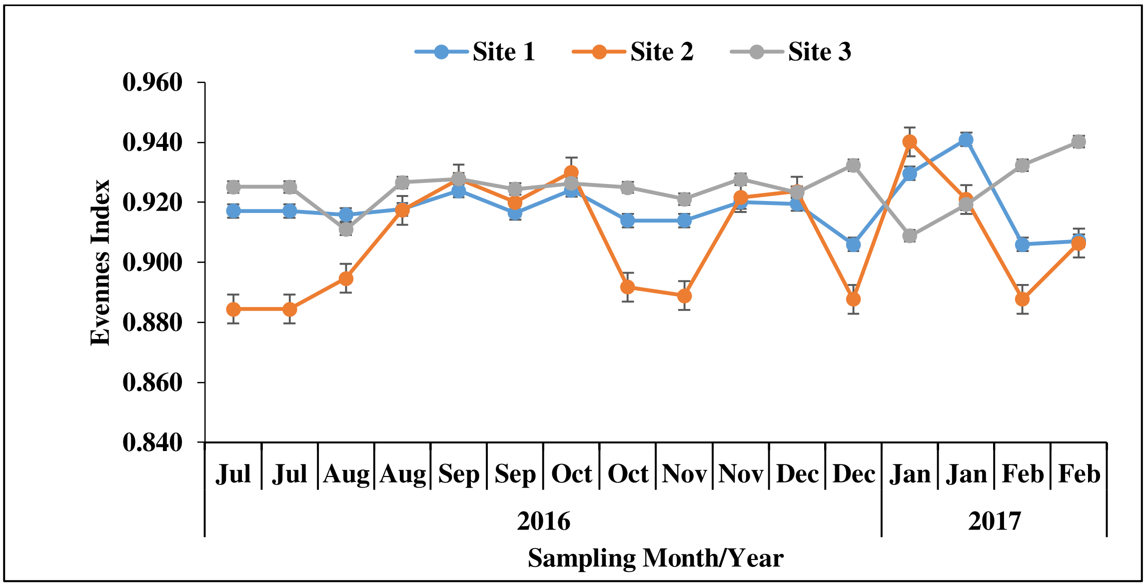


Figure 4.24 Fortnightly variation in the Evenness index of total phytoplankton at three sampling sites

4.4.2 Total zooplankton

Shannon-Wiener Index

The value of Shannon-Wiener index of total zooplankton is showed to be varied from 1.565-2.278, 1.677-2.295 and 1.468-2.292 at site 1, 2 and 3 respectively. Highest value of Shannon-Wiener index for total zooplankton 2.295 found at site 2 during the month of November-2016 and the lowest value 1.468 found at site 3 during the month of July-2016 (Figure 4.25). Fortnightly variation in the Shannon-Wiener index of total zooplankton at different sampling sites of Atrai river is shown in Figure 4.25.

