COMPARATIVE STUDY ON THE PHYSICO-CHEMICAL AND BIOLOGICAL DIVERSITY OF TWO URBAN LAKES OF DHAKA CITY

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Department of Zoology
University of Dhaka
Bangladesh

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By

Syed Lutfor Rahman

B. Sc. (Hons.) Fisheries, M. Sc. Fisheries, BAU
M. S. Aquaculture, AIT, Thailand

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A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D) IN ZOOLOGY [FISHERIES]

By

Syed Lutfor Rahman

B. Sc. Fisheries (Honours), M. Sc. Fisheries, BAU,
M. S. Aquaculture, AIT, Thailand

Department of Zoology
University of Dhaka
Bangladesh

January 2019

Declaration

I do hereby declare that the whole work submitted as a thesis entitled **“Comparative study on the physico-chemical and biological diversity of two urban lakes of Dhaka city”** submitted to the Department of Zoology, University of Dhaka in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Ph.D) is the result of my own investigation. No part of this thesis has been presented before for any degree, diploma or any other similar title to any university.

January 2019

Syed Lutfor Rahman
Ph.D. Research Fellow
Registration number: 54 Session: 2007-08
Re-registration number: 95 Session: 2016-17
Department of Zoology
University of Dhaka
Bangladesh

Certificate

This is to certify that the Doctor of Philosophy (Ph.D) dissertation entitled **"Comparative study on the physico-chemical and biological diversity of two urban lakes of Dhaka city**" submitted to the Department of Zoology, Faculty of Biological Sciences, University of Dhaka in partial fulfillment of the requirements for the degree. We also certify that this documentation is of real research work by the Ph.D fellow **Syed Lutfor Rahman**, registration number: 54 session 2007-08 and re-registration number: 95 session 2016-17 under our supervision. The work is original and to the best of our knowledge no part of this work has been submitted for any other degree or diploma from any institution of Bangladesh.

Dr. Md. Niamul Naser
Professor and Supervisor
Department of Zoology
University of Dhaka
Bangladesh

Dr. Md. Shahadat Ali
Professor and Supervisor
Department of Zoology
University of Dhaka
Bangladesh

DEDICATION

My loving wife, children,
brothers and sisters
for keeping me in their prayers

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ABSTRACT

The present study was conducted from April 2010 to March 2013 in two urban lakes, Ghulshan lake and Dhanmondi lake to determine the limnological quality, heavy metals of water and sediments and diversity of plankton and benthos.

Water quality results showed that the Gulshan lake water were higher values of ammonia-nitrogen, alkalinity, hardness, conductivity, total dissolved solids, biological oxygen demand and chemical oxygen demand. Dissolved oxygen and transparency showed higher values in the Dhanmondi lake. Water depth, air temperature, water temperature, carbon dioxide and pH values recorded normal values.

In the Gulshan lake water depth, dissolved oxygen, pH, carbon dioxide, alkalinity and hardness were not statistically significant differences in three years data. Air temperature, water temperature, transparency, ammonia-nitrogen, conductivity, total dissolved solids, biological oxygen demand and chemical oxygen demand values of the Gulshan lake shows statistically significant differences. In the Dhanmondi lake water depth, air temperature, water temperature, dissolved oxygen, pH, hardness, conductivity, total dissolved solids, biological oxygen demand and chemical oxygen demand values were not statistically significant differences in three years data. Transparency, ammonia-nitrogen and alkalinity values showed statistically significant differences in the Dhanmondi lake water.

In comparison of the two lakes in first year air temperature, water temperature, transparency, pH, carbon dioxide and hardness values were showed no statistically significant differences between Gulshan and Dhanmondi lakes. Water depth, dissolved oxygen, ammonia-nitrogen, alkalinity, conductivity, total dissolved solids, biological oxygen demand and chemical oxygen demand values showed statistically significant differences between the Gulshan and Dhanmondi lakes. In second year water depth, air temperature, water temperature, dissolved oxygen, pH, carbon dioxide and hardness values were not statistically differences among two lakes. Others parameters values showed statistically differences. In third year water depth, transparency, dissolved oxygen, ammonia-nitrogen, alkalinity, conductivity, total dissolved solids, biological oxygen demand and chemical oxygen demand values showed statistically significant differences. Others parameters were not statistically different among two lakes.

Among heavy metals of lake water Chromium and Nickel were found not detection level in both the lakes. Other heavy metals Cadmium, Zinc, Copper, Lead and Manganese were found higher level in the Gulshan lake water. Among them Manganese was detected higher values while Cadmium showed minimum values. Heavy metals of water like zinc, lead, cadmium, copper and manganese were recorded higher concentrations in the Gulshan lake water compare to the Dhanmondi lake.

Sediments heavy metals Lead showed higher concentration and Cadmium were found in minimum during the study period. Zinc, Chromium, Copper, Nickel and Manganese were present in both the lake sediment. All heavy metals were recorded higher concentrations in the Gulshan lake sediments than the Dhanmondi lake sediments.

Average total plankton density was higher in the Gulshan lake. The phytoplankton was about 80% and their density ranged between 14532 to 42200 ind/L in the Gulshan lake. In the Dhanmondi lake phytoplankton contributed 55% out of total plankton and density ranged between 821 and 2386 ind/L. The major groups of phytoplankton were Cyanophyceae, Chlorophyceae and Bacillariophyceae. Zooplankton density ranged between 4720 to 10515 ind/L in the Gulshan lake. In Dhanmondi lake density ranged between 710 and 1580 ind/L. Zooplankton fauna comprised of Protozoans, Copepods, Cladocera and Rotifers. Statistically highly significant differences were recorded in both phytoplankton and zooplankton among two lakes.

Benthos population in the Gulshan lake ranged from 950 to 2237 ind/m^2. In the Dhanmondi lake it ranged from 862 to 1930 ind/m^2. Benthic population was higher in the Gulshan lake where bivalve molluscs were very few in number. The following groups and species were identified from benthic organism. Chironomids: *Chironomus* sp larvae (Red blood), *Chironomus* larvae (others); Oligochaetes: *Lumbriculus* sp, *Nais* sp, *Tubifex* sp, *Chaetogaster* sp, *Branchiodrillus semperi*, *Branchiura sowerbyi*, *Aelosoma* sp; Molluscs : *Lamellidens* sp, *Bellamya bengalensis*, *Brotia costula*, *Terabia* sp. Benthic organism shows statistically highly significant differences among two lakes.

The diversity of fishes in the lake was limited. The Dhanmondi lake is partially used for sport fishing and thus major carps and some exotic fishes were introduced. In the Gulshan lake some exotic species like, Thai pangus (*Pangasiodon hypopthalmycthyes*) and Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) were found. Both the lakes were infested with an exotic aquarium fish named Sucker fish (*Catostomus commersonii*).

The Gulshan lake water was moderately polluted throughout the year. The Dhanmondi lake water was found pollution free. Contamination sources were the surroundings polluted materials that drained into the lake water.

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Chapter 1
Introduction

Bangladesh is a water-based country with many of the economical, commercial and recreational activities taking place around the water bodies. Though a small country, it's also a one of the most densely populated countries in the world today. However, Dhaka, the capital of Bangladesh, is one of the mega cities of the world with population more than 15 million. The largest Dhaka has numerous ponds, large lakes and open waters such as Bangabhaban lake (6 ha), Dhanmondi lake (70 ha), Gulshan lake (100 ha), Banani lake (50 ha), Dhaka Zoo lake (50 ha), Uttara lake (100 ha), Ramna lake (75 ha), Sangsad/Crescent lake (50 ha), Govt. owned other ponds (100 ha) and other private ponds (400 ha).

Among those water bodies, Dhanmondi lake and Gulshan lake are well-known. These lakes have been drastically altered because of increases in population density. Rapidly growing population and urbanization activities are greatly disturbing the ecosystem of these water bodies. Water is the most important component for raising fish. Fish are totally dependent on water; they derive oxygen from it, ingest it, excrete their wastes into it, absorb and lose salts into it, and are always in contact with it. Poor water quality can cause massive fish kills and is often the major factor contributing to fish diseases. Water quality does not remain constant. Water quality is directly related to productivity of water body, the growth and production of fish even life and death of them. Water properties are very important as they serve as the medium for living of the commercially important fishes and other fish feed organisms. Water quality is represented by some chemical and physical parameters that regulate aquatic life within a range. Major and rapid changes of these parameters may result in fish kills

Dhaka City Corporation waste dumping place is very near to these water bodies. Sewerage from dumping places and from the industrial mix increases the organic loads in sediments, degraded the water quality of urban water, makes the water unsuitable for household usages, fish culture and other purposes, and ultimately leads to the pollution, health hazards. Fish mass mortality is very common and regular in these city lakes.

Beside these water bodies, there are number of large ponds, beels, open waters, ditches and small river in the periphery of Dhaka. These water bodies are used in various purposes such as domestic uses, recreation, fisheries (both commercial and recreational), or aesthetics. Human activities are now a major force of affecting the ecosystem. The disturbances by human activities can generate severe disturbances for water bodies.

Rivers and lakes are very important part of our natural heritage also. They have been widely utilized by mankind such as drinking water, food, travel, recreation, wildlife habitat, connection to place, aesthetic appeal, economic development etc. over the centuries to the extent that very few if any are now in a natural condition. One of the most significant manmade changes has been the addition of chemicals containing a lot of heavy metals to the waters. Such inputs to water can be derived from a variety of sources some of them are obvious and others less so. They can be varied so that the concentrations of chemicals in water are rarely constant.

Earlier lakes in Dhaka have been the focus of extensive scientific enquiry over the past decade because of the social and environmental implications of degrading water quality with increasing levels of pollution (Quraishi 2010). The sources of these lakes flow through the middle of Dhaka becoming polluted with industrial effluents, municipal wastes, agricultural run-off, sewage and other hazardous substances with many human health and economic implications particularly regarding the poor and slum dwellers. Aquatic biodiversity also is threatened with many zooplankton being at risk of extinction.

Gulshan Lake is the northernmost lake in a chain of water bodies (Gulshan Lake, Hatirjheel, Begunbari Khal, Balu River and Shitalakhya River) in Dhaka, suffering from highly significant pollution. Gulshan lake is located $23^{\circ}48'$ N and $90^{\circ}25'$ E of Dhaka city. The length of the lake is 3.8 km which covers an area of 0.0160 km^2. It has an average depth 2.5 m and volume $12\times105m^3$. This study focuses on the assessment of water and sediment qualities of Gulshan lake, identification of sources of pollution and characterization of selected major outfalls of the Lake.

The lake is a channel-like elongated water body. The peripheral sides are northern at Baridhara southern at Tejgaon-Hatirjheel western at Gulsan-Banani and eastern at Badda area. Gulshan-Baridhara Lake was declared an Ecologically Critical Area (ECA) in 2001 to save the water body from becoming further polluted and to protect it from encroachment. The lake has inlets through which it is connected with some old river channel and is therefore affected by flood water during peak flooding seasons. Many drains and gullies discharge into the lake. Previous study revealed that among the heavy metals only Pb concentration exceeded the standard level during the monsoon other concentrations of all other four heavy metals (Cd, Cr, Cu and Ni) exceeded the standard level of drinking, fishing and surface water as set up by WHO, GOB, USEPA, DOE and FWPCA for the summer period. (Mohuya, 2010).

Most of the lakes of Dhaka city are now more or less occupied due to formal and informal settlements, the lakes are still an integral part of the eco-system. A lake from Latin lacus is a terrain feature a body of liquid on the surface of the world that is localized to the bottom of basin and moves slowly if it moves at all. They act as water retention basins during the Monsoon; and besides being the sources of biodiversity of the area, they are an important part of the scenic beauty. Dhanmondi and Gulshan lakes is the part of long demand of the urban dwellers for their physical as well as mental nourishment. The parks beside the lakes have also vision to restore the environmental quality enhancement of public facilities. Thousands of people of different ages visit both of the lakes every day. Among them some take exercise in groups or individually, but most of them walk along the walkways around the lake breathing fresh air.

Dhanmondi lake is situated in the middle of Dhaka City (23°43'N latitude and 90°26'E longitude). Beginning from Jigatola to road-27 and bounded by the Mohammadpur-Lalmatia area in the north, Satmasjid Road in the west, Bangladesh Rifles gate in the south and in the east by Kalabagan residential area. It is 3 km in length, width varies from 35 m to 100 m with a maximum depth of 4.77 m and the total area of the water body is approximately 37.37 ha. There is one box culvert in the lake near Sukrabad area, which is the only outlet of the lake. The lake is under the management of several authorities looking after its various aspects. The Ministry of Works has its ownership the Fisheries Department looks after fishery development the Dhaka North City Corporation being the principal civic body exercises some responsibility in its improvement. The Department of Environment looks after the aspects of proper environment and protection of aquatic resources of the lake. In and around Dhanmondi lake some renovation works were carried out from 1998 to 2001 with a view to making the lake a pollution free recreation zone.

Dhanmondi and Gulshan lakes are precious assets of Dhaka city with unique regional characteristics. Apart from their scenic beauty they have great economical and environmental value. During extremely dry seasons the lakes retain considerable amount of water. These water bodies account for fisheries and provide a habitat for a wide variety of aquatic vegetation and birds. In the past the different parts of the Dhanmondi and Gulshan lakes have been drained through engineering interventions and turned into land for meeting growing housing and transportation demand of the locality. The adverse effects of such interventions have been deleterious to the environment. They have destroyed the fish and aquatic vegetables that thrive in the lake. They have also blocked the natural flow of water. In order to assist the natural processes of groundwater recharge maintenance of aquatic life and ecological balance and for turning the lakes and surrounding areas into recreational places planned development of the lakes is very much essential.

Gulshan a Persian word that means flower garden but now days Gulshan lake is nothing but a dirty sanitary and washing pool. Lake is surrounded on both the east and west shores with slums. These residents of the slums, lakes are used and been using as their washroom, toilet, as well as a source of household water. Gulshan lake in particular is the northernmost lake in a chain of water bodies (Gulshan lake, Hatirjheel, Begunbari khal) in Dhaka, suffering from highly significant pollution. However Gulshan lake is one of the major of few remaining water bodies of Dhaka city not only is its presence important for the sustenance of the eco-system it is also considered as major main source of groundwater recharge at those area.

Gulshan lake has a lot of prevailing pollution problems because of rapid urbanization and loss of sociological balance. The lake water is not properly maintained and it has lost its clarity and nutrient balance. Flood water runoff flows into these water bodies practically turning these into buffer flood control reservoirs except some pockets of transient after-logging. Drains and sewerage pipes dumping wastes in the Gulshan lake has been identified as major pollution problem by DWASA. The malodorous wastes tend to spill over when the roads are flooded. People do not come close to the water edge for their refreshment and recreation because of the ill-maintenance and poor treatment by the people themselves. It's a vicious cycle of human intervention in the nature's own state and the extreme consequences of nature bouncing back on the human being them.

Aquatic organisms need a healthy environment to live and have adequate nutrients for their growth. The productivity depends on the physico-chemical characteristics of the water body. The maximum productivity obtained when the physical and chemical parameters are at the optimum level. Water quality plays an important role in decision making process for pollution control. Researches on the water quality aspects are of permanent significance in developing fresh water quality. Therefore water quality is paramount factor in ecosystem productivity.

Contaminated sediments are significant for water pollution. Water is also a vital resource for agriculture, manufacturing and other human activities. In urban areas the careless disposal of industrial effluents and other wastes in river and lakes may contribute greatly to the poor quality of river water. Among environmental pollutants metals are of particular concern due to their potential toxic effect and ability to bioaccumulation in aquatic ecosystems. Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology to be toxic to living organisms.

Worsley *et.al.* (2006) is presented sediment pollution records from several small, urban, man-made lakes from Merseyside and Halton (N.W. England, UK). They demonstrate that lake sediments can be used to reconstruct atmospheric pollution histories that encompass the entire Industrial Revolution in last 250 years in the U.K. Regionally this was a period that saw the instigation development and subsequent expansion of major industrial activity such as iron and steel production petro-chemical manufacture and power generation followed by rises in road and air travel. Through the use of analytical techniques such as environmental magnetism together with 210Pb dating, urban lacustrine stratigraphic records illustrate that the types and levels of atmospheric pollution have changed temporally. The work promotes the ethos that such archives could be vital to our understanding of past, present and future relationships between human health and the environment.

Lake sediments in addition to peat and estuarine deposits act as repositories of atmospheric and catchment-based materials which can reveal archived environmental information. Furthermore they are particularly useful because by capturing atmospheric pollutants they retain a record of anthropogenic activity and natural change. However to date most research programs involving temporal reconstructions particularly atmospheric pollution have utilized sites in remote areas e.g. in upland locations that are often considerable distances from any potential sources of industrial output

Anthropogenic activities continuously increase the amount of heavy metals in the environment especially in aquatic ecosystem. Pollution of heavy metals in aquatic system is growing at an alarming rate and has become an important worldwide problem. Increase in population urbanization industrialization and agriculture practices have further aggravated the situation. As heavy metals cannot be degraded they are deposited assimilated or incorporated in water, sediment and aquatic animals and causing heavy metal pollution in water bodies. Therefore heavy metals can be bioaccumulated and biomagnified via the food chain and finally assimilated by human consumers resulting in health risks As a consequence fish are often used as indicators of heavy metals contamination in the aquatic ecosystem because they occupy high tropic levels and are important food source.

According to the World Health Organization (WHO, 2011) the common toxic heavy metals that can be of public health concerns include beryllium (Be), aluminium (Al), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), molybdenum (Mo), silver (Ag), cadmium (Ca), tin (Sn), antimony (Sb), barium (Ba), mercury (Hg), thallium (Tl) and lead (Pb). This beryllium which is the second lightest metallic element (an alkaline earth metal) after lithium with an atomic number of four as well as aluminums one of the most widely used industrial light metals with a density of 2.7 g/cm^3 and arsenic and selenium, which are not even metals but a metalloid and a non-metal respectively. These metals are found widely in the earth's crust and are non-biodegradable in nature. They enter into the human body via air water and food. Metals in environmental waters arise from both natural and anthropogenic sources. In many cases anthropogenic inputs of metals exceed natural inputs. Living organisms require some metals as essential nutrients including calcium, sodium, potassium, magnesium, iron, zinc, chromium, cobalt, copper, nickel, manganese, molybdenum and selenium. Excessive levels or certain oxidation states of some essential metals however are detrimental to living organisms. In addition to non-nutrient metals generally recognized as toxic such as antimony, arsenic, beryllium, cadmium, lead and mercury health based water quality standards will also include the nutrient metals chromium, copper, nickel, selenium and zinc all of which can be toxic at too-high levels or in certain oxidation states.

The direct contamination of aquatic systems by industries is wide spread and a source of considerable concern. Tannery, urea, newsprint, paper and pulp and jute mills are releasing untreated waters into lakes, rivers and nearby water bodies. Amongst the pollutants known to be discharged are mercury, lead, zinc, chromium and cadmium. Even at relatively low concentrations these pollutants are harmful to aquatic organisms. The high biological oxygen demand created by sewage effluents from densely populated areas in another source of water quality deterioration that adversely affects the fish production.

Heavy metal one of the most hazardous pollutants that can pose serious threat to human and environment. The concentrations of metals are increasing at an alarming rate due to boost of unplanned industrialization and urbanization. Though some metals are playing crucial role as micronutrients but the excessive amount exert negative impact at great extent. The existence of toxic heavy metals in the air, water and sediment can cause severe problems to all organisms because of their long persistence nature and bioaccumulation in the food chain. (Bhuyan and Islam, 2017).

Most human communities that surround lakes depend heavily on lake biodiversity and natural lake processes for their water, food and way of life. Similarly urban lake*s* are active aquatic ecosystems, storehouses for large quantities of water, sources of food, hydropower, recreation, home to an enormous range of biodiversity. Lakes are critically important to the people for nutritional security and livelihood. World's poorest people depend on freshwater biodiversity for their protein needs. In Malawi, Lake Malawi provides 70% to 75% of the animal protein consumed by both urban and rural communities. Lakes provide critical habitat for an amazing array of plants and animals including bacteria, fungi, algae, plankton, mussels, snails, crustaceans, insects, fish, amphibians, reptiles, birds and mammals. Lake biodiversity globally is severely threatened. Currently 30% of freshwater fish and over 800 other freshwater species are on the brink of extinction.

Jongkroy (2009) presents findings from a research on urbanization and changes of settlement patterns in the peri-urban areas of Bangkok metropolis completed in mid-2008. The research objectives were to investigate population dynamics, and changes of economic base and settlement patterns in peri-urban Bangkok; and to obtain an understanding on existing conditions of urbanization. To analyze how the peri-urban areas have transformed over the year 1988 › 2007; statistical data on population and gross provincial products were used together with direct field observations and interpretation of satellite images from landsat TM 5. The empirical evidences gathered in 2008 highlighted that peri-urban Bangkok has been in urbanization stage whereas the metropolitan region as a whole was in the stage of suburbanization indicating by the high rate of population growth in peri-urban areas, by transforming economic base to non-farming economy and by rapid expansion of built-up areas. The expansion of built-up areas reflects the changes of settlement patterns being characterized as concentration by increasing density in the eastern side of the Chao Phraya River and as de-concentration to new areas by clustering around provincial centers along major roads and rivers and sprawling in agricultural areas. So far these changes have generated a number of problems in the peri-urban areas of the Bangkok Metropolis. Recommendations were to encourage planning agencies to use urban planning strategies in promoting agglomeration of settlements that would help alleviating problems from insufficient provision of basic services. The need to improve local government staffs coordination skills regarding urban management and administration was also suggested. Moreover, each province should develop database system for urban development planning so that decisions on the prioritization of problems, problem solving and spatial planning strategies can be made in an efficient way.

Human alterations of flow regimes alteration of water stores in lakes, introduction of pollutants and nutrients into waterways disrupt the biogeochemical process. Aquatic particles derived from either biogenic or detritus pathways are deposited in the sediments, extensive chemical, microbial and physical transformation occur by the biological degradation of natural organic matter. Water body can become eutrophic to excessive inputs of nutrients from point or non-point sources, primarily phosphorus and nitrogen, and can occur under natural or manmade conditions. Therefore the onset of eutrophication is marked by strong links between biota in the water column and sediments which in turn lead to changes in sediment invertebrate biodiversity and abundance as well as change in microbial processes. The resultant increase in fertility of affected water bodies causes symptoms such as algal blooms, heavy growth of rooted aquatic plants (macrophytes), algal mats, deoxygenating and in some cases unpleasant odour which often affects most of the vital uses of the water such as water supply, recreation, fisheries both commercial and recreational or aesthetics. In addition lakes become unattractive for bathing, boating and other water oriented recreations. Most often economically and socially important species decline or disappear and are replaced by coarser fish of reduced economic and social value.