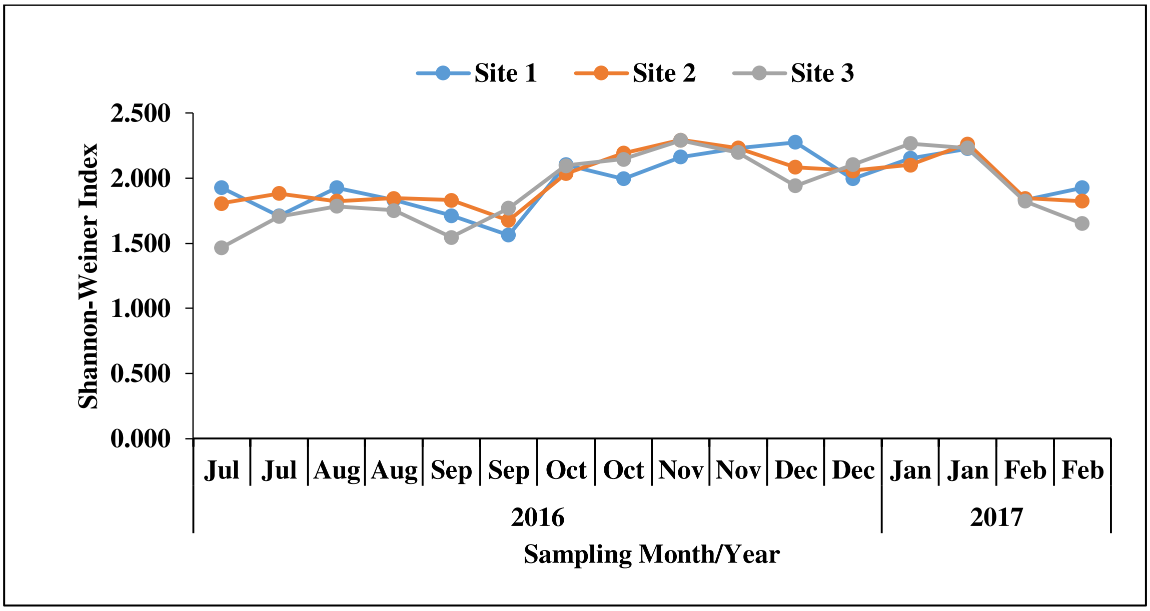


Figure 4.25 Fortnightly variation in the Shannon-Wiener index of total zooplankton at three sampling sites

Evenness Index

The fluctuation in the value of Evenness index for total zooplankton was relatively high than total phytoplankton. The value of Evenness index at site 3 show the highest value at majority of time during the sampling period. Figure 4.26 representing the fortnightly variation in the Evenness index of total zooplankton at different sampling sites of Atrai river.

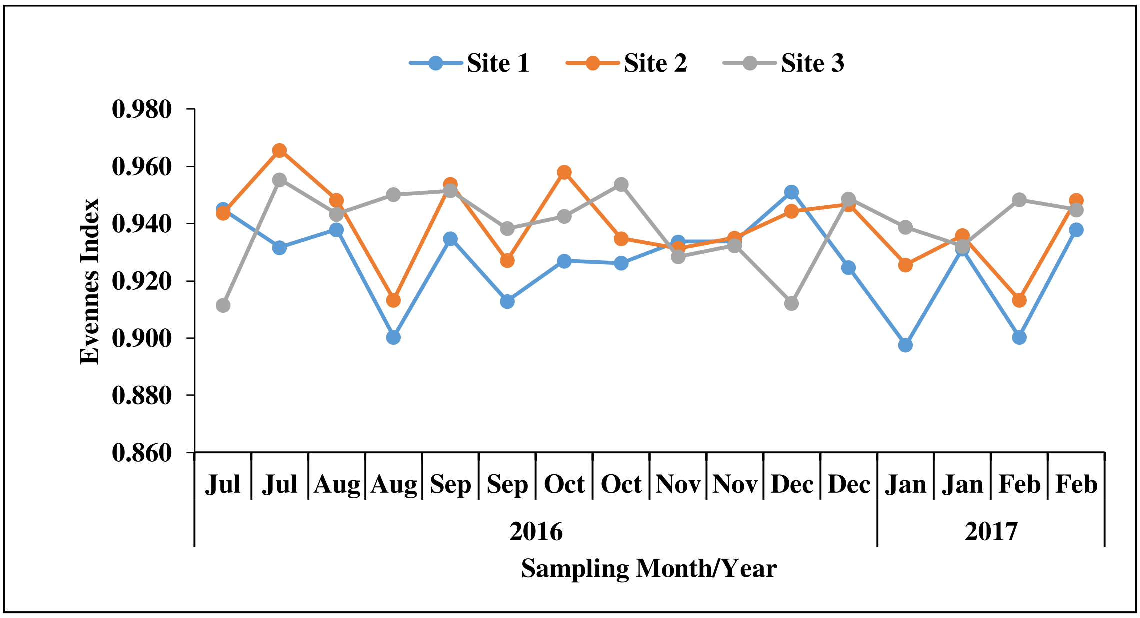


Figure 4.26 Fortnightly variation in the Evenness index of total zooplankton at three sampling sites

Table 4.7 Correlation among different physico-chemical parameters and plankton community.

Different Parameters	Water Temperature	Dissolved Oxygen	pH	Water Level	Alkalinity	Transparency	Total Phytoplankton	Total Zooplankton	Total Plankton
Water Temperature	1.00								
Dissolved Oxygen	-0.648(**)	1.00							
pH	0.326(**)	0.140	1.00						
Water Level	0.745(**)	-0.538(**)	-0.024	1.00					
Alkalinity	-0.934(**)	0.637(**)	0.358(**)	-0.729(**)	1.00				
Transparency	0.742(**)	-0.224(**)	-0.246(**)	0.735(**)	-0.735(**)	1.00			
Total Phytoplankton	-0.703(**)	0.499(**)	0.116	0.684(**)	0.684(**)	-0.590(**)	1.00		
Total Zooplankton	-0.527(**)	0.302(**)	-0.137	0.483(**)	0.483(**)	-0.582(**)	0.830(**)	1.00	
Total Plankton	-0.682(**)	0.467(**)	-0.057	0.656(**)	0.656(**)	-0.607(**)	0.990(**)	0.899(**)	1.00