Zooplankton are small animals that float freely in the water column of lakes and whose distribution is primarily determined by water currents and mixing. The zooplankton community of most lakes ranges in size from a few tens of microns (Protozoa) to >2 mm (macro zooplankton). Fresh water zooplankton is dominated by four major groups of animals. These are protozoa, rotifers and two sub-classes of crustaceans, the cladocerans and copepods. Little is known about the productivity of planktonic protozoans. However under certain circumstances flagellate, rhizopod and ciliated protozoans make a substantial component of zooplankton communities. The rotifers are also the major components of zooplankton. Ali and Chakrabarty (1992) reported 100 species of planktonic rotifers from waters of Bangladesh. Zooplankton play a pivotal role in aquatic food webs because they are important food for fish and invertebrate predators and they graze heavily on algae, bacteria, protozoa, and other invertebrates. Zooplankton communities are typically diverse (>20 species) and occur in almost all lakes.

However zooplankton communities are typically diverse and occur in almost all lakes. They are important communities of aquatic ecosystem which are also connected with the terminal biological production. In the consumer food chain of aquatic ecosystems it plays an important role in the transfer of energy from the primary producer to the fish and it constitutes an important food item of omnivorous and carnivorous fishes.

Organisms living in the bottom sediments of the water body is called benthos. The benthic animals are conveniently divided into filter feeders (eg. Mussels) and deposit feeders (eg. Snails) (Ameen *et.al*, 1986). Benthic macro-invertebrate also play a vital role in aquatic ecosystem. Biological potentiality of an aquatic system depend on the biomass of the plankton and benthos. The knowledge on the abundance, composition and seasonal succession of the same is a prerequisite for the successful management of lake.

Benthic macro-invertebrates constitute an important intermediate link between phytoplankton, zooplankton and the fish stock in the food chain. Assessment of monthly fluctuation in abundance of benthos may lead to the assessment of bio-nutrient status of productivity in the aquatic habitat. In order to assess the tropic base for fishes, knowledge of net production and assimilation by benthic species is necessary. Many benthic organisms are important not only as fish food but also in that they take part in the process of biological water purification. They are also the basic sources of other bio-living in media. It indicates the productivity of water bodies (Latifa *et.al*. 1997). The distributions of seasonal variations of the benthic fauna are interesting. The abundance and distribution varies with depth in relation to physico-chemical factors and also with the change of seasons (Habib *et.al* 1984a).

The knowledge of the benthic fauna is also essential for the proper management of the environment as it constitutes a part of the biological environment. The functional role of benthic communities in the tropic dynamics through the detritus food chain of the lake ecosystem is well known. The bottom fauna plays a significant role as food for most of the bottom dwelling fishes and recycling of materials in the ecosystem concerned and overall biological productivity of the natural water is dependent on the abundance of benthic fauna.

Conservation of freshwater resources has now become an issue of global concern because water is one of the vital resources to the modern society. Bangladesh because of its geographical location holds adequate reserves of freshwater but due to excessive population pressure very few of her water bodies retain good water quality and aquatic biodiversity. Manmade lakes like Dhanmondi and Gulshan are vulnerable towards the disposal of organic matter and sewage inflows which makes the lake water very rich in organic matter and to support a luxuriant algal bloom almost all over the year. This nuisance actually hampers the main goal of creating such a water body.

Therefore as yet limited understanding and large gaps in our knowledge about these lake resources and environmental dangers and policy for pollution control and biodiversity conservation. Sound policy for the sustainable use of lakes and their resources should be basis in sound science. In term of water quality management there is a great values in investigating lakes. A cooperative permanent mechanism is needed to effectively manage lake environment and conserve biodiversity.

These study emphases on the assessment of physico-chemical characteristics of water and sediment and biological diversity of the Gulshan lake and the Dhanmondi lake. Also make a comparative study on limnological parameters between this two urban lakes.

The specific objectives of the study are as follows:

1. Determine the physico-chemical parameters of water and sediment of the Gulshan lake and the Dhanmondi lake.
2. Determine the heavy metals of water and sediment of the lakes.
3. Assess the biodiversity status (plankton and benthos) of the lakes.
4. Comparison of limnological parameters of the lakes.

Chapter 2
Review of Literature

Lake is smaller than river. In a city lake is thought to be the store house of drain water, though some lakes may be kept free from the connection with drains. Lake water plays an important role to serve as many purposes like irrigation, aquaculture and livestock usage. Water quality is deteriorated day by day due to numerous of biological, physical and chemical variables causing water toxicity. When concentration of any element or compound exceeds the tolerance limit for organisms and other usage treated as pollutants. Bangladesh is one of the most density populated country of the world with population growth rate of 1.48 per annum (BBS, 2005). The people of Bangladesh have easy access to both surface and ground water supply to support their lives. In fact, water stands as a second available resource after human resources (Azad, 2003). Dhaka metropolitan city is expanding rapidly.

Dhaka city has one of the highest urban growth rates in the world. Every year population of Dhaka city is increasing due to large job opportunities which are inadequate in rural areas resulting the development of slums and squatters are continuously increasing which is also a cause of degrading the water environment (World Bank, 2000). A few days back, BBC telecast the lifestyle of polluted Dhaka city under the caption “Dhaka is the worst polluted city in the world”. In Bangladesh, lake water sources are being polluted for many reasons. Drain channeling lakes receives human waste (excreta), municipal solid waste, industrial waste, heavy metals etc. The average sanitation coverage in Bangladesh is around 43% which indicates that rest 57% of the 150 million people lack sanitation facilities (Ali, 2002a). Everyday 20,000 metric tons of faeces deposited in the open places of Dhaka city due to open defecation and hanging latrines pollute the water bodies like river, cannels, drains and ponds etc. (Ali, 2002b). These finally reach to lakes and thus lake water polluting happen.

Buriganga, Balu, Shitalakhya, Turag and Tongi river are the peripheral channels around Dhaka City receive large quantity of untreated sewage, industrial liquid and municipal waste everyday which leads to serious surface water contamination. (Rahman *et. al.,* 2013). They focus on the status of heavy metal concentrations of Cd, Cr, Ni and Zn in those peripheral rivers and canals. The presence of these heavy metals mostly crosses the standard limit and identifies water as adulterated. The concentration of lead (Pb) is found higher than the allowable limits and may be harmful for all the three cases. Concentrations of the selected heavy metals are higher than Bangladesh Standards for Drinking water in most of the cases for the five selected peripheral water bodies. Tannery and other industrial wastes, unplanned sewage system, medical wastes, nuclear and toxic materials mixing with drain water passes to lakes and thus polluting lake waters, threatening people's liver with health hazards related to toxicity (Abadeen, 2002).

Lakes in Dhaka have been the focus of extensive scientific enquiry over the past decade because of the social and environmental implications of degrading water quality, with many studies examining their increasing levels of pollution. The sources of these lakes flow through the middle of Dhaka becoming polluted with industrial effluents, municipal wastes, agricultural run-off, sewage and hazardous substances (Hossain *et. al.,* 2010).

Ahmed (2013) observed that pH was 5.23 to 7.42 in Gulshan lake. The spatial variation shows the pH increase slightly from upstream (Near Madani-avenue.) to downstream (Gulshan-Badda link road). The Lake water has been characterized by very low DO (mostly below 5 mg/l) & the high BOD_5 (up to 101.0 mg/l) indicated significant organic pollution. Among the other tested parameters-Color, TDS, Turbidity and TSS showed the most significant seasonal variation due to the influence of rain and storm runoff. The concentration of Color and TDS increased in dry season and concentration of TSS and Turbidity increased during the wet season.

Razzak *et al.,* (2013) reported that water of the Gulshan lake is severely polluted compared to the Ramna Lake. Sewage from the Badda, Baridhara, Gulshan and Banani residential areas along toxic discharges from the nearby industries have contaminated the water of Gulshan lake.They also observed that seasonal variation of lake water chemistry, due to pollution and water level affects its biodiversity (flora, fauna) and ecological stability and the same time ground water chemistry also varies with this.

Gulshan and Ramna lake was within the ECR standard in both spring and winter. Gulshan lake samples were found more turbid and colored in spring than winter. Iron in water samples was within the range where 5 day BOD was found higher in both Gulshan and Ramna lakes. Dhaka city is expanding day by day with the increasing rate of population nowadays it has become a regular event that lake areas are used up by the land grabbers resulted the lakes are becoming narrower day by day. Wetlands of Dhaka city has been squeezed so that the pollution has become a great threat (Razzak. *et al*. 2013).

Mokaddes *et al*., (2013) evaluated the level of water pollution and its influence on heavy metal contaminations of lake water of Dhaka metropolitan city. The results revealed that lakes of Dhaka city including Dhanmondi and gulshan lake, the concentrations of heavy metal of lakes water were recorded as pH=6.95, EC=22.44 (μscm^{-1}), Cu=0.018 ppm, Zn=0.274 ppm, Mn=0.084 ppm, As=0.002 ppb, Pb=0.002 ppm and Cd=0.044 ppm. The pH value of lakes water was found betweenm 5.34 to 7.68 an indication of slightly acidic to alkaline in nature. The also found average EC value for lakes water ranged from 17.61 to 34.61 μScm^{-1}, where EC value varied from 14.24 to 33.48 μScm^{-1} in the lake water.

Mokaddes *et al.*, (2013) also reported that the lakes of Dhaka metropolitan city including Dhanmondi and Gulshan contained acceptable amount of As, Zn, Pb, and Cd where Mn exceeded the recommended limit for drinking water, public water irrigation water and for aquaculture. In that sense it is hazardous for health, crops and aquaculture. All the water of lakes of Dhaka city can safely be used for specific purpose after proper treatment. Routine research work with wide public awareness government participation and government regulations can save the water of Dhaka metropolitan city and thus a safe and sound water environment can be made for future generations.

Lake water quality parameters such as pH, conductivity, metals (Na, K, Ca, Mg, Pb, Cd, Cr, Co, Ni, Cu, Fe, Mn, Zn) and 5 anions (F^{-}, Cl^{-}, CN^{-}, $SO_4$2- and $PO_4$3-) concentrations in Dhanmondi and Gulshan lakes were reported by Hossain *et al*., (2010). A clear seasonal variation was observed for K, Ca and for all anions except phosphate in both lakes. This study also confirmed that the levels of different toxic and essential elements were mostly remaining within the permissible limit. Although the concentrations were mostly below the established maximum permissible level, a systematic monitoring for toxic elements is recommended for their high toxicity.

Nayek *et. al.,* (2017) focused on the comparative study and assessment of water quality of two constructed lakes, Aritar lake (east Sikkim) and Chaya Taal lake (west Sikkim), India. Their study showed that pH values of Aritar lake water was just below the neutral level (6.45), with higher dissolved oxygen (DO) content (2.3 mg/L) as compared to Chaya Taal (pH=7.7, DO=1.6 mg/L). Aritar lake water samples exhibited higher concentrations of total dissolved solids (TDS), total hardness (TH), chloride (Cl-), sulphate (SO42-), phosphate (PO43-), nitrate (NO3-)and soluble iron (Fe) content in comparison to water samples collected from Chaya Taal lake. The values of water parameters from these two lakes were very much under the acceptable range for surface water standards during winter and summer season, therefore not tend to have any effect/threat on biotic components of lake ecosystem.

Mohuya *et. al*., (2010) were studied the heavy metals viz., cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and lead (Pb) in the pelagic water of Gulshan-Baridhara lake during the summer and moonson seasons. They made observation that concentrations of Cd, Cr, Cu, Ni and Pb in the lake water varied from 0.068-0.091, 0.048-0.225, 0-6.135, 0-0.062 and 0.023-0.067 mg/l during the summer season and in monsoon the concentration of heavy metals varied from 0.016-0.019 mg/l Cd, 0.005-0.035 mg/l Cr, 0.002-0.018 mg/l Cu, 0.007-0.159 mg/l Ni and 0.052-0.151 mg/l Pb respectively. This study indicate that among the heavy metals only Pb concentration exceeded the standard level during the monsoon, otherwise concentrations of all other four heavy metals (Cd, Cr, Cu and Ni) exceeded the standard level of drinking, fishing and surface water as set up by WHO, GOB, USEPA, DOE and FWPCA for the summer period.

The physico-chemical parameters like pH, Electrical conductivity, total hardness, total alkalinity, Chloride, Sulphate, Sodium, Potassium, Mg and Nitrate were studied to analyze the potable ground water quality of the "The City of Lakes", Madhya Pradesh, Bhopal India. Better water quality was found in Post-monsoon season than Pre-monsoon season. Extent of pollution occurred due to over exploitation of ground water, urbanization and anthropogenic activities. (Jinwal and Dixit 2008).

Presence of trace heavy metals in the waters and sediments of River Dakatia in Chandpur district of Bangladesh were reported by Hasan *et. al.*, (2015). Highest concentrations of Pb, Cu, Mn and Zn were found in water. The highest concentrations of Cu, Fe, Cr, and Zn were found in sediment also. The water quality of Dakatia River was fairly good in order to sustain life and also water was in a condition to be used for different purposes.

In Buriganga river of Bangladesh concentration of total chromium, lead, cadmium, zinc, copper, nickel, cobalt and arsenic in water samples were greatly exceeded the toxicity reference values. Concentration of chromium, lead, copper and nickel in sediment samples were mostly higher than that of severe effect level values, at which the sediment is considered heavily polluted. On average 72% chromium, 92% lead, 88% zinc, 73% copper, 63% nickel and 68% of total cobalt were associated with the first three labile sequential extraction phases, which portion is readily bioavailable and might be associated with frequent negative biological effects. Enrichment factor values demonstrated that the lead, cadmium, zinc, chromium and copper in most of the sediment samples were enriched sever to very severely. The pollution load index value for the total area was as high as 21.1 in summer and 24.6 in winter season; while values above one indicates progressive deterioration of the sites and estuarine quality. The extent of heavy metals pollution in the Buriganga river system implies that the condition is much frightening and may severely affect aquatic ecology of river. (Mohiuddin *et.al.*, 2010).

Saha and Hossain (2011) determine the concentrations of five heavy metals (Pb, Cd, Cr, Cu, and Zn) in sediment from the Buriganga River. The ranges of the measured concentrations in the total sediments are as follows: 60.3-105.6 mg/kg for Pb, 0.4-1.6 mg/kg for Cd, 52.8-139.6 mg/kg for Cr, 70-346 mg/kg for Cu and 245-984.9 mg/kg dry weights for Zn and fine portion of sediments contain higher heavy metal concentration compared to total sediments. To assess metal contamination in sediment, US environmental Protection Agency's (USEPA) Guidelines were applied. The concentrations of Pb, Cu, and Zn in all sediment samples are above the EPA guideline for heavily polluted sediment and the concentration of Cd and Cr are fall in the criteria of moderately to highly polluted range. The metals contamination in the sediments was also evaluated by applying Index of geo-accumulation (Igeo), contamination factor (Cf) and toxicity characteristics leaching procedure test (TCLP test). TCLP test results showed that the Buriganga River sediments are not likely to leach hazardous concentrations of particular toxic constituents into the environment as a result of improper management.

Metal contamination in aquatic environments has received huge concern due to its toxicity, abundance and persistence in the environment and subsequent accumulation in aquatic habitats. Heavy metal residues in contaminated habitats may accumulate in microorganisms, aquatic flora and fauna, which in turn may enter into the human food chain and result in health problems (Cook *et al*., 1990; Deniseger *et al*., 1990).

The spatial and temporal distribution of heavy metals in water, sediment and fish (dry weight basis) of Buriganga River, Bangladesh were determined by Ahmad *et. al.*,(2010). In water concentration of Pb, Cd, Ni, Cu and Cr varied seasonally and spatially from 58.17 to 72.45µg/L, 7.08 to 12.33µg/L, 7.15 to 10.32µg/L, 107.38 to 201.29µg/L and 489.27 to 645.26µg/L respectively. Chromium was the most abundant in the water of Balughat during pre-monsoon, whereas, Cadmium was the most scarce in the water of Shawaryghat during monsoon. The sediment also showed spatial and temporal variation of Pb, Cd, Ni, Cu and Cr ranged from 64.71 to 77.13 mg/kg, 2.36 to 4.25 mg/kg, 147.06 to 258.17 mg/kg, 21.75 to 32.54 mg/kg and 118.63 to 218.39 mg/kg respectively. Among all the metals studied in sediment, Nickel was the highest at Foridabad during pre-monsoon and Cadmium was the lowest at Shawaryghat during monsoon. In six species of fish studied the concentration of Pb, Cd, Ni, Cu and Cr varied seasonally from 8.03 to 13.52 mg/kg, 0.73 to 1.25 mg/kg, 8.25 to 11.21 mg/kg, 3.36 to 6.34 mg/kg and 5.27 to 7.38 mg/kg, respectively. Of the five metals studied Pb concentration was the highest in Gudusia chapra during monsoon in contrast Cd concentration was the lowest in Cirrhinus reba during post-monsoon. Some of the heavy metals concentrations are higher than the recommended value, which suggest that the Buriganga is to a certain extent a heavy metal polluted river and the water, sediment and fish are not completely safe for health.

The pollution of the aquatic environment with heavy metals has become a worldwide problem during recent years because they are indestructible and most of them have toxic effects on organisms. Among environmental pollutants metals are of particular concern due to their potential toxic effect and ability to bioaccumulate in aquatic ecosystems (Prasanth and Mahesh, 2016, MacFarlane and Burchett, 2000 and Censi *et.al.,* 2006).

Heavy metals such as copper, iron, chromium and nickel are essential metals since their play an important role in biological systems, whereas cadmium and lead are non-essential metals, as they are toxic, even in trace amounts (Fernandes *et al*., 2008). For the normal metabolism of the fish the essential metals must be taken up from water, food or sediment (Canli and Atli, 2003). These essential metals can also produce toxic effects when the metal intake is excessively elevated (Tuzen, 2003). Heavy metals discharged into a river system by natural or anthropogenic sources during their transport are distributed between the aqueous phase and bed sediments. Sediments are regarded as the ultimate sinks for heavy metal cations (Gibbs, 1973).

Hart *et al.* (1988) demonstrated that the major amount of heavy metals was transported in particulate form (Pb, Zn, Sn) during a major flood event in the Annan River, Australia. Sediments not only act as the carrier of contaminants but also the potential secondary sources of contaminants in aquatic system (Calmano *et al*., 1990). The analysis of river sediments is a useful method to study the metal pollution in an area (Batley, 1989).

Changing environmental conditions in the system may render the remobilization of metals from sediments, Calmano *et al.,* (1990). Malo (1972) as well as Chester and Voutsinou (1981) has reported that metals in the surface of bottom sediments would be released into the water phase by physiochemical processes. Evidiently the higher the metal concentrations in the sediments the greater the quantity of metals that could be desorbed from the sediments (Surija and Branica, 1995).

Lee *et. al.,* (2004) reported urban creeks and lakes can be important habitats for a variety of aquatic life as well as an aesthetic resource to communities. A key component of this resource is the quality of water in these water bodies. This paper is devoted to a review of water quality problems in urban creeks and lakes associated with storm water runoff and other urban sources of pollutants. A discussion is presented of the characteristics of urban storm water runoff as they may impact the water quality-beneficial uses of urban creeks and lakes. Also information is presented on regulatory issues that need to be incorporated into cost-effectively controlling constituents that cause pollution–impairment of urban creek and lake water beneficial uses. A review is presented of current information on some aspects of approaches (BMPs) for managing urban creek and lake water quality. The conclusion from this approximately 50-page review is that very little is known about the impacts of chemical constituents that are present in urban storm water runoff on the beneficial uses of urban creeks and lakes. It is clear that exceedence of US EPA water quality criteria or state standards based on these criteria is likely a poor indicator of the impairment of beneficial uses of urban creeks and lakes. As discussed there is need for comprehensive studies on urban creeks and lakes to determine the impacts of residential and commercial area and street and highway storm water runoff. These studies can lead to the development of wet weather standards that can be used to more appropriately regulate chemical constituents in urban area and highway storm water runoff than is occurring today. These studies also provide the information needed to develop appropriate runoff management practices to control the significant water quality beneficial use impairments that are occurring in urban creeks and lakes due to chemical constituents in the runoff.

Hennya and Meutiab (2014) stated that the need to understand how the shallow urban lakes respond to the broad-ranging impacts of distinct types of lake surrounding and shoreline landscape development is becoming increasingly important especially associated with eutrophication problems to develop management strategy in maintaining urban lake's water quality. This study examines what important indicators related to distinct types of lake surroundings and shoreline landscape development affect an urban lake water quality in relation to nutrient and organic pollution. They examined the water quality of 9 urban lakes in megacity Jakarta with distinct types of lake surroundings based on the type of inhabitant around the lake catchment's area i.e. urban village (dense irregular residential housing), rural village (agricultural area and few residential housing), rural-urban village (mixed rural and urban village), sub-urban village (mixed planned residential and irregular housing with less green area) and urban-industrial area (mixed urban village and industrial area). Shoreline landscape development in lakes included natural shoreline (with green open space), natural-artificial shoreline (lack of green open space with concrete jogging tract) and artificial shoreline (no or less vegetated cover, concrete retaining wall and concrete jogging track). Lakes in rural village with natural shoreline and various types of vegetation in lake's demarcation area, lake littoral habitats are still well maintained indicated by the presence of submerged aquatic and emergent plants and spotted several types of dragonflies and butterflies. These lakes have good water quality with less turbid water, and low COD, TN, TP and chlorophyll-concentrations. The lakes were classified from mesotrophic to eutrophic. Two lakes were considered hypereutrophic with indication of blooming of toxic cynobacteria of microcystis. Although still receiving sewerage, storm water and agricultural runoff the lakes in this rural village type of lake surroundings with natural shoreline landscape can maintain better water quality than those in other types of lake surrounding and shoreline landscape. Vegetation coverage in lake's shoreline and littoral habitat elements such as the presence of submerged and emergent aquatic plants should be managed to improve water quality on urban lakes. These are the important factors for urban lake management strategy to conserve urban lakes.

A number of studies confirmed that sediment of the Shing Mun River in Hong Kong is the main sources of the river's unpleasant smell, resulting from the contamination by industrial, livestock and domestic discharges over the past (Chua *et al*., 1995; Hodgkiss, 1995). Their study also suggest that Water Pollution Control Ordinance establish by the government and it's proper implementation may very effective to control the major pollution sources resulting progressively improved from fair to good.

It is reported that the careless disposal of industrial effluents and other wastes in river and lakes may contribute greatly, to the poor quality of river water in urban areas (Chindah *et.al*., 2004; Emongore *et al.*, 2005; Furtado *et al.,* 1998 and Ugochukwu 2004). Among environmental pollutants, metals are of particular concern due to their potential toxic effect and ability to bioaccmulate in aquatic ecosystems (Censi *et al.,* 2006). Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, to be toxic to living organisms (Storelli *et al.*, 2005).

Singh *et. al.*(2016) reported from the earth observation data sets were employed to study the land use/land cover change in study area from year 2000–2010. Vegetation, built-up area and agriculture classes had shown maximum changes. The lake water samples were analyzed, and further, Water Quality Index (WQI) was computed to categorize the lake water. The average value of WQI is 64.52, 52.23 and 42.45 in premonsoon, monsoon and post-monsoon seasons, respectively. Generally, pre-monsoon samples have higher number of polluted samples. Moreover, we applied the multivariate statistical techniques for handling large and complex data sets in order to get better information about the lake water quality. Factor analysis and principal component analysis are applied to understand the latent structure of the data sets, and we have identified a total of four factors in pre-monsoon, three factors in monsoon and three factors in post-monsoon season, which are responsible for the whole data structure. These factors have explained that 90.908%, 89.078% and 85.456% of the cumulative percentage variance of the pre-monsoon, monsoon and post-monsoon data sets. Overall analysis reveals that the agricultural runoff, waste disposal, leaching and irrigation with wastewater, land transformation in the surrounding areas are the main causes of lake water pollution followed by some degree of pollution from geogenic sources such as rock weathering. Hence there is an urgent need of proper attention and management of resources.

Bioaccumulation and magnification is capable of Leading to toxic level of these metals in fish even when the exposure is low. The presence of metal pollutant in freshwater is known to disturb the delicate balance of the aquatic systems. Fishes are notorious for their ability to concentrate heavy metals in their muscles and since the play important role in human an nutrition, they need to be carefully screened to ensure that unnecessary high level of some toxic trace metals are not being transferred to man through fish consumption (Adeniyi and Yusuf, 2007). Anthropogenic activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystem. Pollution of heavy metals in aquatic system is growing at an alarming rate and has become an important worldwide problem (Malik *et al*., 2010). Increase in population, urbanization, industrialization and agriculture Practices have further aggravated the situation (Giguere *et al*., 2004; Gupta *et al*., 2009).

Britton *et. al.* (1977) stated that lakes are bodies of water formed in depressions on the earth's surface, and as such, act as depositories for a variety of chemical and biological materials. The study of lakes has become increasingly prevalent in recent years. Lakes are a valuable resource, and their multiple uses have made them susceptible to water-quality problems such as algal blooms, sediment deposition and fish kills. These problems are products of the eutrophication process (enrichment, aging and extinction of lakes), which is often accelerated by man. Therefore it becomes important to understand the properties and processes of lakes which govern lake enrichment and the measures available to control enrichment. Lakes are described in terms of their physical (light penetration, temperature, sediment and morphology), chemical (chemical constituents, plant nutrients and dissolved gases) and biological (plankton, benthos and nekton) properties. These properties are all interrelated and are important variables to measure to evaluate water quality. In addition lake processes such as photosynthesis, respiration, eutrophication and biogeochemical cycling are important factors in determining the sources and extent of enrichment and managing a lake for maximum benefit. Meeting demands for water of high quality requires a general knowledge of lake properties and processes coupled with lake-basin planning, watershed and lake management, and water-quality control. There are many lake-management and control practices but the best tools for quality control are preventive measures. Once extensive enrichment has occurred there are few management or control options available. As lake studies become more common sampling techniques for data collection need increased accuracy and consistency in order to make meaningful comparisons between different lakes. The report discusses the main factors involved in conducting lake studies. These factors include the types and frequency of measurements useful in lake reconnaissance studies and a review of literature on sampling equipment and techniques. A glossary of selected terms begins the report which is intended for guideline use by urban planners and managers.

As heavy metals cannot be degraded they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko, 2000) and thus causing heavy metal pollution in water bodies (Malik *et al*., 2010). Heavy metals can be bioaccumulated and biomagnified via the food chain and finally assimilated by human consumers resulting in health risks (Agah *et al*., 2009). As a consequence fish are often used as indicators of heavy metals contamination in the aquatic ecosystem because they occupy high tropic levels and are important food source (Blasco *et al*., 1999; Agah *et al*., 2009).

The scientists found that in Triveni lake, physicochemical parameters viz., water temperature, air temperature, pH, humidity, conductivity, free CO_2, total solid, dissolved oxygen, Total alkalinity, Total hardness, $CaCO_3$, Ca++, Mg++ were almost normal significantly varied studied. The results revealed that there was significant seasonal variation in some physicochemical parameters and most of the parameters were in normal range and indicated better quality of lake water. It has been found that the water is best for drinking purpose in winter and summer seasons (Rafiullah *et al*., 2012).

Zhiyi (2015) are studied main pollutants of the urban scenic river in Nanjing City. In the study area a total of 39 monitoring points are set in natural water around pumping stations and near the tail water of sewage treatment plant. Through the monitoring of pollution sources of receiving conventional index the pollution sources distribution and river pollution factors are detailed analyzed as nutrient salts, heavy metals and environmental endocrine disruptors. And sources of the pollution factors are analyzed by principal component analysis to get the main pollution factors in this channel.

Dahegaonkar *et al.* (2012) observed that the quality of water affects species composition, abundance, productivity and physiological condition of aquatic communities. The bottom fauna play an important role in the mineralization and recycling of organic matter. They also serve as good indicators of water quality. Biomonitoring is an appropriate technology which makes use of existing synthesized information already present in the form of animals and plants in an aquatic ecosystem. Hagan *et al.*, (2011) studied the water and sediment samples from the Densu River in Ghana to ascertain the water quality and results revealed that the pH values were ranged 6.55-7.33 which indicate the natural background level of 6.5-8.5. Total Dissolved Solids values ranged from 67.1-113.0mg/L and were below the World Health Organization recommended value of 1000mg/L.

Ahmad *et al*., (2010) stated the the spatial and temporal distribution of heavy metals in water, sediment and fish (dry weight basis) of Buriganga River, Bangladesh. In water concentration of Pb, Cd, Ni, Cu and Cr varied seasonally and spatially from 58.17 to 72.45µg/L, 7.08 to 12.33µg/L, 7.15 to 10.32µg/L, 107.38 to 201.29µg/L and 489.27 to 645.26µg/L, respectively. Chromium was the most abundant in the water of Balughat during pre-monsoon, whereas Cd was the scarcest in the water of Shawaryghat during monsoon. The sediment also showed spatial and temporal variation of Pb, Cd, Ni, Cu and Cr ranged from 64.71 to 77.13 mg/kg, 2.36 to 4.25 mg/kg, 147.06 to 258.17 mg/kg, 21.75 to 32.54 mg/kg and 118.63 to 218.39mg/kg, respectively. Also the study made observation that among all the metals in sediment, Ni was the highest at Foridabad during pre-monsoon and Cd was the lowest at Shawaryghat during monsoon.

It was also found that metals concentration *viz.*, Pb, Cd, Ni, Cu and Cr in fish species varied seasonally from 8.03 to 13.52 mg/kg, 0.73 to 1.25 mg/kg, 8.25 to 11.21 mg/kg, 3.36 to 6.34 mg/kg and 5.27 to 7.38 mg/kg respectively. Among Pb concentration was the highest in *Gudusia chapra* during monsoon in contrast Cd concentration was the lowest in *Cirrhinus reba* during post-monsoon. Some of the heavy metals concentrations are higher than the recommended value, which suggest that the Buriganga is to a certain extent a heavy metal polluted river and the water, sediment and fish are not completely safe for health (Ahmad *et al*., 2010).

Islam *et al.*(2014) examined Heavy metals viz., Pb, Cd, Cu, Cr, Zn and Ni in particular of water, soil and available fish species from Buriganga and Shitalakhya rivers**.** The higher amount of heavy metals found in soils viz., Pb varied between 29.04 mg/kg and 64.78, Cd varied between 0.31 mg/kg and 5.01 mg/kg, Cu varied between 40.13 mg/kg and 111.10 mg/kg, Zn varied between 75.19 mg/kg and 333.76mg/kg, Cr varied between 51.51 mg/kg and 118.14 mg/kg and Ni varied between 35.81 and 44.41 mg/kg over the whole year. A remarkable amount of Pb, Zn and Cr was recorded in the whole fish species collected from both rivers. In Buriganga Pb varied between 4.32 mg/kg and 31.51 mg/kg and in Shitalakhya 11.44 mg/kg and 17.03 mg/kg. Zn values ranged 3.95 mg/kg to 51.50 mg/kg in Buriganga and 6.29 mg/kg to 62.02 mg/kg in Shitalakhya. The similar trend of Cr was recorded at Buriganga and Shitalakhya and it's ranged 7.83 mg/kg to 21.72 mg/kg. Cu and Ni were found under acceptable level. This finding indicates a major threat to human health in regard to consumption of fishes of those rivers. Dissolved oxygen (DO) content of the river Buriganga was found only 1.1 mg/l and 4.6 mg/l in Shitalakhya during winter. NH_3, BOD, COD and conductivity were recorded very higher values both in winter and summer period. The lower survival rate of fishes in these rivers may directly relate to the lower level of oxygen content. In addition the study made observation that the water of these two rivers inhabitable for aquatic organisms during winter and summer periods. While during monsoon period water of these rivers were found fairly unpolluted and which may allow aquatic organisms to live it in that period.

Furhan *et. al.,* (2006) reported that inorganic elements and heavy metals concentration viz., sodium, potassium, magnesium, iron, nickel, cobalt, copper, cadmium, lead and zinc) of Kallar Kahar Lake water was nickel 0.117 $mg.L^{-1}$, iron 1.456 $mg.L^{-1}$, cobalt 0.061 $mg.L^{-1}$, copper 0.258 $mg.L^{-1}$, cadmium 0.024 $mg.L^{-1}$, lead 0.118 $mg.L^{-1}$ sodium 397.97$mg.L^{-1}$, magnesium 115.71$mg.L^{-1}$, potassium 28.29$mg.L^{-1}$ and zinc 1.41$mg.L^{-1}$.

Concentrations of five heavy metals (Pb, Cd, Cr, Cu, and Zn) for sediment from the Buriganga River were studied and results revealed that 60.3-105.6 mg/kg for Pb, 0.4-1.6 mg/kg for Cd, 52.8-139.6 mg/kg for Cr, 70-346 mg/kg for Cu and 245-984.9 mg/kg dry weights for Zn and fine portion of sediments contain higher heavy metal concentration compared to total sediments. Subsequently the concentrations of Pb, Cu, and Zn in all sediment samples were found above the EPA guideline for heavily polluted sediment and the concentration of Cd and Cr are fall in the criteria of moderately to highly polluted range (Saha and Hossain, 2011).

Mohiuddin *et. al.,* (2010) was found that the concentration of total chromium, lead, cadmium, zinc, copper, nickel, cobalt and arsenic in water samples of the river Buriganga were greatly exceeded the recommended values during summer and winter period. Subsequently, concentration of chromium, lead, copper and nickel in sediment samples were mostly higher than that of severe effect level values, at which the sediment is considered heavily polluted. On average 72% chromium, 92% lead, 88% zinc, 73% copper, 63% nickel and 68% of total cobalt were associated with the first three labile sequential extraction phases, which portion is readily bioavailable and might be associated with frequent negative biological effects. Enrichment factor values demonstrated that the lead, cadmium, zinc, chromium and copper in most of the sediment samples were enriched sever to very severely. The pollution load index value for the total area was as high as 21.1 in Summer and 24.6 in Winter season; while values above one indicates progressive deterioration of the sites and estuarine quality. The extent of heavy metals pollution in the Buriganga river system implies that the condition is much frightening and may severely affect the aquatic ecology of the river.

A study was conducted to determine the pollution level of water of Buriganga river by Moniruzzaman *et. al.,* (2009). Different water quality parameters such as pH, EC, TDS, DO, Cations (Na+, K+, Ca^2+, Mg^2+,NH_4+) and anions (HCO_3-, Cl-, SO_4-, PO_4-, NO_3-) were examined for water of each sampling points to monitor the level of these parameters where it exceed or within the permissible limit. Dissolved Oxygen (DO) concentration of water of Buriganga river was very low particularly in dry season (2-3 mg/l). Ammonium (NH_4+) and Nitrate (NO_3-) concentration near Hazaribagh, Sadarghat, Zinzira, Lalbagh, Kotouali and Shutrapur area were very high, which crossed the maximum permissible limit. In dry season the level of pollution was much high than wet season. It indicates the water of Buriganga was not safe for drinking purposes, irrigation, fisheries, recreational activities and various industrial uses for most of the times of year.

The contamination of water with heavy metals is a major environmental problem. Some of these metals are potentially toxic or carcinogenic at high concentrations and can cause serious health hazard if they enter into the food chain. Heavy metals like Cu, Zn, Mn, Fe, Ni, Cd, Cr, Co, Pb etc. are usually present in water at low concentration, but enhanced concentration of these metals have found as a result of human activities. Investigation have been made in different countries by different researchers on the extent of heavy metals pollution in surface water, ground water, sediment and vegetation (Zakir *et al*., 2012;Mohiuddin *et al*., 2010;Akbal *et al*., 2011;Zakir *et al*., 2012;Shikazono *et al*., 2012).

Gupta *et. al.,* (2011) reported from the three lakes of Jaipur, India; physico chemical parameters *viz*., temperature, pH, alkanity, hardness and dissolved oxygen were found to be on the higher side at Jalmahal Lake as compared to Amer and Galta Lake. The Jalmahal lake water was highly polluted and was found to be unsuitable for drinking and propagation of wildlife and fish culture. Amer lake water was also polluted but Galta Lake was less polluted as the parameters analyzed were within the permissible limits.

Water quality parameters of Surha lake of Uttar Pradesh, India was assessed by Mishra *et. al*., (2015). They found average CPI was 0.98, 1.11 and 1.16 in year 2006, 2007 and 2008 whereas NSFWQI were found as 47.25, 49 and 49.88 respectively. The results indicate that the water quality is polluted and the consistently rising from slight to moderate during 2006-08, due to increased input of domestic waste and agricultural runoff from the lake catchments. Therefore, the lake water is not suitable for drinking, bathing and other life supporting activity.

Limnological studies of Keenjhar lake were carried out by Lashari *et. al.*, (2009). The physico-chemical properties were reported as, temperature 18-33^{0}C, pH 7.3-8.9, alkalinity 160-240 mg/l, minimum chlorides 30-85mg/l, conductivity 320-496 µS/cm, total dissolve solids were 240-391 mg/l, turbidity was 30 to 78 NTU, dissolve oxygen was 7.0-9.0 mg/l, calcium 50-78 mg/l, magnesium 21-35 mg/l. Concluded that the variation in parameters were due to rain and flow of River Indus.

Some limnological parameters of water of Dhaka-Narayongonj-Demra (DND) dam canal were studied by Habib *et. al.*, (2013). Water temperature was 18.3-31.5°C. Water transparency was 24.56- 38.1cm. The concentration of dissolved oxygen was 4.0-6.8mg/l. The BOD was 15-34mg/l. Free CO2 was recorded as 3.81 to 29.6mg/l. Hardness was 196.2-271.20mg/l. pH was found average 7.15. Although some water quality parameters of DND canal were found to be suitable for aquaculture but it was organically polluted.

Srivastava *et al.*, (2003) reported that the Jal Mahal Lake water was most polluted due to high pH, hardness, alkalinity, free Carbon dioxide and Zinc content and a low level of dissolved oxygen. Dewan (1973) made observation DO showed an inverse relationship with temperature and free CO_2 and positive correlation with pH and total alkalinity. The highest value of pH recorded during summer and winter and the lowest during monsoon.

Khan and Siddiqui (1974) investigated the seasonal changes in limnology in a perennial fish pond at Aligarh. The transparency was found to be affected by turbidity and phytoplankton crop. They observed in their study that the temperature was uniform at all the depths. Zooplanktons were mainly reported by Rotifers, Cladocerans and Copepods. They observed an inverse relationship between phytoplankton and zooplankton. The phytoplankton formed food for zooplankton.

Mahmood *et al.* (1976) made a study on the hydrology of the Karnafuli estuary. In their study the average value of water temperature for different months varied between 22.6^{0}C and 29.9^{0}C. Maximum water temperature (29.9^{0}C) was recorded in June and minimum (22.6^{0}C) in January. During their investigated area pH ranged between 6.9 and 7.8. The lowest value was recorded in September and the highest value in January. DO content varied between 3.62 mg/l in September and 4.97 mg/l in January.

Hussain *et al*. (1978) studied the relationship between primary productivity and some limnological parameters in a local pond in Mymenshingh. They found the maximum yield of gross primary productivity in the month of September and the minimum in the month of December in the pond and also found that primary productivity was more or less positively correlated with water temperature, pH, alkalinity, solar radiation and community respiration and inversely with water transparency. No correlation generally obtained between primary productivity and DO, water depth, sunshine, rainfall etc.

Shafi *et al*., (1978) studied the limnology of the river Meghna at Daudkandi and Chandpur. They found high value of nutrients in summer and early monsoon and low values in winter. DO and Free CO_2 showed favorable condition for aquatic life. The standing crops of plankton showed bimodal curves, presenting two maxima, one in May and other in October, and two minima, one in August and other in January. Mollah and Haque (1978) studied the monthly variation of plankton in relation to the physico-chemical conditions of water and bottom soil of two ponds. They reported that the physico-chemical characteristic of water was had some effects on the zooplankton.

Altogether 31 species of phytoplankton and 61 species of zooplankton were recorded from the wetland during August 2008 to July 2009. Among these, Chlorophyceae was the most dominant class in planktonic (54.84%) followed by Cyanophyceae (25.81%) and Bacillariophyceae (19.35%) while zooplanktonic rotifera constituted (75.41%) followed by copepoda (11.48%) and cladocera (13.11%). The seasonal abundance of planktonic communities in relation to wetland health was correlated and a slight seasonal variation occurs in certain physico-chemical parameters due to the surface run-off and other excessive human activities. (Abujam *et. al.*, 2011).

Senapati *et. al.,* (2011) studied on species diversity of phytoplankton of a semi-lentic water body its relation with physicochemical parameters to establish the occurrence of the various phytoplankton throughout the year. Species diversity index value 3.824, 3.701 and 3.354 in pre-monsoon, monsoon and post-monsoon respectively indicates the quality of the water body. Chlorophycean representatives are dominant mostly and Cyanophycean members are least in representation. Plankton density reaches its maximum level in monsoon time. This work demonstrates changes in phytoplankton diversity and expresses the possibilities of using these minute organisms as an indicator in biomonitoring system to determine the quality of water body.

Ali *et al*., (1980) studied the ecology and seasonal abundance of zooplankton in an artificial fish pond. The pH was found to fluctuate between 7.5-9.5 and dissolved oxygen varied from 12 to 22 mg/l during the experimental period. Rahman *et al*., (1982) studied the physico-chemical conditions in four selected ponds. The physico-chemical aspects investigated were area, average depth, temperature, dissolved oxygen, free carbon dioxide, pH, carbonate, bicarbonate, total alkalinity, phosphate, nitrate-nitrogen, calcium and magnesium. They found vertical variations in temperature and in all the chemical factors. They also observed water temperature, dissolved oxygen and pH values which were higher at the surface water than the bottom water and some of physico-chemical conditions were affected by heavy rainfall.

Sufi and Farooque (1983) studied the physico-chemical factors and nutrients in the ponds of Dhaka city. In their study, the data of temperature, pH, CO_2, O_2, N and phosphate indicated the existence of poor to average aquatic productive when compared with the data of the optimal condition of high yield fish pond. Khondaker *et al.* (1988) made a study on the primary productivity of Dhanmondi Lake showed the range from 0.17 to 2.71 O_2 mg^{-l-h}. They also measured the some important physico-chemical parameters of Dhanmondi lake. The water temperature ranged from 20^0C in mid summer to 29.5^0C in late summer. The range of secchi disc transparency was 23.8-48.5 cm (mean value 37.80 cm). The range of pH was 6.36-7.7 and alkalinity was 3.32-4.47 mg/l. Mean value of free CO_2 was 11.64 mg/l and mean value of under saturation of DO was 47.79%. Such much low secchi disc transparency, under saturation of DO and high content of free CO_2 indicate an overall deterioration of the water quality.

Ali *et al*., (1989) investigated on seasonal variation of physico-chemical conditions of water, plankton and benthic macro invertebrates in a pond of Dhaka. The water temperature varied from 20.5^0C to 36.0^0C and showed an alkaline tendency at pH 6.7 to 8.4. The highest value of free CO_2 was recorded during summer (42 ppm). The carbonate alkalinity varied from 3.2 to 24 ppm and the highest was noted in September. The bicarbonate alkalinity showed the peak value at 170 ppm in October. The dissolved oxygen content recorded high value in winter and early summer. During their investigation an inverse relationship was found between the density of phytoplankton and temperature whereas the zooplankton showed a direct relationship.

Khan *et. al.*, (1990) reported that the productivity of water bodies is related to pH. High seasonal pH condition in the water may pose some health hazards. Hardness of water is directly related with biological productivity. Hardness above 500mg/l is unsuitable for domestic use 170 mg/l is termed as good quality water. Naser *et al*., (1990) studied the physico-chemical conditions of two ponds stocked with Magur, *Clarias batrachus* (L.) showed that the parameters were related to each other. The weekly differences of the variables were interrelated in such a way that they were not affected by the population of fish but by the environment. The weekly fluctuations followed more or less similar interrelations observed in the monthly fluctuations.

Hasan *et al.*, (1994) analyzed the some physico-chemical parameters of Dhanmondi lake during the study period from September 1990 to August 1991. The temperature of lake water ranged from 20 to 31.5^0C with a mean value of 28.11 ± 3.35^0C. The pH value ranged from 6.7 to 7.8 with an average of 7.24 ± 0.35. The mean oxygen content in surface water of the lake was 6.75 ±1.21 mg/l with a range of 5.1 to 9.2 mg/l. The free CO_2 of the lake water varied from 1.3 to 6.9 mg/l with an average value of 4.25±1.86. Total alkalinity was ranged from 37-70.24 mg/l.

Khondaker *et al., (*1994) predicted the eutrophication status of Banani lake during the study period from December 1991 to November 1992. In their study 18 variables relating to water quality of the lake were assessed. Seasonal average of water temperature varied by 10.5 ^{0}C showing its minimum in winter and maximum in monsoon. The depth of visibility ranged between 0.2 and 0.9 m. The sestonic load was almost similar in summer and monsoon while it varied (by 26.6 mg/l) appreciably between winter and autumn. However, p^H did not show much change from winter to monsoon but it dropped to slightly acidic level (6.8) in autumn. Conductivity rose by 133.5 µs/cm in autumn from its previous season monsoon, winter and summer showed almost equal values of conductivity. Alkalinity was higher in autumn. Dissolved oxygen from winter to monsoon was close to the lower level of the range required for fishes (3.2-5.6 mg/l). It dropped to a lethal level (0.8 mg/l) in autumn. BOD_5 was high in winter (10.4 mg/l) and summer (14.5 mg/l). In other season it was low (about 8 mg/l). COD, silicate, Na and K content did not show major changes over the season.