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

4.5 Effects of physical-chemical parameters on plankton abundance

Table 4.7 is showing the effects of different physical chemical parameters on the abundance of plankton with the correlation between them. Temperature showed negative significant effects on the abundance of planktonic community. With increase in temperature significantly lowered (-0.692) the abundance of total phytoplankton (Table 4.7). Similarly water level also showed negative correlation with the abundance of plankton. Whereas, number of total phytoplankton, total zooplankton and total plankton found to increase with increasing dissolved oxygen. Moreover, highly alkaline water found to favour the growth of total phytoplankton, zooplankton and total plankton.

In addition, significant negative correlation observed among water temperature, dissolved oxygen and alkalinity. Water transparency has a significant negative relationship with total phytoplankton (-0.590), total zooplankton (-0.582) and total plankton (-0.607) whereas, significant positive (0.425) relationship with water level (Table 4.7).

CHAPTER V

DISCUSSION

CHAPTER V

DISCUSSION

Water is an indispensable natural resource which plays a vital role in the sustainability of life. Water quality is determined by various physico-chemical and biological factors, as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Moses 1983). The good river system on the other hand is determined by its plankton composition that gives more information on changes in water quality.

5.1 Physico-chemical Parameters

Study of physico-chemical parameters is a basic tool that contributes in making up of the ecosystems and determine the tropic dynamics of the water body. A minor change in physico-chemical parameters can influence the primary production (Sharma *et al.* 2007). The changes in water quality tend to change the living conditions especially in the number, diversity and distribution of the biota of the ecosystem (Sharma and Singh 2013).

Water temperature is thought to be one of the important factors that control aquatic life in a headwater stream (Wetzel 1983). Surface waters are subject to temperature variation due to fluctuation in sunlight and air temperature (Tchobanoglous and Schroeder 1985).Temperature is one of the important factors in environment since it regulates the various physico-chemical and biological activities (Kumar 1996). Water temperature of Atrai river found to range between 18.28^0C to 32.51^0C, 17.97^0C to 32.00^0C and 18.70^0C to 32.83^0C in three sites river which were near the ranges of water temperature recorded in Dhepa river (17.00-33.50^0C) of Dinajpur (Rakiba and Ferdoushi 2013) and 17.20-30.90^0C in Atrai River of Naogaon (Chaki *et al.* 2014).

Boyd and Lichtkoppler (1979) suggested that the clay turbidity in water to 30 cm or less may prevent development of plankton blooms, 30 to 60 cm and as below 30 cm generally adequate for good fish production. There is an increase in the frequency of dissolved oxygen problems when values above 60 cm, as light penetrates to greater depths encourage underwater macrophyte growth. According to Bhatnagar *et al.* (2004) turbidity range from 30-80 cm is good for fish health; 15-40 cm is good for intensive culture system and more than 12 cm causes stress. In the present study, transparency value was between 32-76cm which is equivalent to 6-21 NTU (Nephelometric Turbidity Unit). Highest value of transparency (74.67cm) was found at site 3 in the month of August-2016 and lowest value (34.67cm) was at the site 1 in the month of January-2017 during the sampling period. This values were a little bit higher than it ranged from a minimum of 9.62 NTU in May to a maximum of 31.90 NTU in December in Oti river in Ghana (Razak *et al.*2009). Same condition also noticed by Olele and Ekelemu (2008) in Onah lake of Nigeria. Low value of transparency was may be the dense growth of algae or plankton in the water column of site 1 located in the upstream of the river.

Highest water level at the sampling sites of Atrai river (2.36 m) found at site 2 in the month of July-2016 and lowest (1.03 m) was at site 3 in the month of February-2017. Variation of water level might be the cause of rainfall and some seasonal change .Water level fluctuate between 0.3m and 2.29m at beel Joshi in Rajshahi (Joadder 2012) and 0.23m-1.65m in Iril river in India (Singh *et al.* 2010). Similar results were also observed by in Nnamdi Azikiwe University (unizik) and Amansea streams in Nigeria (Charles 2016). Olele and Ekelemu (2008) also recorded highest mean water depth at narrowest site of Onah lake in Nigeria.