Chowdhury *et al.*, (1998) conducted a study on the physico-chemical and biological conditions of a large canal receiving effluent from the Harian sugar Mills at Rajshahi during the sugar production period. They found higher water temperature, TSS, TDS, Chloride, hardness, conductivity and BOD values with anoxic condition which indicate a highly polluted condition of water. The specific status of limnological characteristic and diversity of plankton in lake Pichhola of Rajshtan, India have been studied by Riddhi *et. al.,* (2011) and reported that water remained moderately alkaline (pH 7.5) while electrical conductance (0.3958 mS/cm), TDS (237.5mg/l), chloride (176mg/l), hardness (174.33mg/l) and alkalinity (207.16mg/l) showed low mean values. Average dissolved oxygen levels were at 5.75mg/l while average nitrate and phosphate levels were 3.70mg/l and 2.79mg/l respectively. On the basis of water quality parameters in general, lake

Pichhola was found to be eutrophic. A high rate of primary production (302.085mgc/m^2/hr), diversity of phytoplankton (58 forms), zooplankton (104 forms) and fish (15 species) were also observed during the study period. Therefore, lake Pichhola has rich number of species and biodiversity of aquatic animals.

The diversity of phytoplankton and its relationships to the physico-chemical environment were studied by Ariyadej *et. al.,* (2004) in anglang Reservoir, located on the Pattani River in Southern Thailand. One-hundred and thirty-five species in seven divisions of phytoplankton were found. The greatest number of species were in division Chlorophyta (50%), followed by Cyanophyta(21%), Bacillariophyta (13%), Pyrrophyta (6%), Cryptophyta (4%), Chrysophyta (3%) and Euglenophyta (3%). The most diverse genus was *Staurastrum* (15 species). Phytoplankton density ranged from zero to 2.1x109 cells.m-3. *Microcystis aeruginosa* had the highest phytoplankton density.

Das and Bhuiyan (1974) recorded fifty seven species of planktonic organisms including 25 rotifers, 14 Cladocerans, 10 copepods, and 8 Ostracods from two ponds and two lakes of Dhaka city. The greatest abundance of plankton was observed in the months of April, May, October and the greatest depletion was observed in the months of August and January to February. Affan *et. al.,* (2005) studied the plankton diversity of an oxbow lake, beel in Dibrugarh district, Assam, India.. Altogether 31 species of phytoplankton and 61 species of zooplankton were recorded from the wetland. Among these, Chlorophyceae was the most dominant class in planktonic(54.84%) followed by Cyanophyceae (25.81%) and Bacillariophyceae (19.35%) while zooplanktonic rotifera constituted (75.41%) followed by copepoda (11.48%) and cladocera (13.11%). The seasonal abundance of planktonic communities in relation to wetland health was correlated and a slight seasonal variation occurs in certain physico-chemical parameters due to the surface run-off and other excessive human activities

Ismail *et al*., (1984) investigated on limnology and some aspects of biology of *Sarotherodon nilotica* (L.) in a pond at Jorain, Dhaka. They noted the general relationships among physico-chemical features and zooplankton. They found zooplankton higher in number (68.63%) than phytoplankton (31.37%) and was inversely related. Alfasane *et. al*., (2012) investigated limnology of lake Ashura. They reported air and water temperatures were 31.5±0.25ºC and 30.0±0.45ºC. Alkalinity, pH, conductivity, dissolved oxygen and TDS of water were 2.96±0.58 meq/l, 7.11±0.02, 760.67±8.08 µS/cm, 7.72±0.41 mg/l and 104.67±1.53 mg/l respectively. The concentration of NO_3-N, SRP and SRS were 63.33±25.16 µg/l, 11.60±1.60 µg/l and 14.36±0.25 mg/l respectively. The density of phytoplankton was 552.84×103 ind/l. A total of 35 species of phytoplankton were recorded of which 15 belonged to Euglenophyceae, followed by Chlorophyceae (8), Bacillariophyceae (7), Cyanophyceae (4) and Cryptophyceae. Macrophyte flora was represented by 31 species. The dominant species were *Eichhornia crassipes* (Mart.) *Solms, Ludwigia adscendens* (L.) *Hara and Oryza sativa* L.

Merla *et al*., (1985) determined the abundance of biomas and standing crop of zooplankton in ponds. They found that the zooplankton stock decreased with increasing standing fish stock. Patra and Azadi (1987) made a qualitative and quantitative study of plankton in relation to physico-chemical factors of the Halda river water. Zooplankton growth cycle was noticeably less than the phytoplankton abundance almost throughout their study period. Sharma, (2011) reported plankton of two floodplain lakes in Manipur, India revealed species rich zooplankton (121 species) with diverse nature of Rotifera (75 species). Zooplankton formed important quantitative component (56.0±4.3% and 55.1±5.1%) of net plankton of the two pats; Rotifera dominantly contributed to their abundance while Cladocera>Copepoda were sub-dominant groups. The richness and abundance showed significant variations between pats and between months and followed oscillating annual patterns in each pat except for peaks during winter.

Hasan *et al*., (1995) studied the seasonal occurrence of micro crustacean zooplankton in Dhanmondi lake, Dhaka. They reported 12 species of micro crustacean species of which 6 species belonging to Cladocera and 6 species to Copepoda. They found peak growth of micro crustaceans during winter (1775 units/l) and occupied 50.53% of the total. Copepods were found to be perennial while the Cladocerans were seasonal. Seasonally copepods showed maximum density (800 units/l and 462.5 units/l) in spring and summer which occupied 43.53 % and 25.17% of the total copepods, respectively. Copepods were dominated by *Cyclops scutifer* while the Cladocerans were by *Moinodaphnia macleayii.*

Chowdhury *et al.,* (1998) made a evaluation of plankton abundance in a canal receiving sugar mill effluent in Rajshahi during the sugar production period from February 1994 to April 1994. They reported 20 genera of zooplankton of which 16 protozoans, one Porifera and 3 genera of Rotifera. Protozoa formed 85.38% followed by Rotifera (14.7%) and Porifera (77%) of the total zooplankton abundance which were found to be pollution tolerant. *Trinema* sp. and Notholca sp. were the dominant among Protozoans and Rotifers respectively.

A total of 45 species were identified by Kumar and Oommen (2009) belonging to Cyanophyceae, Chlorophyceae and Bacillariophyceae but members of Euglenophyceae were found to be absent indicating a lesser degree of organic pollution. Moreover species of Bacillariophyceae were recorded to be the most occurred group compared to others throughout the study which shows relatively unpolluted nature of wetland. Seasonal changes in species composition and abundance of zooplankton in Chandbill baor of Meherpur were studied by Kabir and Naser (2008). A total of 59 taxa was identified of which 13 species were protozoans, 34 rotifers, eight copepods, three cladocerans, and one species belonged to ostracods. Rotifers were the dominant group with a monthly average of 1656.58 indiv./l (89.47%) followed by copepods with 119.33 indiv./l (6.45%), protozoans with 71.92 indiv./l (3.88%), Cladocerans with 3.42 indiv./l (0.18%) and ostracods with 0.33 indiv./l (0.02%), respectively. Zooplankton showed two distinct high peaks, one in February and another one in June. Annual zooplankton abundance ranged from 393 to 4460 indiv/l.

Sultana *et al*., (1999) studied the plankton composition and its seasonal dynamics in two urban ponds of Dhaka metropolis namely Shahidulla Hall pond and Museum pond. Annual total zooplankton standing crop of Shahidullah Hall pond and Museum pond were 6975 and 13790 indiv/l respectively. The highest number (2800 indiv/l and 1600 indiv/l) of zooplankton standing crop ware recorded in the month of June in Museum pond and Shahidullah Hall pond, respectively. On an average basis zooplankton population was higher in the museum pond (mean value 1149.16 indiv/l) than in the Shahidullah Hall pond (mean value 529.16 indiv/l).

Chowdhury and Raknuzzaman (2005) conducted a study on the zooplankton communities of polluted waters in Hazaribagh area of the Buriganga river, Dhaka, Bangladesh. They identified 23 genera of zooplankton of which 12 genera rotifers, four copepods, six Cladocerans and one Ostracod. The highest abundance was observed in rotifers throughout the year with a monthly average of 347.85 ind/l followed by Copepods with 60.91 ind/l, Cladocerans with 57.25 ind/l and Ostracods with 4.91 ind/l. From each group, the species of *Brachionus* and *Filinia* belonging to Rotifers, Naupleus to Copepods, *Moina* sp. to Cladocerans and *Cypris* sp. to Ostracods were the most abundant zooplankton. Seasonal variations showed that abundance of Rotifers, Copepods and Cladocerans were highest in summer while Ostracods were highest in monsoon.

Rajashekhar *et. al.*, (2009) focused on the taxonomic composition of zooplankton in three freshwater lakes (Sharanabasaveshwara lake and Gobbur lake, Bosga lake,) of Gulbarga, India. They reported 39 species of zooplankton were to the different groups i.e., Rotifera, Copepoda, Cladocera, Ostrocoda in the lake Sharanabasaveshwara, the zooplankton was composed of nine taxa of Rotifera, four taxa of Cladocera, four taxa of Copepoda and three taxa of Ostrocoda, while in Bosga lake ten taxa of Rotifera six taxa of Cladocera four taxa of Copepoda three taxa of Ostracoda and in Gobbur lake thirteen taxa of Rotifera nine taxa of Cladocera four taxa of Copepoda and three taxa of Ostrocoda were encountered respectively. Comparison of the obtained results with those of earlier investigations performed during 1986-1987 showed that changes have occurred in the interval. The total zooplankton composition is significantly changed in all the three water bodies. Comparison of diversity and density in three lakes was studied with diversity indices. The study results clearly indicate intensified eutrophication of lakes. These fragile ecosystems have to prevent from further eutrophication.

Latifa *et al*., (1997) reported benthic macro-invertebrates constitute an important intermediate link between phytoplankton, zooplankton and the fish stock in the food chain. Many benthic organisms are important not only as fish food but also in that they take part in the process of biological water purification. They are also the basic sources of other bio-living in media. It also indicates the productivity of water bodies. These organisms are essential food items for cultivated of introduced fisheries in the managed water bodies.

The distributions of seasonal variations of the benthic fauna are interesting. The abundance and distribution varies with depth in relation to physico-chemical factors and also with the change of seasons (Habib *et. al.,* 1984b). Kabir and Naser (2009) was recorded 20 species (10 families) and 15 species (nine families) of benthic organisms from non-dredged oxbow lake Chandbill baor and dredged oxbow lake Harda baor, respectively of Meherpur district, Bangladesh. The abundance showed significant differences between the dredged and the nondredged oxbow lake

Ali (1973) studied aquatic Oligochates of Dhaka city with short notes on their ecology. He observed more than one hundred specimens during the study period. *Daro vagus, D. digitata* and *Stylaria vempi* were reported from the countries for the first time. Ali and Issaque (1975) studied the systematic of freshwater Oligochaetes of Dhaka city. Collection included 18 species, 11 genera and 2 families. *Nais simplex* was reported from this sub-continent. Recorded species were *Chaetogaster crystallinus, Nais simplex, Slavina oppendiculata, Stylaria fossularis, S. kempi, Branchiodrillus semperi, B. menoni, B. hortensis, Dero dorsalis, D.digitata. D. indica, D. zeylanica D.(Aulophorus) furcatus, D.(Aulophorus). hymanae, D.(Aulophorus) tonkinensis, Pristina foreli, P. proboscidea, Mimnodrillus hoffmeisteri, Aulodrillus remex and Brachiura sowerbyi.*

Khan *et. al.,* (2007) were identified twenty (20) different species in the the Mouri river, Khulna, Bangladesh. Polychaeta dominated all over the river and represented by Nemalycastis indica, Nephthys oligobranchia, Dasybranchus caducus and Nereis lamellose. The population of Oligochaeta was represented by Nais simplex, Stylaria fossularis and Limnodrilus hoffmeisteri. Insecta population was represented by a single species *Chironomus javanus*. Bivalvea population represented by *Lamellidens marginalis* and *Lamellidens jenkinsianus*. Gastropoda dominated *by Bellamya bengalensis, Pila globosa, Lymnea acuminate, Indoplanorbis exustus* and *Thiara granifera*. Organic pollution indicator *Limnodrilus hoffmeisteri* was fairly dominated. The maximum abundance of macrobenthic organisms recorded was 630 ind/m^2 and 1040 ind/m^2 in sediment respectively.

Rahman *et. al.,* (1975) studied the ecology of fish ponds with special reference to bottom fauna. They reported that Oligochaetes and dipterans larvae were chief benthic fauna and concentrations of bottom fauna influenced the growth of fish. Sharma et. *al.,* (2010) reported seven species of Oligochaeta like *Tubifex*, *Chaetogaster* sp., *Nais simplex*, *Aeolosoma bengalensis*, *Dero limosa*, *Branchiura soverbyi*, Stylaria fossularis from Kishanpura Lake, Indore (M.P.) India. *Helobdella* sp. *Glossiphonia* sp. and *HemicIepsis marginata* of the family Glossiphonidae. Planorbidae. Lymnaidae and Viviparidae were recorded among class Gastropoda. In the family Planorbidae only one species *Planorbis* was identified. Among family Lymnaidae three species *Limnaea auricularia*, *L. acumainata* and other *Limnaea* sp. *Limnaea auricularia* and *L. acumainata* family Viviparidae only three species namely *Vivipara bengalenis, V. oxytropsis* and *Bellamya* sp. were identified. Only two species of Lamellidens was identified in the family unionidae. Insecta *Chironomus phumosus, Strictochironomus*. sp, *Baetis*.sp., *Corixa*.sp., *Berosus* sp., *Hydaticus* sp. *Crustacea Apus* (tadpole shrimp) and *Daphnia* was identified.

Ali and Begum (1976) investigated freshwater molluscs of Dhaka (Bangladesh) with notes on their ecology. They identified 18 species under two classes namlely Gastropoda and Pelecypoda of which three species belonging to family Vivipariedae, one species to Ampullariidae, two species to Amnicolidae, four species to Melaniidae, two species to Lymnaedae, one species to Planorbidae, three species to Unionidae, one species to Corbiculidae and one species to Shaeriidae. Most of the species except a few were widely distributed in all the water bodies. Their study revealed that gastropods might prefer the bottom containing mud and organic debris and plenty of aquatic vegetation whereas the pelecypods might prefers the sandy bottom and less aquatic vegetation.

Ali and Hoque (1977) made a study on the abundance and biomass of the freshwater snails of three fish ponds of Dacca city from August 1975 to April 1976. They found eight species of fresh water snails from these three ponds of which the dominant groups were *Lymnaea* sp. from Fisheries department pond, *Digoniestoma pulchella* from Circuit house pond and *Viviparous bengalensis* from Aquirium pond. The maximum abundance occurred at station A at 0.20 meter depth. The fauna was found absent at station B at 1 meter depth. The population of *Viviparus bengalensis* was found maximum (540 ind./m^2 and 243090 ind./m^2) in the December at Aquarium pond, *Lymnaea* sp. showed highest peak in the September with 236 ind./m^2 and 26758 ind./m^2 in Fisheries department pond while *Digoniestma pulchella* showed highest peak in the April with 511 ind./m^2 and 10212 ind./m^2 in circuit pond.

Ali *et al.*, (1978a) studied the bottom fauna of Dhaka city with seasonal abundance, percentage composition and biomass of three ponds. A total of 58 species were recorded with 47 in the Fisheries Department pond, 38 in Circuit House pond and 32 in Aquarium pond. Twenty two species were common in all the three ponds. Chironomids, Oligochaetes and Molluscs were found as dominant groups. Chironomids and Oligichaetes constituted 95% of the total fauna but in biomass they formed only 61 % of the total. However the Molluscs accounted for 35% of the total biomass although in number they formed 3 % only.

Ali and Begum (1979) noted that the Chironomid larvae play an important role in the aquatic food chain. He also noted that several fishes particularly bottom dwelling fishes feed on these insect larvae. In their study he recorded six species of Chironomid larvae belonging to three sub-families for the first time from Dhaka city, Bangladesh.

Ali *et. al.*, (1989) made a study on seasonal variations of biological conditions in a pond of Dhaka between November 1978 and October 1979. The benthic macro-invertebrates encountered during their study were Oligochaetes, Chironomids, Molluscs and Leeches. The abundance of benthic fauna ranged from 330 indiv/m^2 in April and July to 7835 indiv/m^2 in December. Oligochaetes were the dominant fauna among the benthic organisms comprising 87.3% followed by Chironomids (6.9%), Molluscs (3.8%) and Leeches (2%) of the total macro-invertebrates.

Hasan *et al*., (1994) found low production of fish in Dhanmondi lake due to improper fish stocking ratio, availability of guppy fish and over crowding by tilapia. Thirty two fish species have been recorded from Mancher Lake, Dadu, Shindh, Pakistan among these 13 commercial species are harvested on regular basis (Mahar *et al*., 2000). Fish production is estimated to be 500 metric ton/year. The physico-chemical parameters of lake water are towards higher side for a typical fresh water body. Thus the decrease in fish population in Mancher lake may be attributed to higher values of environmental factors.

The average fish yield has been estimated to be 96.8 kg/ha. *Puntius* c*hola* contribute to the bulk of the lake fish yield registering an annual relative yield of 24.60% in the biggest freshwater lake Sone (3458.12 ha) in Assam, India. (Kar *et. al.,* 2006). The study revealed the occurance of 69 species of fishes in the lake belonging to 49 genera, 24 families and 11 orders. Of these fishes 84.2% belonged to the primary freshwater group (Cyprinids 35.39%), while the rest to the peripheral class. Results of linear regression revealed significant correlations between fish yield and soil organic carbon, soil potassium, water pH, total alkalinity and conductivity and aquatic macrophytic biomass.

Chapter 3
Materials and Methods

Water quality of all natural water bodies vary both spatially and temporally, therefore can rarely be adequately represented by a single sample collected from a single point. It is important to note that seasonal and spatial variation in lake flow may affect interpretation of water quality trends. Other factors affecting the monitoring of water quality trends include the selection of sampling points, their geographic locations, sample collection schedules, sample collection methods, sample processing methods, analytical methods and period of sample collection. This section describes the methodology followed for analysis of water and sediment characteristics and assessment of biodiversity of two lakes namely Gulshan and Dhanmondi.

3.1. Characterization of water quality of lakes:

Water quality monitoring in a natural water body is a valuable tool for understanding how surrounding factors are affecting water quality and also for identifying emerging problems. This requires assessment of the physical, chemical and biological characteristics of the water and sediment of the lake. Therefore study was carried out program covering pre-monsoon, monsoon and post-monsoon period to characterize the water and sediment quality as well as assess the biodiversity of Dhanmondi and Gulshan Lake. During this study both of primary and secondary data, comprehensive literature review and extracts of information from relevant sources was done.

3.2. Collection of Primary and Secondary data:

Secondary data of water quality, pollution, heavy metals, plankton, benthos and fish biodiversity, environment of lakes, rivers and different wet lands of Bangladesh and other countries reports, published articles was collected from different related organization such as DNCC, DoF, Bangladesh Meteorological Department, BFRI, BWDB, DPHE, DoE, CEGIS and BUET. However, electronic copies of reports, scientific articles and popular articles also collected by using internet.

3.3. Preliminary survey:

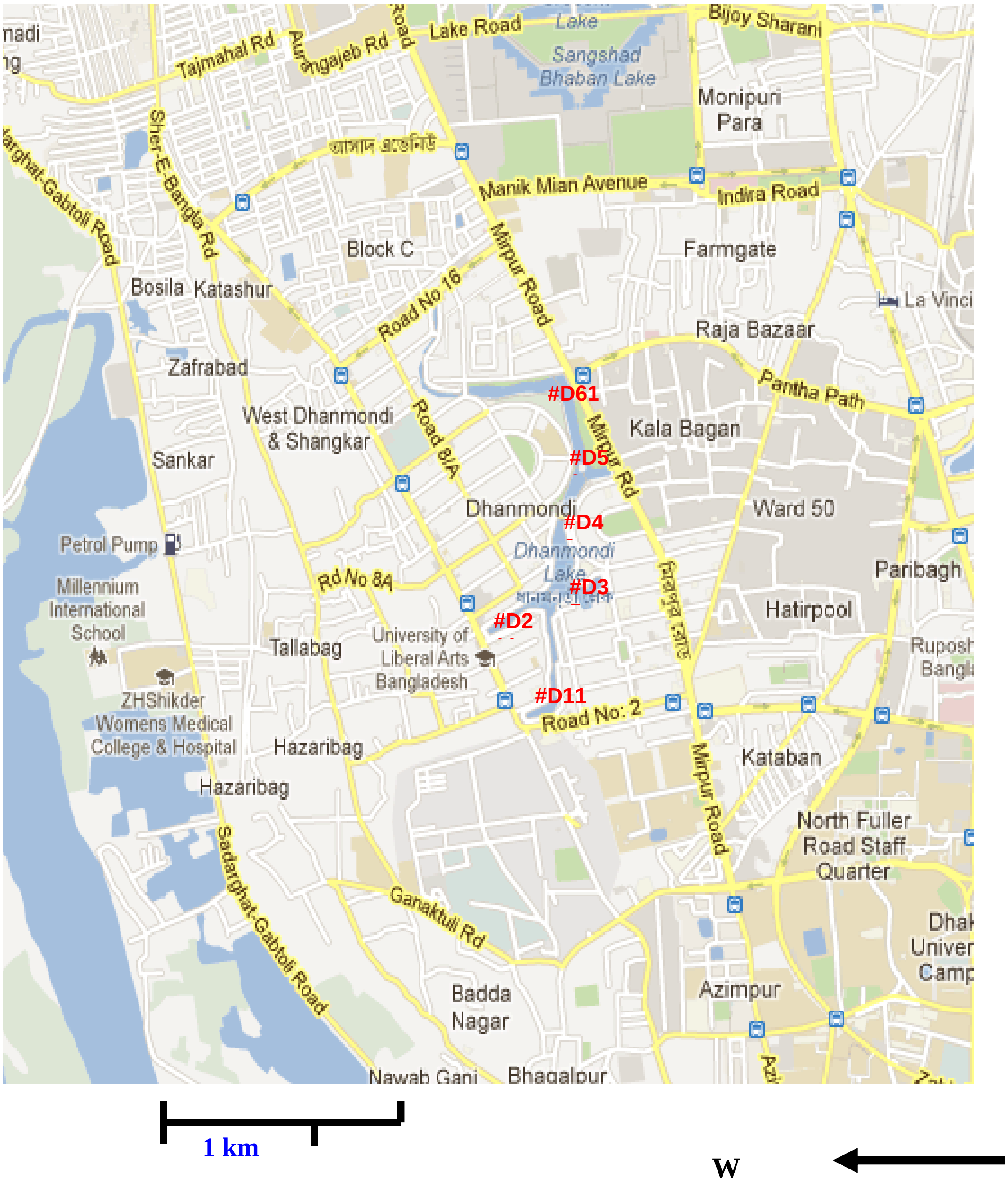
The preliminary survey was conducted in lakes to collect background information about the global position its aquatic habitat and source of pollution ecology. Depending on the preliminary survey data sampling stations in each lake was selected. Data collection system was designed to collect water, sediment, plankton and benthos data.

In the Gulshan lake a total of six sampling points taken. Similarly six sampling points were also randomly selected in Dhanmondi lake. The GPS (Global Positioning System) values of the sampling points of Gulshan and Dhanmondi lakes are given in Table 1. Subsequently the different sampling points with properly numbered of Gulshan and Dhanmondi lakes are also shown in Map 1 and Map 2 respectively.

Table 1. Geographical positions of different sampling locations of Gulshan and Dhanmondi lakes, Dhaka. Bangladesh.

Name of lake	Sampling locations	Position	
		Latitude	Longitude
Gulshan lake	**G_1**	23^0 46.660 N	90^0 25.133 E
	G_2	23^0 47.330 N	90^0 25.271 E
	G_3	23^0 47.658 N	90^0 25.207 E
	G_4	23^0 48.010 N	90^0 25.073 E
	G_5	23^0 47.211 N	90^0 24.868 E
	G_6	23^0 46.845 N	90^0 24.654 E
Dhanmondi lake	**D_1**	23^0 44.399 N	90^0 22.637 E
	D_2	23^0 44.529 N	90^0 22.544 E
	D_3	23^0 44.660 N	90^0 22.642 E
	D_4	23^0 44.867 N	90^0 22.694 E
	D_5	23^0 44.995 N	90^0 22.678 E
	D_6	23^0 45.037 N	90^0 22.456 E

Map 1. Sampling Stations of Gulshan lake



Map 2. Sampling Stations of Dhanmondi lake

3.4. General Phenomenon of Sample Collection:

A number of water, sediments, plankton and benthos samples were collected monthly across the width of the both Gulshan and Dhanmondi lakes. After collection samples were mixed together and then one representative sub-sample were taken for analysis. For heavy metal analysis, water and sediment sample was collect thrice a year, during pre-monsoon (summer), monsoon (rainy) and post-monsoon (winter) season.

In this study six sampling points in each of the lake were chosen for collection of water sample. At every sampling point the water samples were collected from approximately 10-15 cm below the surface level. Collection of water was restricted within the marked area of the selected station using a plastic bottle. The bottle was allowed to sink up to the desired depth and its mouth was opened and then the bottle was fallen out of water.

Water samples were collected in acid washed one liter high density polyethylene (HDPE) plastic bottles by dipping into 0.5 meter depth. Bottles were also rinsed with lake water at the sampling location three times before collecting water samples from that each particular sampling point. Samples were collected with necessary precaution so that sampling bottles are free from air bubbles. Immediately after sampling the sampling bottles were stored in ice box and then carried to the laboratory. In the laboratory collected water samples of 500 ml was separated into another bottle and were preserved in a refrigerator after adding 2 ml HNO_3.

3.5. Analysis of Water Samples:

Temperature, Dissolved Oxygen and pH of water samples were measured in the field with the help of mercury glass thermometer, portable DO and pH meter respectively. Other physico-chemical parameters were analyzed in the laboratory within 4 hours of collection. Dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total alkalinity, hardness were estimated in laboratory following the standard methods as outlined in Standard methods, APHA (2005). Electrical conductivity was measured by a Conductivity meter. Total Dissolved Solids (TDS) of water was determined by use of a pre-calibrated portable meter.

3.5.1. Water depth:

The depth of the lakes water was measured by sending a heavy weight iron ring attached with nylon rope into the lake bottom from a boat and the depth value was recorded with the help of measuring tape.

Water quality analysis in lake

3.5.2. Air and Water temperature:

Temperature was measured with a celsius thermometer of minimum readability of 0.1^0C at the lakes bank. Water temperature was recorded directly from the water body by dipping and keeping the celsius thermometer into the water body for some time and then taking measurements quickly after withdrawal from water.

3.5.3. Transparency:

Transparency reading were taken with the help of a secchi disc (20 cm diameter and divided into alternate black and white quadrates) following the technique of Almazan and Boyd (1978). According to Almazan and Boyd (1978) the secchi disc depth was determined using the following formula.

$$Z_S = \frac{d_1 + d_2}{2}$$

Where Z_S = Secchi disc depth

d_1 = the depth where the disc went out of sight.

d_2 = the depth when the disc was again visible.

3.5.4. Dissolved Oxygen (DO):

Glass stopper DO bottle was submerged into the sample water and allow it to fill to the top and the stopper was inserted with a quick thrust that no air bubbles are present. Carefully removing the stopper sample water was treated with Dissolved oxygen 1 reagent and Dissolved oxygen 2 reagent powder pillows and then the bottle was coppered firmly to avoid trapping air and shake vigorously to develop orange brown color. Dissolved oxygen 3 powder pillow was then added to develop a yellow color. This is the prepared sample which was filled into plastic measuring tube to the top and then poured into the mixing bottle to titrate with sodium thiosulphate Standard solution drop by drop until the sample changes from yellow to colorless. Then calculate dissolve oxygen (DO) in mg/l.

3.5.5. Water pH:

The pH of the water was measured on site using a portable pH meter (Model: HI 8314 HANNA instruments, Romania). The pH probe was lowered to a depth of about 0.3 m allowed to stabilize and pH value was read.

3.5.6. Ammonia-Nitrite:

One viewing tube is filled with de-ionized water and another with sample water to the 5-ml mark. One drop of Rochelle Salt Solution is added to each tube. After mixing the sample containing tube, 3 drops of Nessler Reagent is added to tube and again swirled to mix then allowed 10 minute for color development. Prepared sample tube was inserted into right hand opening and reagent blank tube into left hand opening of color comparator. Holding the color comparator up to light source, rotated the color comparator disc until the colors in the left and right windows were matched.

3.5.7. Free Carbon dioxide (CO_2):

Plastic measuring tube was filled with sample water to the top and then poured into the mixing bottle. After adding and mixing one drop of phenolphthalein Indicator Solution, Sodium Hydroxide Solution was added drop by drop until the solution becomes light pink. Then calculate total mg/l CO_2.

3.5.8. Total Alkalinity:

Sample water was filled into plastic measuring tube to the top and then poured into the mixing bottle. After adding 1 drop of Phenolphthalein Indicator Solution if the water remains colorless, the Phenolphthalein alkalinity is zero. If sample turns pink, Sulfuric Standard Solution was added drop by drop until the sample turns colorless and then 1 Bromocresol Green Methyl Red Indicator powder pillow was added to develop blue green. After mixing the sample properly again sulfuric acid Standard Solution was added drop by drop until the sample changes from blue green to pink. Used total number of drops of Sulfuric acid to calculate the total mg/l Alkalinity.

3.5.9. Total Hardness:

Plastic measuring tube was filled with sample water to the top and then poured into the mixing bottle which was treated with 3 drops of Hardness 1 Buffer solution. After mixing the solution one or two drops of Hardness 2 Test Solution was added to form a pink color. Titrant Reagent Hardness 3 was then added drop by drop until the solution color changes from pink to blue. Then calculate total mg/l hardness (as $CaCO_3$).

3.5.10. Conductivity:

A multi-range pre-calibrated portable conductivity meter (Model: HI 9033 HANNA instruments, Romania) was used to measure electrical conductivity (EC) of surface water in all sampling sites. The meter was lowered into the reservoir water to a depth of 0.3 m then allowed to stabilize before taking the conductivity readings in µS/cm.

3.5.11. Total Dissolved Solids (TDS):

Total Dissolved Solids (TDS) of water in all sampling sites was determined by use of a pre-calibrated portable meter (Model: 2100P, Hach Company, USA).

3.5.12. Biological Oxygen Demand (BOD):

Glass bottles (300ml) for BOD samples were used to collect surface water samples. For BOD special care has been taken to avoid the entrapment of atmospheric oxygen during collection. Collected samples were brought to the laboratory carefully by preserving at -4^{0}C using thermo coal box containing ice caps. BOD_5 was measured by incubating samples in BOD incubator at 20^{0}C for 5 days. Biochemical oxygen demand (BOD) was determined by the difference between DO of samples immediately after collection and DO of samples after incubation at 20^{0}C for five days.

3.5.13. Chemical Oxygen Demand (COD):

Chemical oxygen demand (COD) of lake water was determined in laboratory by refluxing digestion methods. Place 50 mL water sample in a 500 mL Refluxing flask. Blank 50ml distilled water take in one flask. Add 1 gm $HgSO_4$, Several glass beads and very slowly add 5 mL Sulfuric acid reagent with mixing to dissolve $HgSO_4$. Cool while mixing to avoid possible loss of Volatile materials. Add 25 ml 0.0417 m $K_2Cr_2O_7$ solution and mix. Add remaining Sulfuric acid reagent, 70 ml through open end of condenser. Continue swirling and mixing while adding the Sulphuric acid reagent. Cover open end of condenser with a small beaker to prevent foreign materials & reflux for two hours. Cool and washed down condenser with distilled water. Disconnect reflux condenser and dilute mixture to about twice its volume with distilled water. Cool to room temperature and titrate excess $K_2Cr_2O_7$ with Ferric ammonium sulfate (FAS) using 2-3 drops Ferroin indicator. Take as end point of titration the first sharp color change from Blue green to Reddish brown. Blue green may reappear. Then calculate COD using following formula.

$$\text{COD as mg } O_2/L = \frac{(A-B) \times M \times 8000}{\text{mL of sample water}}$$

Where, A = mL FAS used for blank

B = mL FAS used for sample and

M = Molarity of FAS

COD and BOD analysis in laboratory

3.6. Water Analysis for Heavy metals:

3.6.1. Collection of water samples:

For the determination of heavy metals in the lake water, 250 ml of surface water were collected in triplicate from each of the five sites in the colored, sterilized bottle and preserved with adding 1.0 ml concentrated HNO_3. Sampling was usually done in the morning hours. Sample bottles were acid washed a day before sampling day in 1-2% HNO_3 solution, rinsed in distilled water and then dried. Sample bottles were immediately transferred to the laboratories for the estimation of various heavy metals content in lake water. In the laboratory water was filtrate by filter paper. The filtrate of water was then assayed by Atomic absorption spectrophotometer (AAS) for Cd, Zn, Pb, Cu, Cr, Ni and Mn in advance Science laboratory of Dhaka University.

3.7. Collection of Sediment Samples:

Sediments are normally the final pathway of both natural and anthropogenic components produced in or derived from the environment of a lake. Sediment quality is a good indicator of pollution in water column, where it tends to concentrate the metals and other organic pollutants. The present study aimed to investigate sediment samples for Organic Carbon, Acidity, Total nitrogen, pH, Calcium, Magnesium, Potassium and Phosphorus. For monitoring of sediment quality of Dhanmondi and Gulshan lakes sediment samples were collected during pre-monsoon, monsoon and post-monsoon period in three consecutive years *viz*., 2010-2011, 2011-2012 and 2012-2013. At each sampling location top 20 cm of sediment was collected which represents the most biologically active depositional layer in relatively low flowing streams. Sediment samples were collected by an Ekman grab (15 x15cm) was employed for collecting sediment samples. The surface (0-3 cm) sediment was collected from the central portion of the grab sample. About 500 gram sample was collected from each sampling point. Care was taken to ensure that the sampling procedure created minimal disturbance at the sediment-water interface. The collected samples were quickly extruded from the sampler emptied into pre-labeled clean polyethylene bags and kept in ice box for transport to the laboratory. The samples were shade dried crushed into powder in a porcelain mortar and sieved through 40 micron sieve then stored at 4°C in a refrigerator until analysis.

Sediments collection from Gulshan lake

3.7.1. Analysis of sediment sample:

Sediment samples were analysed from Soil Resource Development Institute (SRDI), Dhaka using an Atomic Absorption Spectrophotometer (AAS) attached with a graphite furnace (Shimadzu, Japan, AA 6800).

3.8. Biodiversity assessment:

During the investigation the Quantitative and qualitative assessment of phytoplankton and zooplankton and macro zoo benthos were considered. The detailed sampling and analytical procedure are given below.

3.8.1. Phytoplankton collection and identification:

Samples were collected from surface water, littoral region and bottom mud. For qualitative analysis, the plankton samples were collected by towing Hensen's standard plankton net with uniform speed. The net was made of no. 25 bolting silk. The plankton sample for phytoplankton counting and identification were immediately fixed with Lugol's solution and stored in dark glass bottles. Phytoplankton was condensed by settling 100 ml of water sample in an Utermohl chamber and enumerated (3 replications) using the inverted microscope technique.

Diversity and relationships to the physico-chemical environment, Prescott (1973) and John et al. (2002) were used to identify phytoplankton species. The diversity of phytoplankton was expressed both as the number of species and the number of individuals (cells.m-3). The abundance of species was estimated by number of individuals and was calculated using Simpson's index.

3.8.2. Zooplankton collection and identification:

Quantitative estimation of the zooplankton, 100 liters of water was filtered successively through 64µm mesh nylon nets (Millipore corp., Bedford, USA), and 50 ml of the concentrates was collected initially as a crude measure of zooplankton. From 50 ml, 10 ml was for analysis and the samples were immediately preserved by 5% buffered formaldehyde. For qualitative and quantitative study, samples were observed under a compound microscope in a S-R (Sedgeweak-Rafter cell, U.K.) cell (Plate 12.1) following published methods (Welch, 1952). Briefly, 1 ml samples of 5% buffer formalin-fixed zooplankton was pipetted on to a clean S-R (Sedgeweak-Rafter cell) cell and observed at 10X10 magnification, using a (KRUSS, MBL 2100, Germany) compound microscope. Taxonomic identification of plankton was carried out with the help of taxonomic keys (George, 1966).

Plankton collection from Gulshan and Dhanmondi lake

For identification of the zooplankton species and preparation of the keys, the following authors were consulted: Das and Bhuiyan, 1974; Ali and Chakrabarty, 1992; Ward and Whipple, 1959; Mellanby, 1975; Bhouyain and Asmat, 1992; and Tonapi, 1980. Quantitative analysis of zooplankton was followed by the total count method. The number of zooplankton estimated per ml was calculated by adopting the following formula (Welch, 1952):

$$N = \frac{AxC}{L}$$

Here,

N = Number of Zooplankton/L

A = Total concentrate amount of Zooplankton (50 ml)

C = Number of Zooplankton counted in 1 ml sample

L = Amount of water (In liter) passed through plankton net (100 liter)

Identification of zooplankton species

The species of zooplankton was identified according to Gojdics (1953), Berzins (1973), Huber-Pestalozzi (1955), Ward and Whipple (1959), Tonapai (1980), Sudzuki (1964), Dhanapathi (1976), Mellanby (1975), Bhouyain and Asmat (1992), Ali and Chakrabarty (1992) and Kabir *et al.* (1996, 1997).

Zooplankton abundance

After identification of zooplankton they were then enumerated for the study of abundance of zooplankton in the investigated area. The abundance of zooplankton were estimated by counting their presence per focus of the microscopic field. The total number of zooplankton per liter of water were estimated by the following formula :

$$D = \frac{N \times V_s \times S}{N_A \times V}$$

Where,

- D = density of organisms in number per liter
- N = number of organisms
- N_A = number of 1 mL aliquot examined
- V_s = volume of sub samples from which aliquot were removed
- S = split factor
- V = volume of water filtered (Liter)

3.8.3. Benthos collection and identification:

Benthic organisms samples were collected with a sampler and the collected samples were washed through sieve no 40 (256 meshes/cm^2) and benthic organisms were transferred to vials containing 5% formalin for further identification. The organisms were segregated and their abundance was calculated as no. per square meter. Preserved samples of macro benthic invertebrates were identified according to Ward and Whipple 1959, Tonapai, 1980, Adoni 1985, Pennak 1978). However, for quantitative analysis, species-wise individual counting was done in the whole sample or sub sample.

The number of benthos per unit area was calculated as follows:

$$\text{Benthos (No./m}^2) = \frac{N}{A \times S} \times 10{,}000$$

Where,

N = Number of organism collected per sample

A = Area of sampler (m^2)

S = Number of samples taken

Benthic organism collection

3.9. Statistical analysis:

The statistical analysis of different limnological parameters were performed using Microsoft Excel and Statistical Package for Social Science (SPSS, version 20).

The results were analyzed using Pearson correlation analysis and single factor analysis of variance (ANOVA). Pearson correlation coefficient, r, is a dimensionless index that ranges from -1.0 to 1.0 inclusive. If there is perfect linear relationship with positive slope between the two variables, correlation coefficient is 1; if there is positive correlation, whenever one variable has a high (low) value, so does the other. If there is negative correlation, whenever one variable has a high (low) value, the other has a low (high) value. A correlation coefficient of 0 means that there is no linear relationship between the variables and shows the degree of linear relationship between two sets of data, {X} and {Y}. An ANOVA is an analysis of the variation present in an experiment. It is a test of the hypothesis that the variation in an experiment is no greater than that due to normal variation of individuals characteristics and error in their measurement. ANOVA puts all the data into one number (F) and gives us one P for the null hypothesis. The t-test tells us if the variation between two groups is "Significant". P reports the significance level.

Chapter 4
Results and Observations

This study was conducted in Gulshan lake and Dhanmondi lake during April 2010 and March 2013 to determine the present status of physico-chemical quality and heavy metals of water and sediment and biological diversity of plankton and benthos. Comparison of limnological parameters among the two lakes was determined. The results are discussed bellows.

4.1. Geomorphology:

Gulshan lake divided into two portions. Historically originated from the same water canal system and was connected with nearby Hatir-jheel wetland and Rampura canal. The canal was led to the Balu river in eastern Dhaka periphery. Now this urban lake was separated from river and divided into many section. The Dhanmondi lake was also earlier period connecting with the Buriganga river. In course of urbanization process of Dhaka the urban lake was separated from the river at Pilkhana area and the connective canal was blocked and converted into PanthaPath road cum drainage system.

The study made observation that the Gulshan lake are presently used as sewage and domestic water dumping grounds from the nearby housing. Dhanmondi lake was previously used as dumping ground of domestic water and sewage drainage from the residential area. However, in mid-90's decade the total lake was re-excavated and cleaned and all sewage drainages were blocked.

4.2. Physico-chemical parameters:

The physicochemical characteristics are important for environment to maintain ecological condition of the lake. Major and rapid changes of these parameters may result in fish mortality. Some parameters are directly involved with fish losses such as dissolved oxygen, temperature and ammonia. Others such as pH, alkalinity and hardness affected fish but usually are not directly toxic. During the study period data were recorded in monthly for three sampling years (April 2010 to March 2011, April 2011 to March 2012, April 2012 to March 2013). Data were presented as pre monsoon, monsoon and post-monsoon to determine the seasonal variations of physico-chemical parameters of Gulshan and Dhanmondi lakes. The details results and observation are presented as follows.

4.2.1. Water depth:

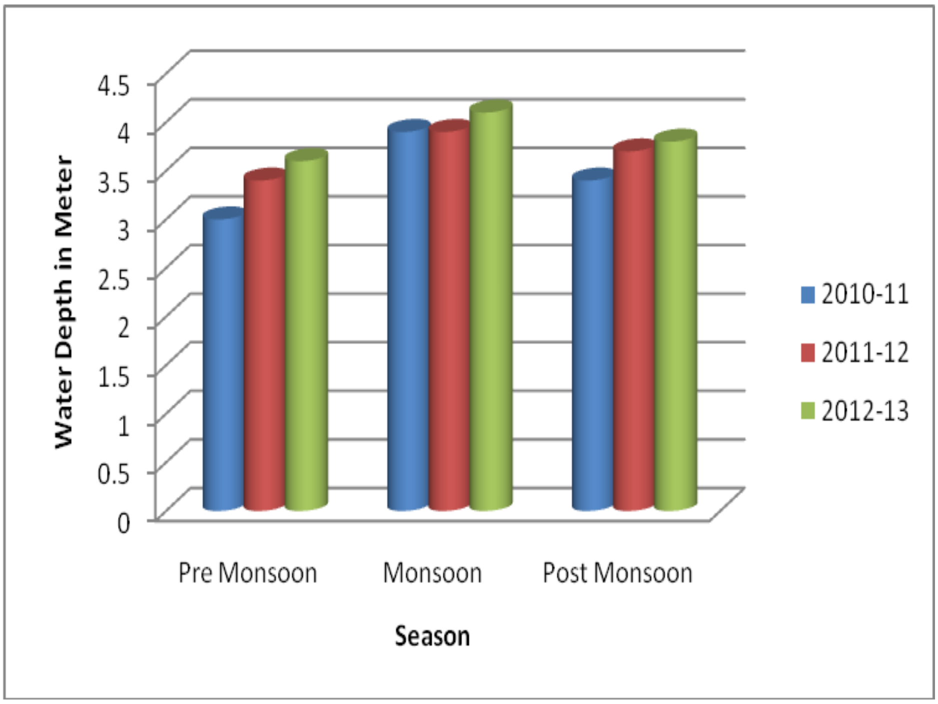


Figure 1. Average water Depth of Gulshan lake

The average water depth of the Gulshan lake varied from 2.9 to 4.2m (3.6±0.3m). In first year average value was 3.4±0.5m, in second year 3.7±0.3m and third year was 3.6±0.2 m. There were no significant differences recorded among the three years data of Gulshan lake. [Table 2]. In pre monsoon average water depth was 3.4m±0.2, in monsoon 4.0m±0.7 and in post monsoon 3.7m±0.1. The lowest depth was recorded in pre monsoon and highest obviously in monsoon. Water depth of post monsoon shows significantly difference ($P=0.042$, $P<0.05$) from pre and post monsoon. [Table 4].