Dissolved oxygen is the measure of the amount of oxygen which is in solution in the water. The levels of dissolved oxygen in a stream are a direct indicator of overall stream health. It is an important environmental parameter that determines ecological health of a stream and protects aquatic life (Chang 2002). High dissolved oxygen is an important indicator of clean and healthy water. Dissolved oxygen (DO) levels decrease and primary production increases with increasing stream temperature (Chapra 1997). It is vital for aquatic organisms (USGS 2012). For healthy fresh water body at least 5 mg/l DO is essential (WHO 1971). In a healthy stream, dissolved oxygen levels of 5 to 6 ppm and above are necessary for normal growth and activity (GA DNR-EPD 2009). In the current study, highest mean value of dissolved oxygen was observed in site 1 followed by site 2 and 3 respectively. All values found to remaining within the suitable range according to World Health Organization (1971).

The pH required for most aquatic organisms to thrive is between 6.5 and 8.2 (GA DNR - EPD 2009).The recorded pH in the current research (6.70-8.73) compares well with all those of river Tano (6.34 -8.31), Semenyih river (7.07- 8.4), Oinyi river (6.8 -7.26), Oti river (7.87 -8.29). The result also very close to the required optimum pH for the good fish production 6.5-8.5 (Banerjea 1967) and within the recommended range (6-9) suggested by the (DoE 1997). Again the average pH value in the three sampling site was 7.81, 7.64 and 7.48 respectively which suit well with the average value of pH at Paddle Georgia and Jesup area 7.2 and 7.0 respectively in Altamaha river basin (Reyher 2013).

The alkalinity measurement is reported as milligrams per liter of calcium carbonate (U. S. EPA 2012). Alkalinity provides a buffering capacity to aqueous system. The higher the alkalinity is, the higher the buffering capacity against pH changes. Alkalinity indicates a solution's power to react with acid and "buffer" its pH that is, the power to keep its pH from changing. Recorded mean value of total alkalinity in the present study was 41.50, 36.88 and 33.63 respectively. The recorded alkalinity value was more or less same to the value of alkalinity in Onah lake (Olele and Ekelemu 2008).The value also indicate that the river water is a productive one (Mairs 1996).

5.2 Biological parameter

5.2.1 Plankton population

The abundance of phytoplankton in water bodies has been used as an important indicator of the impacts that aquatic ecosystems experience (Omar 2010).Over the last few decades, there has been much interest in the processes influencing the diversity, distribution and development of phytoplankton communities (Bhosale *et al*. 2010; Achary *et al.* 2010; Negi and Rajput 2011) primarily in relation to physico-chemical factors (Akbay *et al*. 1999 and Achary *et al*. 2010).

Phytoplankton is the productive base of the food chain in freshwater ecosystems and healthy aquatic ecosystem is dependent on its physical, chemical and biological characteristics (Venkatesharaju *et al*. 2010). Moreover, it is essential in maintaining good water quality. Phytoplankton affects oxygen levels, nutrient concentrations, light levels, and zooplankton biomass (Chien 1992). Farm managers often deliberately fertilize aquaculture ponds to stimulate phytoplankton blooms. These blooms shade stock, prevent growth of benthic algae (by shading the benthos), oxygenate water, reduce toxic ammonia levels and provide a food source for zooplankton which in turn can provide a food source for higher trophic levels that may be eaten by stock (Burford 1997).

Four major groups of phytoplankton were identified from Atrai river during study period. Kumar *et al.* (2012) calculated that 13 species of phytoplankton was belongs to bacillariophyceae. Bacillariophyceae showed 11 species and was found to be maximum in postmonsoon season and minimum in monsoon period. Thiruganamoorthy and

Selvaraju (2009) documented abundant count of bacillariophyceae in monsoon season which was lowered in premonsoon. In the current study 13 genera of bacillariophyceae was calculated which show similarity with the above result. Dominant phytoplankton group was chlorophyceae and rare group was euglenophyceae. Percent composition of chlorophyceae, bacillariophyceae, cyanophyceae and euglenophyceae was 51%, 25%, 22% and 2% respectively. Sharma *et al.* (2015) recorded total percent of abundance of chlorophyceae, cyanophyceae, bacillariophyceae and euglenophyceae were 47%, 27%, 23% and 3% respectively. The research finding was very close to the present study.