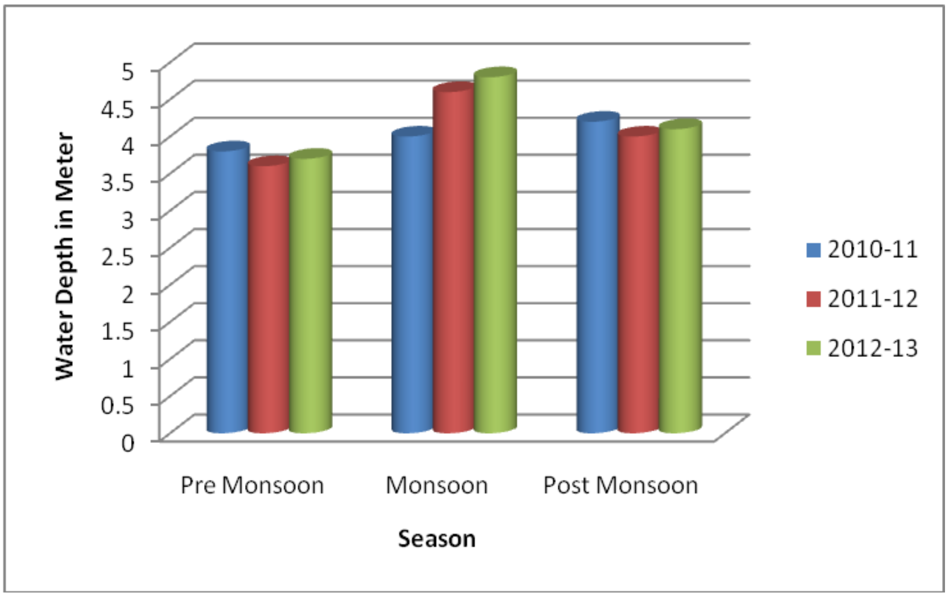


Figure 2. Average water Depth of Dhanmondi lake

The water depth of the Dhanmondi lake varied from 3.5m to 5.0m (4.1±0.4). In first year average was 4.0±0.2m, in second year 4.1±0.5m and third year was 4.2±0.6m. No significant differences observed in three years water depth. [Table 3]. In pre monsoon average water depth was 3.7±0.1m, in monsoon 4.5±0.3m and in post monsoon 4.1±0.1m. The lowest depth was also recorded in pre monsoon and highest obviously in monsoon. Water depth of post monsoon shows significantly difference ($P=0.028$, $P<0.05$) from pre and post monsoon. [Table 5]

In the first year water depth among two lakes show significant differences ($t=-6.91$ $df=142$, $p=0.05$) (Table 6). During second year no significant differences were observed among water depth between two lakes but third year shows significant difference between two lakes ($t=-4.4$, $df=142$, $p<0.05$) [Table 7 and 8}

4.2.2. Air temperature:

The air temperature in season wise of Gulshan and Dhanmondi lake are presented in Figure 1 and 2. In Gulshan lake lowest and highest air temperature was ranged between 17.8^0C and 32.1^0C. In first year it average was 29.1±1.3°C, in second year 27.6±3.3°C and third year was 27.3±3.5°C. First year data shows significantly difference (P=0.007, P<0.01) than second and third year. [Table 2]. In pre monsoon average air temperature was 28.5±0.2^{0}C in monsoon 30.6±0.1^{0}C and in post monsoon 24.9±1.6^{0}C. Lowest temperature was recorded in post-monsoon and highest in monsoon. The data of post monsoon shows significantly difference (P=0.011, P<0.01) from pre and post monsoon. [Table 4].

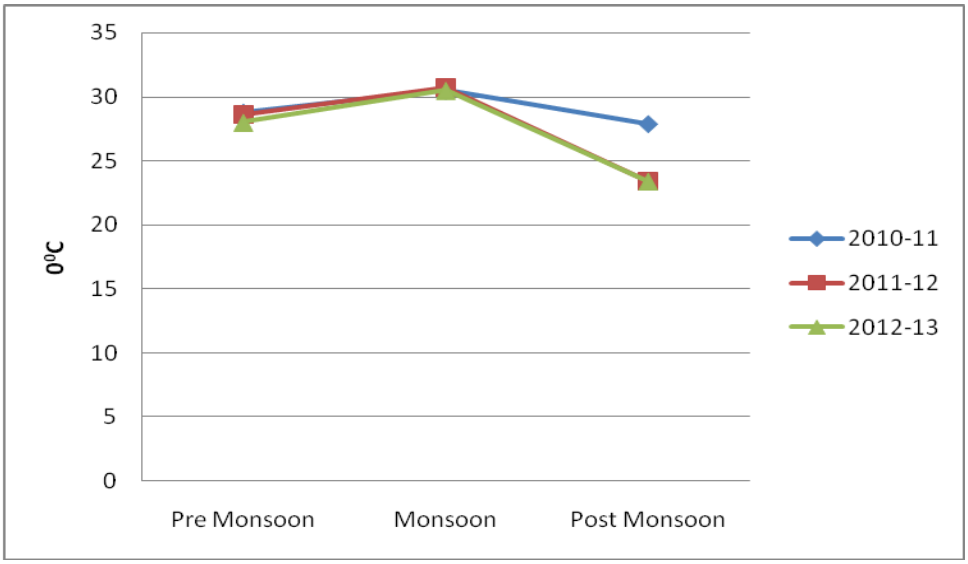


Figure 3. Average air Temperature of Gulshan lake

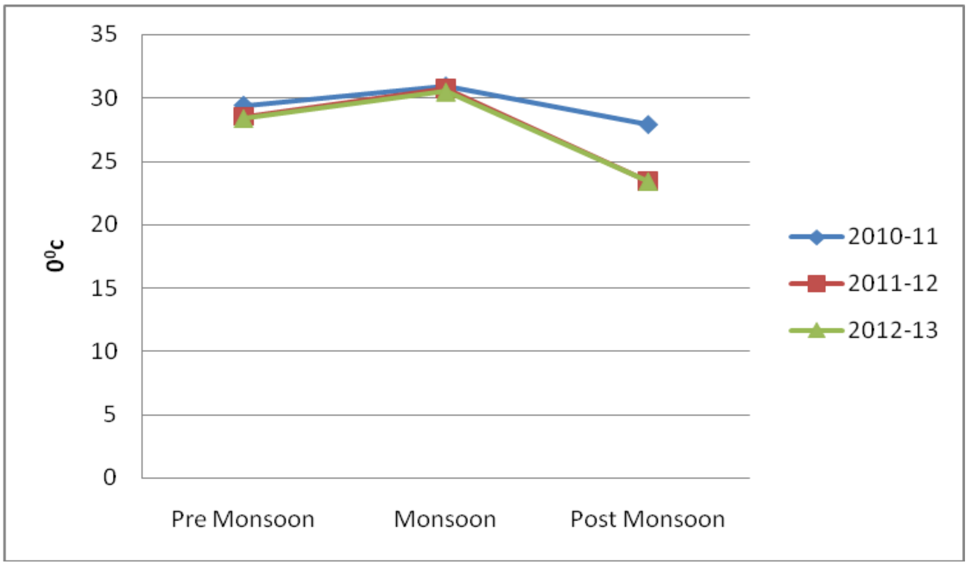


Figure 4. Average air Temperature of Dhanmondi lake

In Dhanmondi lake, air temperature was recorded range of 17.74^0C to 33.3^0C (28.1 $\pm4.4^0C$). In first year average value 29.4±1.5°C, in second year 27.5±3.7°C and third year 27.4±3.6°C. No significant difference was observed in three years. [Table 3].

In pre monsoon average air temperature was 28.8 ± 0.3^0C in monsoon 30.7 ± 0.1^0C and in post monsoon 24.9 ± 1.5^0C. The lowest temperature was also recorded in post-monsoon and highest in monsoon. The data of post monsoon shows significantly difference ($P=0.010$, $P<0.01$) from pre and post monsoon. [Table 5]. No significant differences were observed in comparison Gulshan and Dhanmondi lake of three years data separately [Table 6-8].

4.2.3. Water temperature:

The water temperature of Gulshan and Dhanmondi lake are shown in Figure 5-6. In Gulshan lake water temperature was ranged between 18.2°C to 31.4°C (27.7±3.4°C). In first year it average was 28.3±1.2°C, in second year 27.3±3.3°C and third year was 27.3±3.5°C. First year data shows significantly difference ($P=0.011$, $P<0.05$) than second and third year. [Table 2].

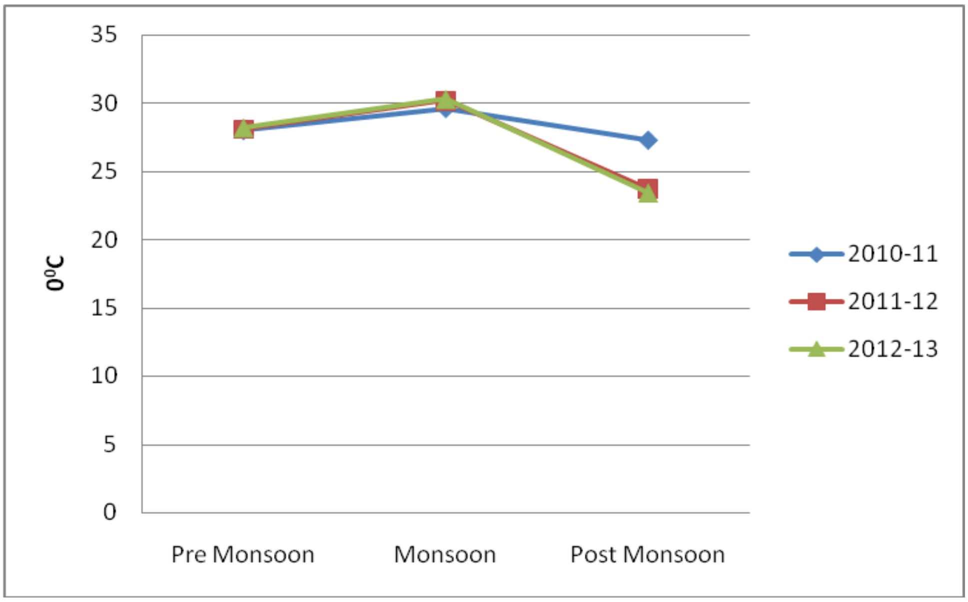


Figure 5. Average Temperature of Gulshan lake water

In pre monsoon average air temperature was 28.1±1.2 ^{0}C in monsoon 30.0±0.2^{0}C and in post monsoon 24.8±1.3^{0}C. The lowest temperature was recorded in post-monsoon and highest in monsoon. The data of post monsoon shows significantly difference (P=0.007, P<0.01) from pre and post monsoon. [Table 3].

In Dhanmondi lake water temperature was ranged 17.9°C to 32.4°C (27.7±4.1°C). In first year average was 28.5±1.5°C, in second year 27.3±3.5°C and third year was 27.3 ±3.6°C. No significantly difference was not found in year wise data. [Table 3].

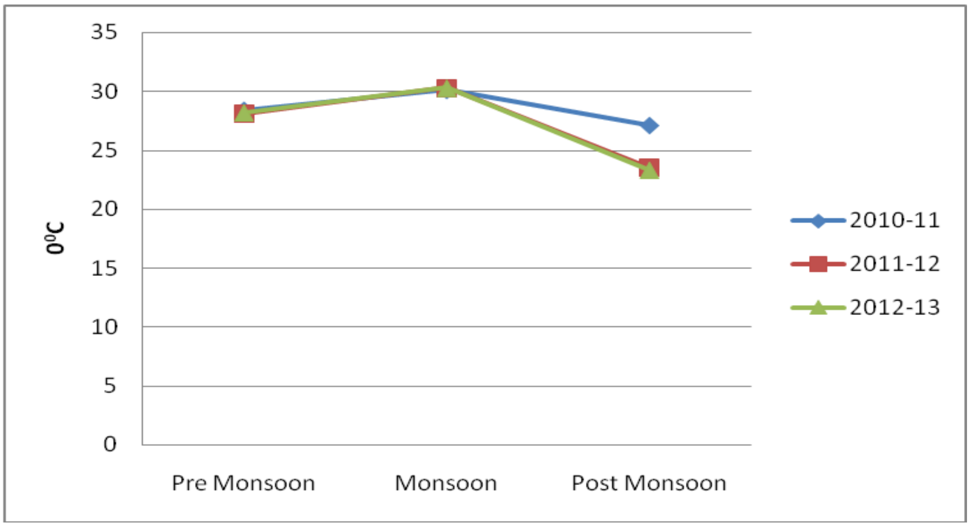


Figure 6. Average Temperature of Dhanmondi lake water

In pre monsoon water temperature was 28.2±0.1^{0}C in monsoon 30.2±0.1^{0}C and in post monsoon 24.6±1.2^{0}C. The lowest temperature was recorded in post-monsoon and highest in monsoon. The data of post monsoon shows significantly difference (P=0.004, P<0.01) from pre and post monsoon. [Table 5]. No significant differences were observed in water temperature between Gulshan and Dhanmondi lake in three years data [Table 6-8].

4.2.4. Transparency:

The transparency of Gulshan lake water was ranged from 28.0cm to 38.8cm (34.1±3.3). In first year average was 35.4±1.7 cm, in second year 33.2±3.5 cm and third year was 33.7±2.8 cm. Statistically first year data shows significant differences with second and third years. (P=0.005, P<0.01). [Table 2]. In pre monsoon average transparency was 35.4±1.7 cm, in monsoon 33.2±3.5 cm and in post monsoon 33.7±2.8 cm. The lowest transparency was recorded in monsoon and highest in pre monsoon. Transparency shows statistically significantly difference among three seasons. (P=0.036, P<0.05). [Table 3].

In Dhanmondi lake water transparency was 70.2cm to 87.0cm (78.5±4.2 cm). Almost double values were recorded in Dhanmondi lake water than to Gulshan lake. The water transparency of Dhanmondi lake indicates it contain less suspended solids**.** In pre monsoon average transparency was 76.4±2.4cm, in monsoon 80.1±2.0cm and in post monsoon 79.1±1.1cm. Lowest transparency was recorded in monsoon and highest in pre monsoon.

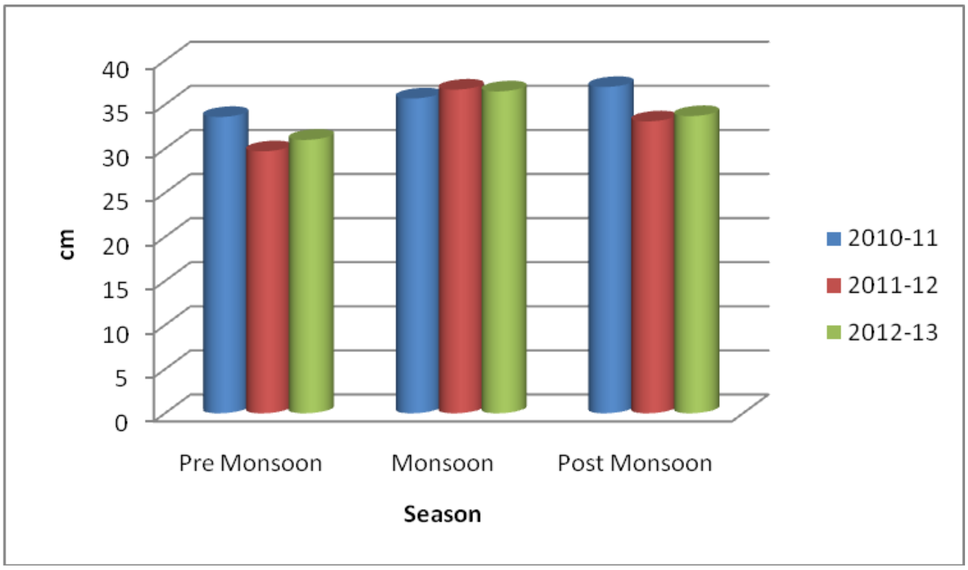


Figure 7. Average Transparency of Gulshan lake water

Transparency shows no significant difference among three seasons. [Table 5]. In first year No significant differences were observed in water Transparency between Gulshan and Dhanmondi Lake [Table 6].

In second year transparency shows highly significant difference (t=-48.96, df=142, p=0.001) [Table 7]. In third year transparency data shows significant results in comparison of two lakes. (t=-59.05, df=142, p<0.005) [Table 8].

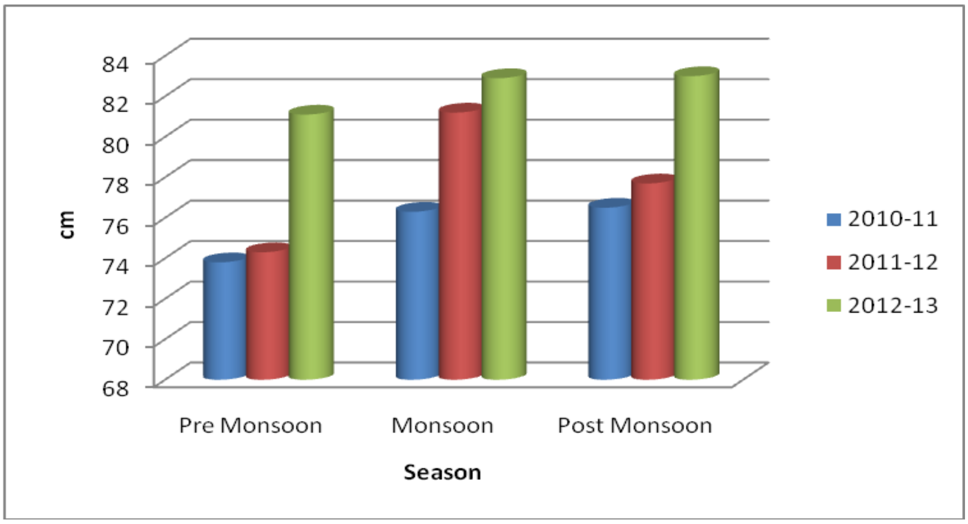


Figure 8. Average Transparency of Dhanmondi lake water

4.2.5. Dissolved Oxygen:

Dissolve Oxygen (DO) is an important indicator for water quality assessment as well as water body's ability to support aquatic life. In this study, it varied from 3.2 to 6.1mg/l for Gulshan lake water.

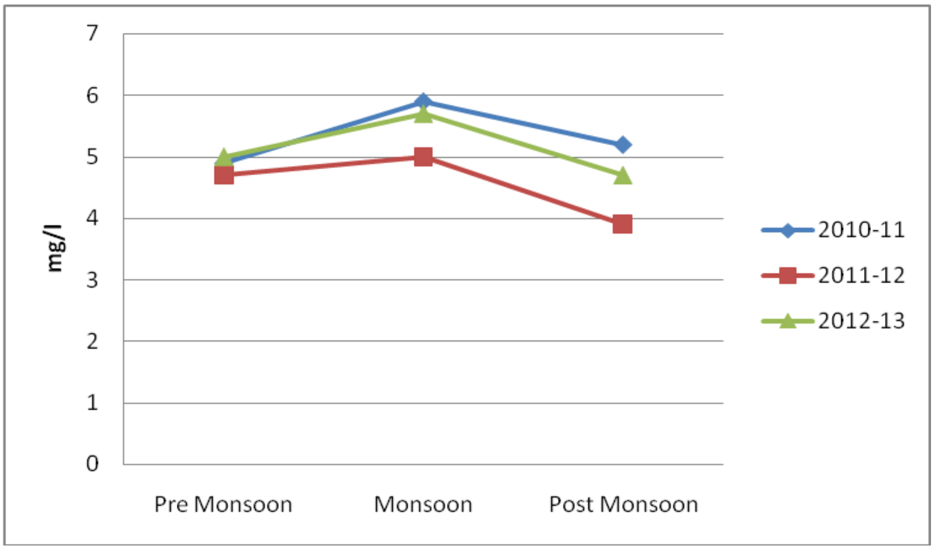


Figure 9. Average Dissolved Oxygen of Gulshan lake water

In first year average was 5.3±0.5 mg/l, in second year 4.5±0.6 mg/l and third year was 5.1±0.5 mg/l. There was no significant correlation was found in the three years data [Table 2]. In pre monsoon average Dissolve Oxygen was 4.8±0.1 mg/l, in monsoon

5.5±0.3 mg/l and in post monsoon 4.6±0.4 mg/l. The minimum DO concentration was observed in post monsoon and the maximum in monsoon. There was no significant correlation was found between the three seasons. [Table 3]. Gulshan lake water shows less dissolved oxygen and in some place it was below the standard level.

Dissolved oxygen for Dhanmondi lake water was found 5.4mg/l to 7.7mg/l. In first year average was 6.7±0.6 mg/l, in second year 6.5±0.4 mg/l and third year was 6.4±0.1 mg/l. Statistically no significant correlation was found between the three years data. [Table 4].

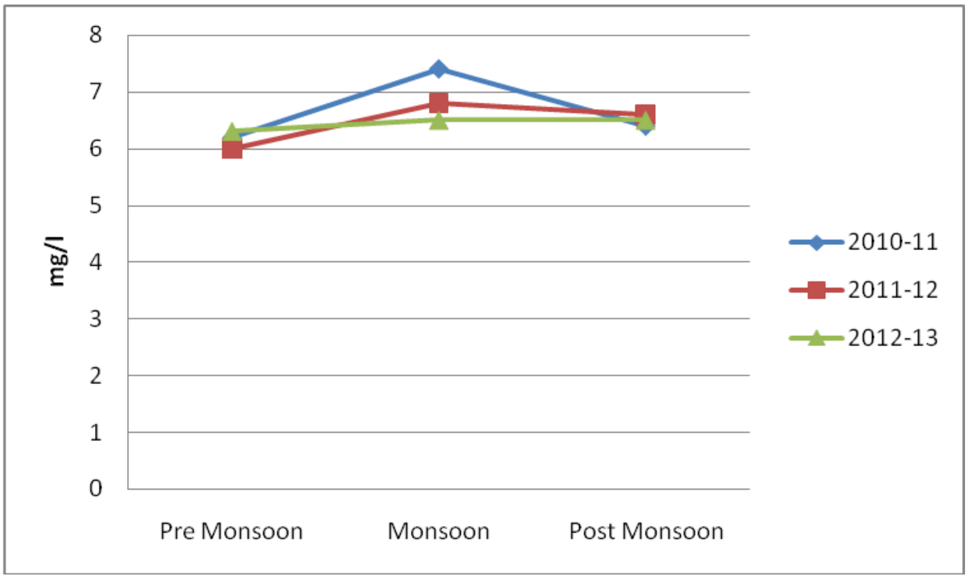


Figure 10. Average Dissolved Oxygen of Dhanmondi lake water

In pre monsoon average Dissolve Oxygen was 6.2±0.1 mg/l, in monsoon 6.9±0.3 mg/l and in post monsoon 6.5±0.1 mg/l. The minimum DO concentration was observed in pre monsoon and the maximum in monsoon. Dissolve Oxygen shows statistically significantly difference among three seasons. ($P=0.050$, $P<0.05$). [Table 5].

In first year highly significant difference ($t=-7.35$, $df=142$, $p=0.01$) were observed between Gulshan and Dhanmondi lake [Table 6]. In second year shows no significant differences [Table 7]. In third year water DO data shows significant results in comparison of two lakes. ($t=-9.69$, $df=142$, $p=0.010$) [Table 8].

4.2.6. pH:

Hydrogen ion concentration or pH as one of the vital environmental characteristics decides the survival, metabolism, physiology and growth of aquatic organisms. pH is one of the most important factors, serving as an index for pollution. The pH in Gulshan lake range between 7.3 to 7.9. In first year average was 7.5±0.2, in second year 7.6±0.1 and third year was 7.6±1.1. There was no significant correlation was found in Gulshan lake water pH among three years data. [Table 2]. In pre monsoon average pH was 7.6±0.0, in monsoon 7.6±01 and in post monsoon 7.5±0.1. pH was observed more or less same in all seasons. There was no significant correlation was found among three seasons. [Table 3].

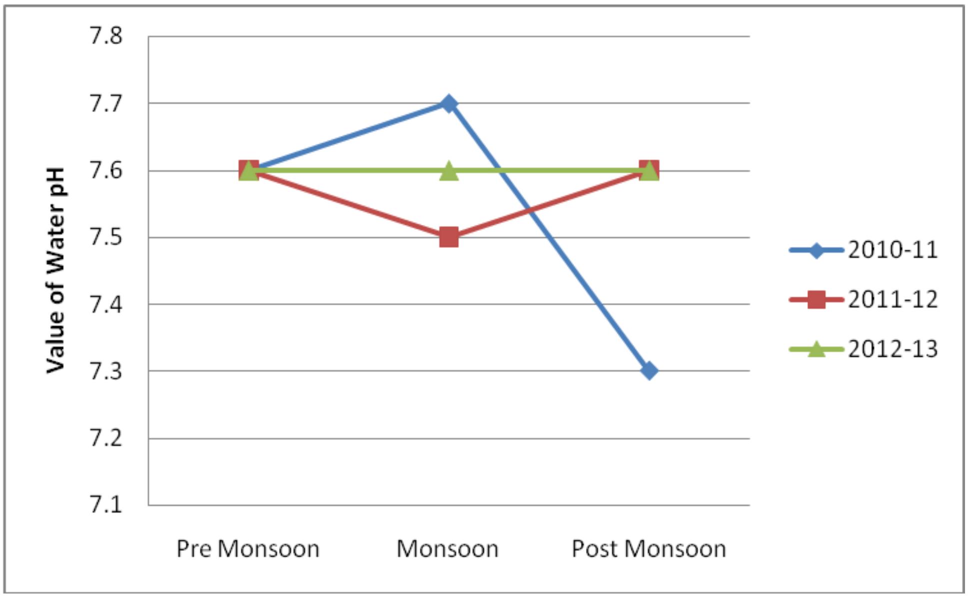


Figure 11. Average pH value of Gulshan lake water

The average pH was found in Dhanmondi lake range between 7.3 and 7.8. In first year average was 7.6±0.1, in second year 7.5±0.1 and third year was 7.6±0.1. There was no significant correlation was found in Dhanmondi lake water pH among three years data. [Table 4]. In pre monsoon average pH was 7.6±0.3, in monsoon 7.5±03 and in post monsoon 7.6±0.0. Monsoon pH significantly shows difference than pre and post monsoon in Dhanmondi lake water. [Table 5].

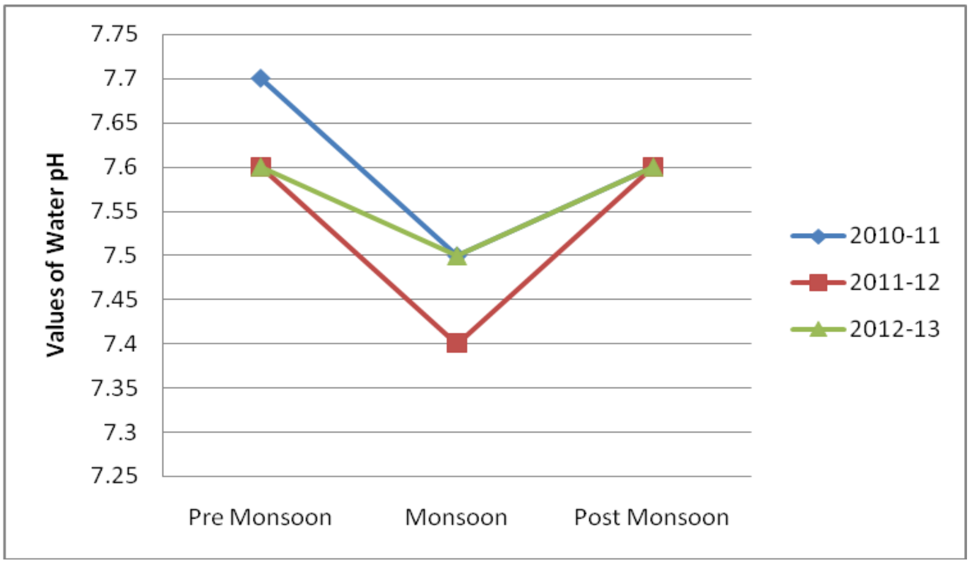


Figure 12. Average pH value of Dhanmondi lake water

It concluded that both lake water were slightly alkaline in nature. The results revealed that the water pH of Gulshan and Dhanmondi lakes was remain desirable and suitable level for aquaculture. The pH value of water samples did not show any significant variation during the three study years. [Table 6-8].

4.2.7. Ammonia-Nitrogen:

Ammonia-Nitrogen is one of the indicators of pollution. The level of average Ammonia-Nitrogen in Gulshan lake water varied from 4.7mg/L to 18.4mg/l. In first year average was 10.9±2.2 mg/l, in second year 11.1±2.3 mg/l and third year was 12.1±1.9 mg/l. First and second year data shows no significant differences but significantly differ from last year data in Gulshan lake water. [Table 2].

In pre monsoon average ammonia-nitrogen was 13.7±0.3 mg/l, in monsoon 8.5±0.7 mg/l and in post monsoon 9.4±0.5 mg/l. The minimum ammonia-nitrogen contents of Gulshan lake water was observed in monsoon and the maximum was in pre monsoon. Pre monsoon data show significant difference than monsoon and post monsoon of Gulshan lake water. ($P=0.001$, $P<0.01$). [Table 3].

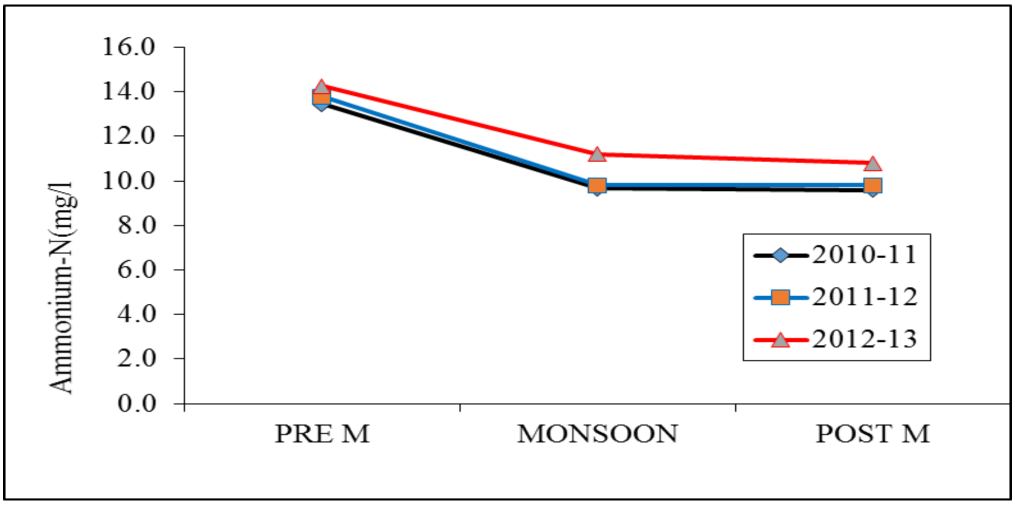


Figure 13. Average Ammonia-Nitrogen of Gulshan lake water

The level of ammonia-nitrogen in Dhanmondi lake water varied from 0.3mg/l to 2.34mg/l. In first year average was 1.2±0.5 mg/l, in second year 0.8±0.2 mg/l and third year was 0.7±0.2 mg/l. There was no significant variations was found in Dhanmondi lake water ammonia-nitrogen in three years data [Table 4].

In pre monsoon average ammonia-nitrogen was 0.9±0.1 mg/l, in monsoon 0.8±0.1 mg/l and in post monsoon 1.0±0.1 mg/l. The minimum ammonia contents of Dhanmondi lake water was observed in monsoon and the maximum was in post monsoon. Dhanmondi lake water shows acceptable value in all season.

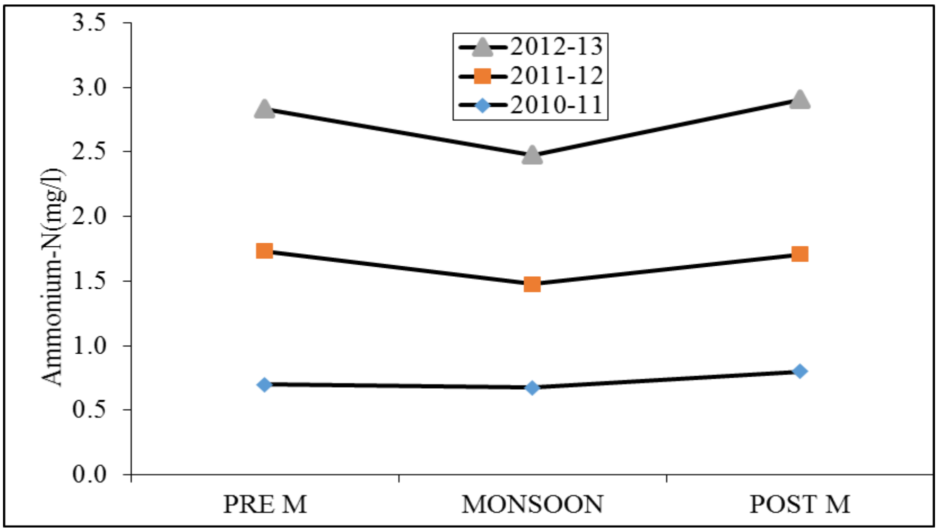


Figure14. Average Ammonia-Nitrogen of Dhanmondi lake water

There was no significant variations were found among three seasons. [Table 5]. In comparison between two lakes water ammonia-nitrogen values showed strongly significant differences in three years data (t=23.56, 20.76 and 25.48, year 1-3 respectively, df=142, $p<0.001$) [Table 6-8].

4.2.8. Free Carbon di Oxide:

Reasonably all natural waters contain less or more free carbon dioxide which plays an important role for water quality. Temporarily dissolved CO_2 combines with water and turned into carbonic acid. This carbonic acid sometime cause negative effect to the water bodies if the water is slightly acidic. During this study the free carbon di oxide in Gulshan lake water the highest and lowest values were found 13.7mg/l and 33.4mg/l. In first year average was 20.5±3.7 mg/l, in second year 20.1±1.8 mg/l and third year was 17.2±0.7 mg/l. There was no significant correlation was found in Gulshan lake water free carbon di oxide of three years data. [Table 2].

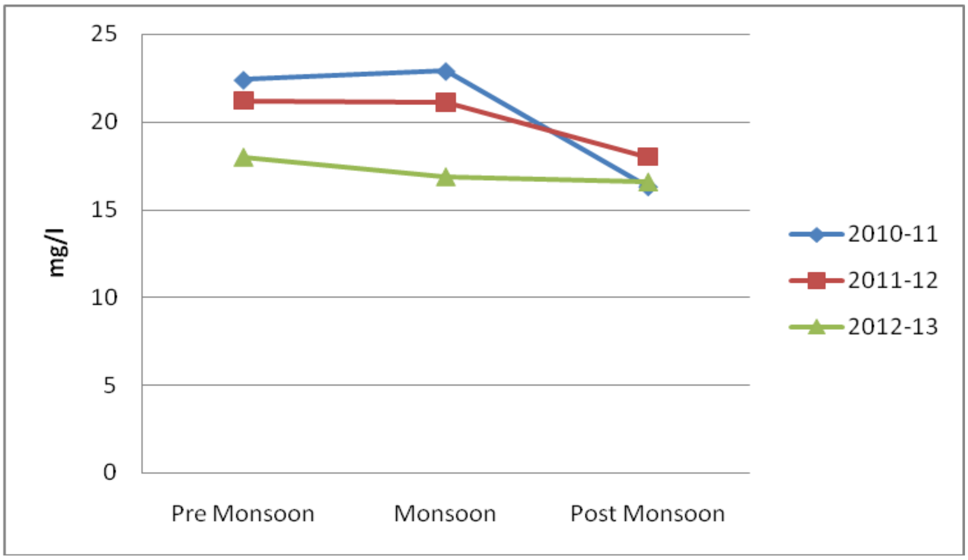


Figure 15. Average Carbon-di-oxide of Gulshan lake water

In pre monsoon average free carbon di oxide was 20.5±1.3 mg/l, in monsoon 20.3±1.8 mg/l and in post monsoon 17.0±0.5 mg/l. The minimum free carbon di oxide contents of Gulshan lake water was observed in post monsoon and the maximum was in pre monsoon. There was no significant variations were found of among three seasons of the two lakes. [Table 3].

Other hand, the free carbon di oxide in Dhanmondi lake water varied from 11.4mg/l to 33.3mg/l. In first year average was 19.5±3.2 mg/l, in second year 20.9±1.1 mg/l and third year was 19.9±0.6 mg/l. There was no significant correlation was found in Dhanmondi lake water free carbon di oxide of three years data. [Table 4].

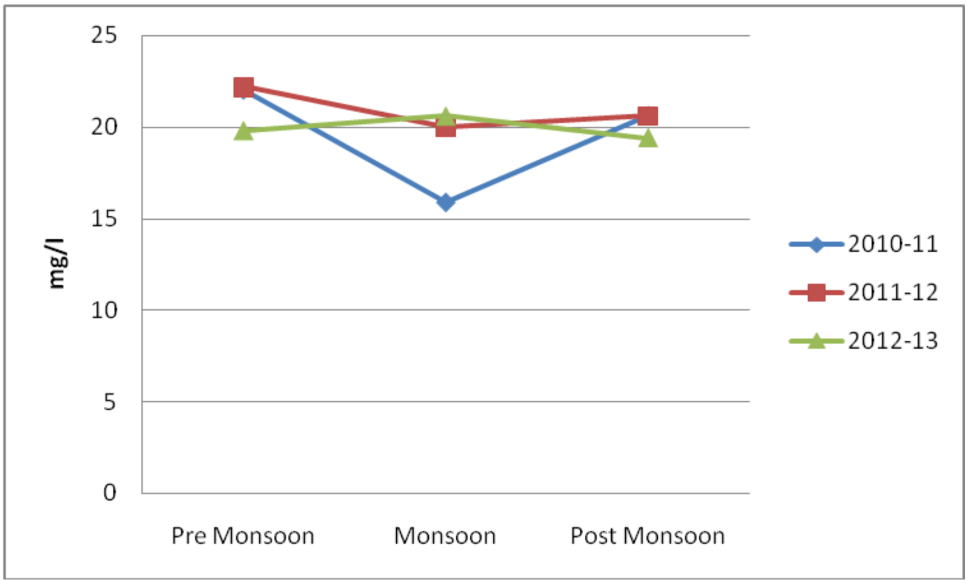


Figure 16. Average Carbon-di-oxide of Dhanmondi lake water

In pre monsoon average free carbon di oxide in Dhanmondi lake was 19.5±3.2 mg/l, in monsoon 20.9±1.1 mg/l and in post monsoon 19.9±0.6 mg/l. The minimum free carbon di oxide contents of Dhanmondi lake water was observed in post monsoon and the maximum was in monsoon. There was no significant differences were found among three seasons in Dhanmondi lake. [Table 5]. Comparison study reveals that significantly no differences between in year's data of two lakes during study period. [Table 6-8].

4.2.9. Alkalinity:

Alkalinity has effect on the buffering capacity of the water systems and needs to be monitored in all cases. High alkalinity is a measure of wastewater strength. It shows the capacity of waste waters to neutralize acids, and is undesirable. Alkalinity was found in the range of 122.4mg/l to 216.7mg/l in the Gulshan lake water. In first year average was 158.4±8.6 mg/l, in second year 168.5±23.1 mg/l and third year was

193.7mg/l±6.9. Alkalinity in the Gulshan lake water was found increasing tendency with the following year. There was no significant variations were found in the Gulshan lake water alkalinity of three years data. [Table 2].

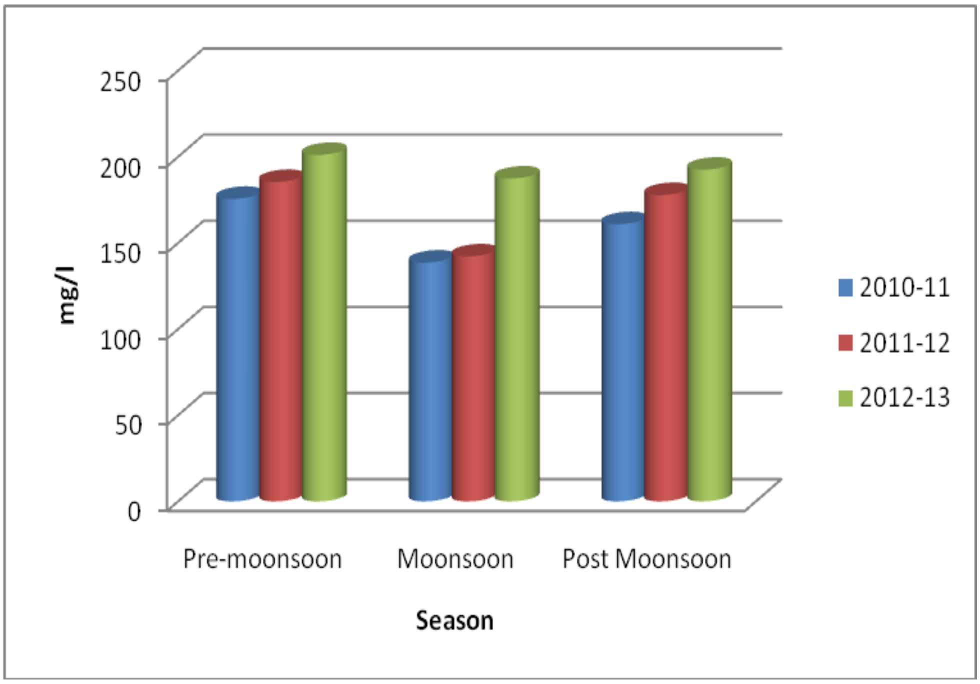


Figure 17 . Average Alkalinity of Gulshan Lake water

In pre monsoon average alkalinity was 187.3±7.5 mg/l, in monsoon 153.5±17.3 mg/l and in post monsoon 187.7±28.3 mg/l. There was no significant correlation was found among three seasons. [Table 3].

Alkalinity in the Dhanmondi lake water varied from 87.5mg/l to 123.1mg/l. In first year average alkalinity was 98.2±2.9 mg/l in second year 104.8±6.6 mg/l and third year was 106.6±2.8 mg/l. Alkalinity of first and second year in the Dhanmondi lake shows significant difference than third year. [Table 4].

In pre monsoon average alkalinity was 105.5±2.3 mg/l in monsoon 99.4±2.3 mg/l and in post monsoon 102.8±2.9 mg/l. Minimum alkalinity of the Dhanmondi lake water was observed also in monsoon and the maximum was in pre monsoon. There was no significant variations were found among three seasons. [Table 5].

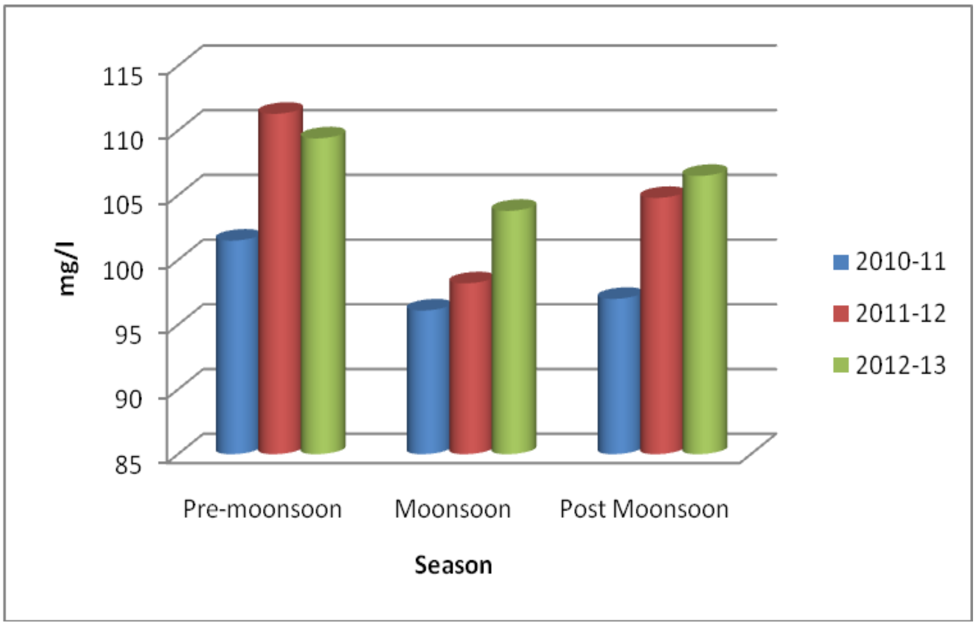


Figure 18. Average Alkalinity of Dhanmondi iake water

In comparison between two lakes alkalinity showed strongly significant differences in three years data (t=34.16, 16.45 and 14.32, year 1 to 3 respectively, df=142, $p<0.001$) [Table 6-8].

4.2.10. Hardness:

Hardness of water is not chemical parameters but indicates the water quality mainly in terms of Ca_2+ and Mg_2+ and expressed as $CaCO_3$. Hardness has no known adverse effect. Hardness concentrations obtained from the Gulshan lake are ranged from 85.7mg/l to 130mg/l. In first year average hardness in the Gulahan lake was 98.2±4.3 mg/l, in second year 104.7±6.6 mg/l and third year was 107.4±3.8 mg/l. The hardness in the Gulshan lake water was found increasing tendency with the year. There was no significant differences were recorded in the Gulshan lake water hardness in three years data. [Table 2].

In the Dhanmondi lake hardness value concentrations was ranged from 85.7mg/l to 130mg/l. In first year average hardness was 98.2±4.3 mg/l, in second year 104.7±6.6 mg/l and third year was 107.4±3.8 mg/l.

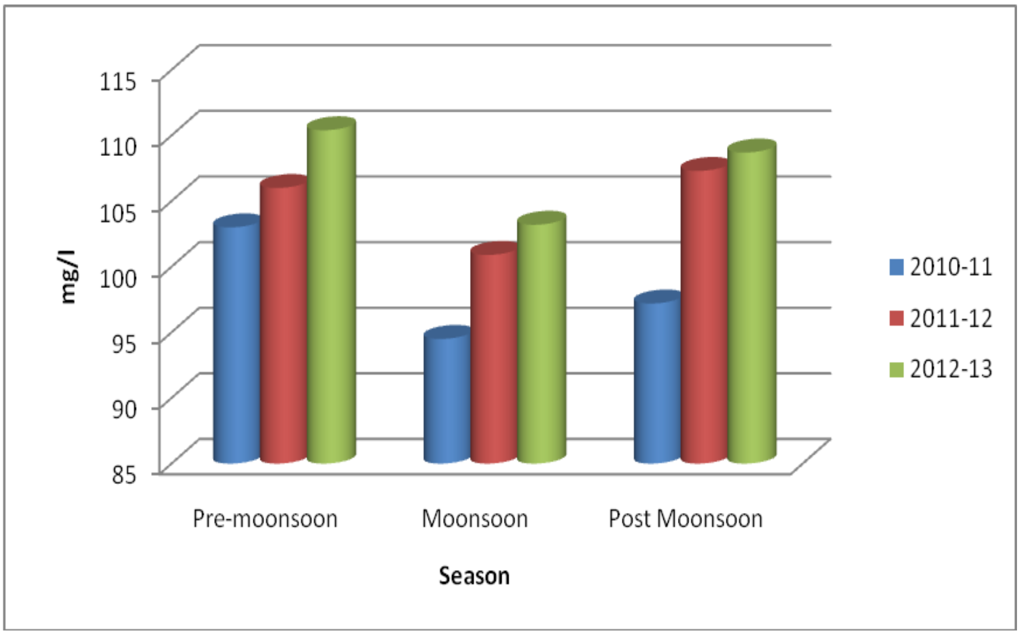


Figure 19. Average Hardness of Gulshan iake water

The hardness in the Gulshan lake water was found increasing tendency with the year. There was no significant differences were recorded in concentrations the Dhanmondi lake water hardness in three years data. [Table 2].