In the present study, chlorophyceae was dominant over other phytoplankton group by 19 genus. Sarwade and Kamble (2014) found that family chlorophyceae was dominating to others with 22 species in Krishna river. Chlorophyceae had algal diversity and it is one of the important indicator of water quality (Jena *et al.* 2008). Bhivgade *et al.* (2010) observed chlorophyceae as a dominant species than other planktons in Nagzari tank, Beed. Similar results were reported by Prescott (1939) and Patil *et al.* (1983). Kumar *et al.* (2012) recorded that there were 21 species belong to Chlorophyceae in Sabarmati river. Barhate (1985) and Zafar (1967) considered that high percentage of dissolved oxygen is favorable for growth and development of cyanophyceae and were re-corded with seven species at Nagzari tank. Cyanophyceae showed diversity of 10 species in Krishna river (Sarwade and Kamble 2014), 11 species of cyanophyceae Sabarmati river (Kumar *et al.* 2012). 9 genera of cyanophyceae was identified from Atrai river during the study period.

Euglenophyceae ranked as rare group of phytoplankton both in number and density. Only two genera of phytoplankton *Euglena* and *Phacus* under euglenophyceae were identified. Ekwu and Sikoki (2006) noticed 5 species of euglenophyceae belonging to 3 genera in Cross river estuary. 3 species found belongs to euglenophyceae in Sabarmati river (Kumar *et al.* 2012), euglenophyceae diversity is represented by single species in river Kshipra (Bhasin *et al.* 2016). The above result was more or less similar with the findings of Atrai river.

Rotifera were the most abundant group, representing more than 50% of the total zooplankton. (Sampaio *et al.* 2002). *Branchionus* was the dominant genus among the rotifers. Genus *Brancionus* indicate eutrophic aquatic body (Sladecek 1983) and hence its abundant presence is considered as biological indicator for eutrophication (Nogueira 2001). *Brachionus calyciflorus* is an indicator of nutrient rich status of a water body

(Berzins and Pejler 1987). A total of 45% rotifera from Atrai river is representing the closest result to the above finding.

Copepods play a key role in the food webs in the oceans and are known to be secondary producers. They make the link between phytoplankton and microzooplankton and higher levels of food chains, such as macrozooplankton and planktivorous fishes (Ohman and Hirch 2001; Calbet *et al.* 2001 and Frangouils *et al.* 2004). At the present study only 3 genera of copepods were found. On the other hand 10 genera of copepods found in the Mond river estuary (Hedayati *et al.* 2017). However, the findings of Atrai river was quite low than the abundance in Mond river estuary.

Cladocera represent by 4 genera of which *Daphnia* and *Moina* was dominant throughout the study period. Twenty species of cladocera belonging to 14 genera were recorded in the Shatt Al-Arab river (Ajeel and Abbas 2012). The results finding in Atrai river was extremely low than the identified genera of Shatt Al-Arab river.

5.2.2 Diversity Indices

Phytoplankton in the aquatic community serves as a food for development and growth of zooplankton. Phytoplankton diversity appeared as a paradox (Hutchinson 1967). Major diversity of zooplankton and phytoplankton composition vary with seasonal differentiation and production of meroplanktons as eggs, larvae and juveniles of the benthos, nekton, etc. (Walsh 1978).The Shannon-Wiener diversity index was used for the estimation of community diversity (Azeiteiro *et al.* 1999; 2000; Morgado *et al.*2003).

Shannon-Wiener index for phytoplankton found to be varied from 2.503-3.520 in the current study. Highest mean value of Shannon index for total phytoplankton was 3.520 at site 3 during the month of February-2017 and lowest 2.503 in the month of July-2016 at site 2. The value of Shannon-Wiener diversity index for phytoplankton was 0.34 to 5.78 in river Loire (Descy *et al.* 2012). Nyakweba and Migiro (2014) recorded the highest Shannon diversity index 2.573 at the Bridge in the month of November and the lowest Shannon index 1.1700 in Matemo for phytoplankton in the month of October from river Chepkoilel.

In the current study the value of Shannon index of total zooplankton was showed to be varied from 1.565-2.278, 1.677-2.295 and 1.468-2.292 at Site 1, 2 and 3 respectively. Highest value of Shannon index for total zooplankton 2.295 found at site 2 during the month of November-2016 and the lowest value 1.468 found at site 3 during the month of

July-2016 in Atrai river. The calculated value of diversity indices Shannon-Wiener index was 2.508, 1.592 and 2.116 in river Ossiomo. Highest value of diversity index found at the station 1 and lowest was at station 3 (Ikhuoriah *et al.* 2015).

The value of Evenness Index for phytoplankton in the sampling sites was between 0.884-0.941. Highest value was found at site 1 during the month of January where the lowest was in July at site 2. Evenness diversity index was from 0.9932 -0.7288 for phytoplankton in river Narmada (Sharma *et al*. 2015). The above value was within the range in river Narmada.

Highest Evenness index 0.9513 found at site 1 in the month of January-2017 and lowest diversity 0.846 found in the month of November-2016 at site 2. The diversity index for the plankton (H) ranged between 1.040 and 1.462 across habitats, while the evenness index ranged between 0.144 and 1.22 in Karangsong Mangrove Conservation Areas (Sihombing *et al.* 2017).

5.3 Correlation between physico-chemical parameters and plankton community of Atrai river in Dinajpur.

Study of correlation between biotic and abiotic factors is essential to gain the basic knowledge of trophic status of a water body. Several researchers have described temperature as a vital factor responsible for the growth of algae (Ramkrishnaiah and Sarkar 1982; Verma and Datta Munshi 1987; Kaushik *et al.*1991; Bohra and Kumar 1999).

In the current study DO, pH and alkalinity was positively correlated with phytoplankton abundance but negatively with water temperature, water level and transparency. Sharma and Singh (2013) showed a positive correlation among water temperature, pH, alkalinity and total phytoplankton but negative correlation with DO and transparency.

The relationship between the zooplankton and physico-chemical parameters thought to be responsible for the differences in species composition, abundance and diversity (Anago *et al.* 2013). Different zooplankton species respond differently at different physico-chemical parameters outside their tolerant limits (Ramachandra *et al.* 2006). Positive correlation among DO, alkalinity and zooplankton were observed in the present study where, water temperature, pH, water level and transparency were negatively correlated with zooplankton. Anamunda (2015) also recorded negative correlation among water temperature, pH and zooplankton but positive correlation with DO in Mweru-Wantipa, Zambia.

CHAPTER VI

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

The study revealed the variability of water quality parameters including water temperature, transparency, water level, dissolved oxygen, pH, alkalinity and diversity in a variable riverine system. Significant variation in water temperature was noticed according to sites. The temperature found to be varied from 18.28^{0}C - 32.51^{0}C, 17.97^{0}C - 32.00^{0}C and 18.70^{0}C - 32.83^{0}C in the site 1, site 2 and site 3 respectively. Mean value (±SD) of transparency at three sampling sites were 54.54±11.77cm, 58.00±11.69cm and 60.48±11.38cm respectively. Highest water level was recorded in site 2 in the month of July-2016. The main cause of high water level at site 2 might be the presence of a rubber dam near the site. The values of dissolved oxygen and pH were found within the optimum range throughout the study period indicating good water quality for the production of fish and plankton. Alkalinity of water during the sampling period was between 14-62 mg/l which was also in a productive range.

Total 57 genera of plankton were identified from Atrai river in Dinajpur of which 43 genera was phytoplankton and 14 genera was zooplankton. Phytoplankton represented by 19 genera of chlorophyceae, 9 genera of cyanophyceae, 13 genera of bacillariophyceae and 2 genera of euglenophyceae where zooplankton represented by 3 genera of copepoda, 6 genera of rotifera, 4 genera of cladocera and 1 genera of crustacean larvae. Chlorophyceae ranked the first position in abundance and number where, euglenophyceae recorded as the minor group of phytoplankton both in number and density. In addition, among zooplankton group, abundances of rotifera were found maximum during the month of November-2016 and January-2017. While few abundance of crustacean larvae was noticed throughout the study period. Temperature showed negative significant effects on the abundance of planktonic community. Dissolved oxygen and alkalinity was negatively correlated with water temperature among the sampling sites. Diversity of plankton was studied to know the quality of the water of Atrai river. Shannon-Weiner index and Evenness index were used to measure the diversity indices. Shannon-Weiner index was between 2.503 and 3.520 where, the Evenness index was between 0.884 and 0.941 for phytoplankton. In case of zooplankton Shannon index show the value from 1.468-2.295 but, Evenness index value was 0.898 and 0.966.

Recommendations

- Comprehensive study is required for understanding the variability of benthic communities in the Atrai river ecosystem.
- Study on the diversity of fish species can be focused to understand the trophic interaction in such riverine systems.

This study can be baseline to enhance our understanding on the trophic interactions and plankton dynamics in such variable riverine ecosystems in Bangladesh.

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