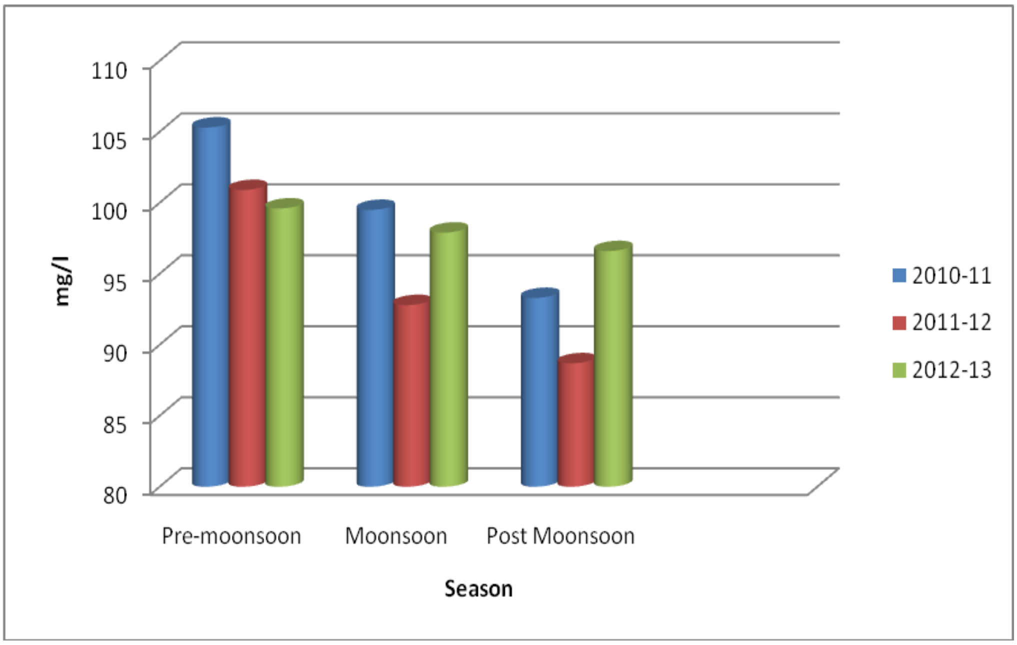


Figure 20. Average Hardness of Dhanmondi lake water

In pre monsoon average hardness was 109.8±3.7 mg/l, in monsoon 99.5±2.6 mg/l and in post monsoon 104.0±3.6 mg/l. The minimum hardness of the Gulshan lake water was observed in monsoon and the maximum was in pre monsoon. There was no significant variations were found among three seasons. [Table 4]. The hardness values ranged from 83.0mg/l to 115.1mg/l in the Dhanmondi lake. In first year average was 99.4±4.3 mg/l, in second year 94.1±6.6 mg/l and third year was 98.0±1.5 mg/l. No significant differences were recorded in hardness in three years data. [Table 3].

In pre monsoon average hardness of the Dhanmondi lake was 102.0±1.7 mg/l in monsoon 96.7±2.0 mg/l and in post monsoon 92.9±2.3 mg/l. No significant differences were recorded among three seasons. [Table 5]. In comparison between two lakes no significant differences was found in first and second year data [Table 6 and 7] but in third year showed significant differences in case of hardness of water. ($t=8.86$, $df=142$, $p<0.001$). [Table 8].

4.2.11. Conductivity:

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions on their total concentration, mobility and valence and on the temperature of measurement. Conductivity measures the salinity of water and depends on the ions present in water.

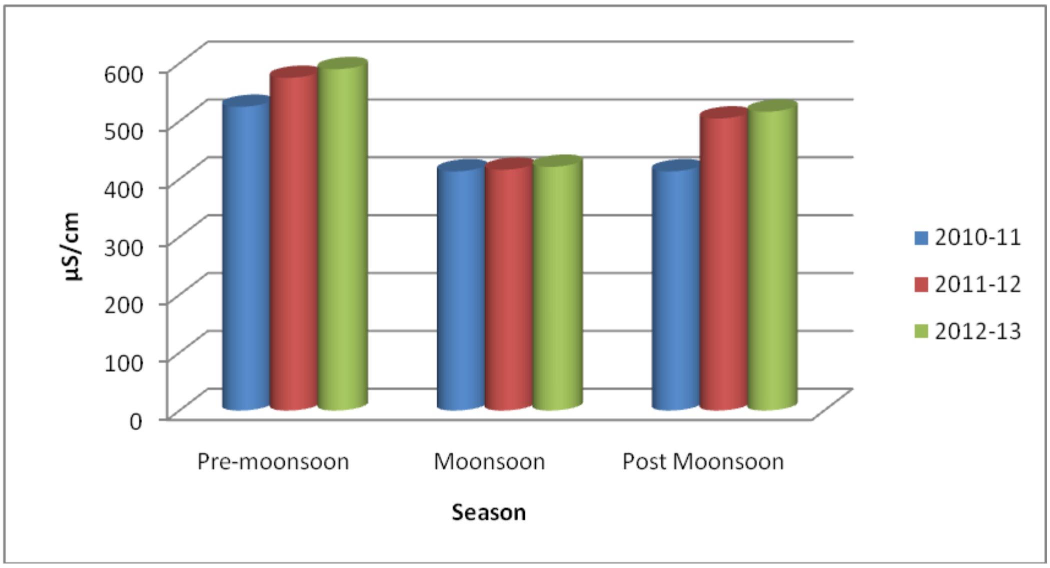


Figure 21. Average Conductivity of Gulshan lake water

The conductivity in the Gulshan lake was found between 372.5 µs/cm and 661.3 µs/cm. In first year average conductivity of Gulshan lake was 450.5 ±64.4 µs/cm, in second year 498.5 ±79.6 µs/cm and in third year 509.1±84.6 µs/cm. First year data show significant difference than second and third year of the Gulshan lake water conductivity ($p=0.018$, $p<0.05$). [Table 2]. In pre monsoon average conductivity was 563.2 ±19.7 µs/cm, in monsoon 432.3 ±13.7 µs/cm and in post monsoon 471.4 ±29.2 µs/cm. The lowest conductivity contents of the Gulshan lake water was observed in monsoon and the highest was in pre monsoon. Conductivity show statistically significant difference among three seasons. ($P=0.014$, $P<0.05$). [Table 4].

The mean values for conductivity in the Dhanmondi lake varied between 202.8 µs/cm to 446.7µs/cm. In first year average conductivity was 325.7±87.0 µs/cm, in second year 351.0±52.9 µs/cm and in third year 354.6 ±45.8 µs/cm. No significant difference was recorded in three years of the Dhanmondi lake water conductivity. [Table 3].

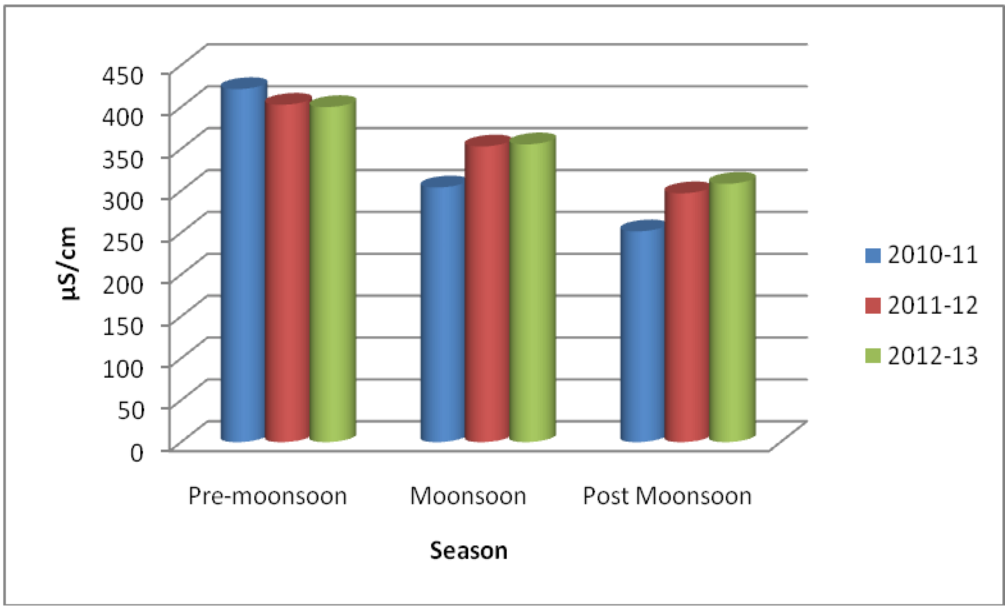


Figure 22. Average Conductivity of Dhanmondi lake water

In pre monsoon average conductivity was 396.5±8.3 µs/cm, in monsoon 337.5±16.8 µs/cm and in post monsoon 285.7±29.2 µs/cm. The lowest conductivity contents of Dhanmondi lake water was observed in monsoon and the highest was in pre monsoon.

Conductivity show statistically significant difference among three seasons of the Dhanmondi lake water. (P=0.005, P<0.01). [Table 5]. In comparison between two lakes water conductivity showed strongly significant differences in three years data (t=9.86, t=11.62 and t=12.43, year 1 to 3 respectively, df=142, p<0.001) [Table 6-8].

4.2.12. Total Dissolved Solids (TDS):

Water with high total dissolved solids (TDS) is of inferior portability and may induce an unfavorable physiological response of the body of consumer. In the present observation indicates the higher total dissolved solids value in the Gulshan lake which varied from 179.5mg/l to 285.5mg/l. In first year average was 232.0±35.8 mg/l, in second year 237.3±38.4 mg/l and third year was 244.8±41.6 mg/l. TDS show statistically significant difference among three years of the Gulshan lake water. (P=0.000, P<0.001). [Table 2].

In pre monsoon average TDS was 273.9±2.9 mg/l in monsoon 179.6±0.9 mg/l and in post monsoon 231.8±3.0 mg/l. TDS show statistically significant difference among three seasons of the Gulshan lake water. (P=0.000, P<0.001). [Table 4].

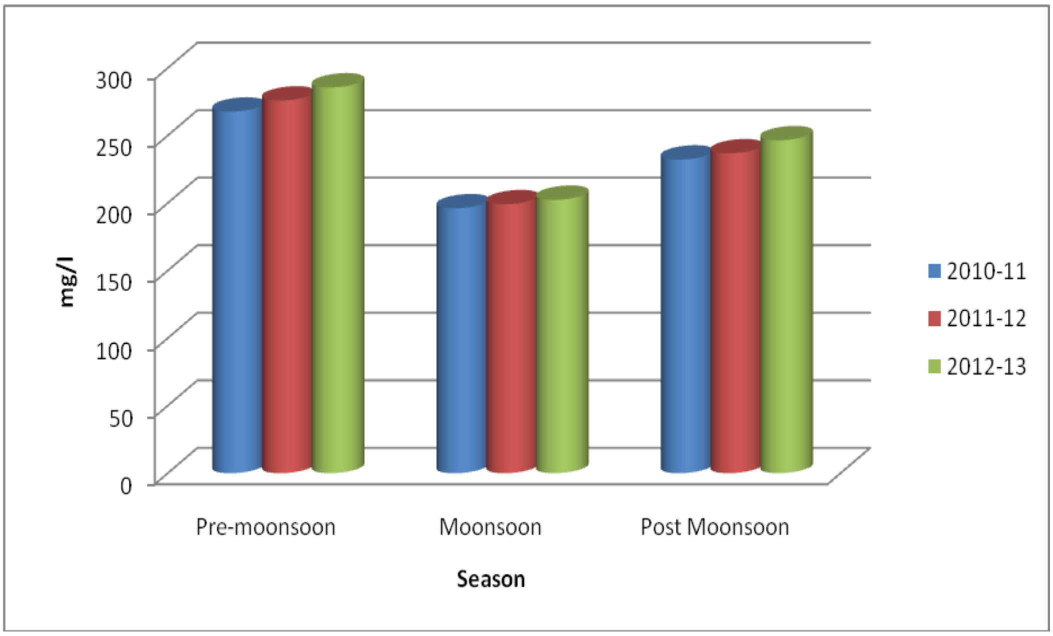


Figure 23. Average Total Dissolve Solids of Gulshan lake water

The highest and lowest TDS of Dhanmondi lake water was recorded 128.5 mg/L and 210.0 mg/l. In first year average was 164.7±25.3 mg/l, in second year 165.1±23.1 mg/l and third year was 179.4±14.0 mg/l. TDS shows no statistical significant difference in three years data of the Dhanmondi lake water. [Table 3].

In pre monsoon average TDS was 189.5±2.4 mg/l in monsoon 171.8±3.0 mg/l and in post monsoon 148.0±9.2 mg/l. TDS of the Dhanmondi lake water show statistically significant difference pre monsoon and monsoon with post monsoon. (P=0.006, P<0.01). [Table 5].

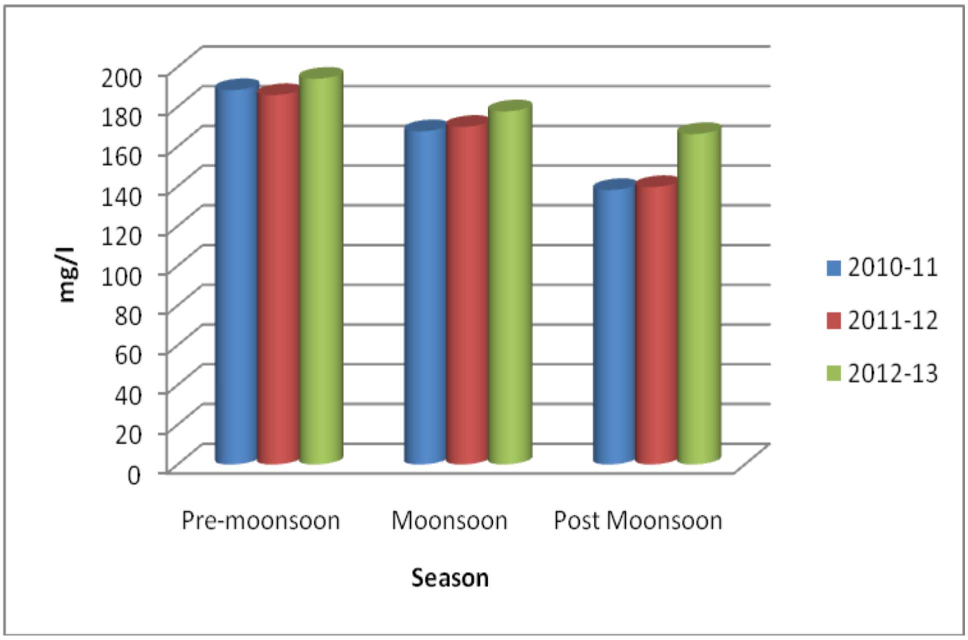


Figure 24. Average Total Dissolve Solids of Dhanmondi lake water

In comparison between two lakes water TDS showed strongly significant differences in three years data (t=11.87 in year 1, t=11.99 in year 2 and t=10.25 in year 3, df=142, p<0.001) [Table 6-8].

4.2.13. Biological Oxygen Demand (BOD):

Biological oxygen demand is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter. Urban runoff carries pet wastes from streets and sidewalks, nutrients from lawn fertilizers, leaves, grass clippings and paper from residential areas which increase oxygen demand. This high level of BOD is an indication of the contamination. This also indicates that there could be low oxygen available for living organisms in the wastewater. Biological Oxygen Demand is a very important indicator of the pollution status of a water body.

It was observed that BOD of the Gulshan lake water varied between 5.4 mg/l and 9.1 mg/l. In first year average was 7.5±0.9 mg/l, in second year 7.8±1.0 mg/l and third year was 7.6±1.1 mg/l. BOD show statistically significant difference among three years of the Gulshan lake water. (P=0.000, P<0.001). [Table 2].

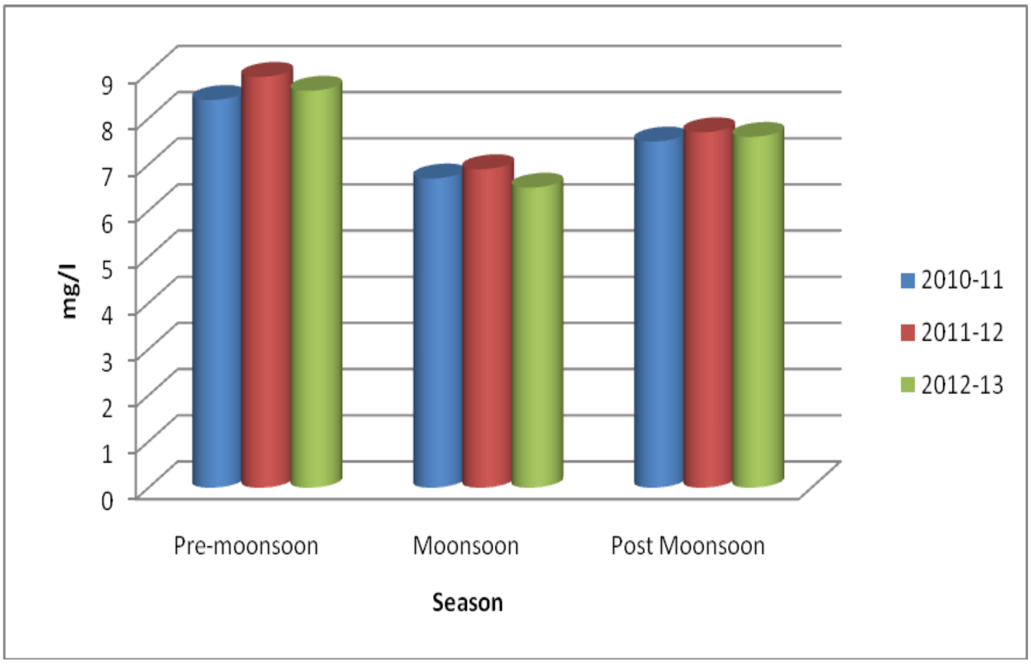


Figure 25. Average Biological Oxygen Demand of Gulshan lake water

In pre monsoon average BOD was 8.6±0.2 mg/l in monsoon 6.7±0.1 mg/l and in post monsoon 7.6±0.1 mg/l. BOD show statistically significant difference among three seasons of Gulshan lake water. (P=0.000, P<0.001). [Table 4].

BOD of the Dhanmondi lake water varied from 2.2mg/L to 4.3mg/L In first year average was 2.9±0.3 mg/l, in second year 2.8±0.2 mg/l and third year was 3.0±0.3 mg/l. BOD show no statistical significant difference in three years data of the

Dhanmondi lake water. [Table 3]. Dhanmondi lake water varied from 2.2 mg/L to 4.3 mg/L In first year average was 2.9±0.3 mg/l, in second year 2.8±0.2 mg/l and third year was 3.0±0.3 mg/l. BOD show no statistical significant difference in three years data of the Dhanmondi lake water. [Table 3]. BOD of the Dhanmondi lake water varied from 2.2 mg/L to 4.3 mg/L In first year average was 2.9±0.3 mg/l, in second year 2.8±0.2 mg/l and third year was 3.0±0.3 mg/l. BOD shows no statistical significant difference in three years data of Dhanmondi lake water. [Table 3].

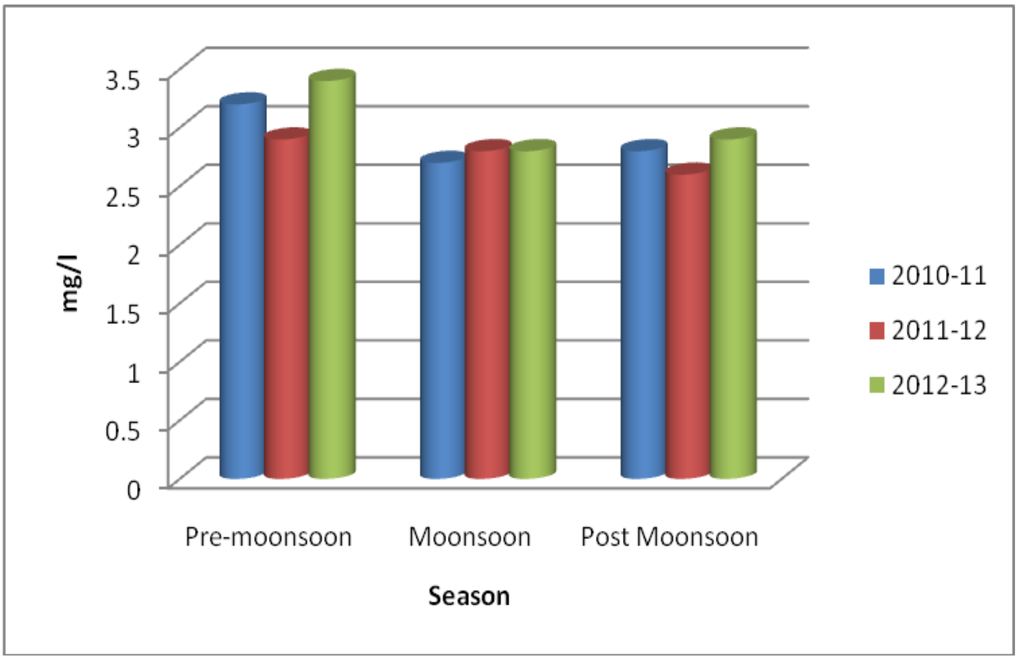


Figure 26. Average Biological Oxygen Demand of Dhanmondi lake water

In pre monsoon average BOD was 3.2±0.2 mg/l in monsoon 2.8±0.03 mg/l and in post monsoon 2.9±0.1 mg/l. BOD of the Dhanmondi lake water show statistically significant difference pre monsoon with monsoon and post monsoon. ($P=0.006$, $P<0.01$). [Table 5]. In comparison between the two lakes water BOD values showed clearly significant differences in three years data ($t=34.17$ in year 1, $t=30.39$ in year 2 and $t=26.50$ in year 3, $df=142$, $p<0.001$) [Table 6-8].

4.2.14. Chemical Oxygen Demand (COD):

Chemical Oxygen Demand (COD) is widely used to characterize the organic strength of waste water and pollution of natural water. The test measures the amount of oxygen required for chemical oxidation of organic matter in the sample to carbon dioxide and water. Chemical Oxygen Demand is a measure of pollution in aquatic ecosystems. High COD levels imply toxic condition and the presence of biologically resistant organic substances.

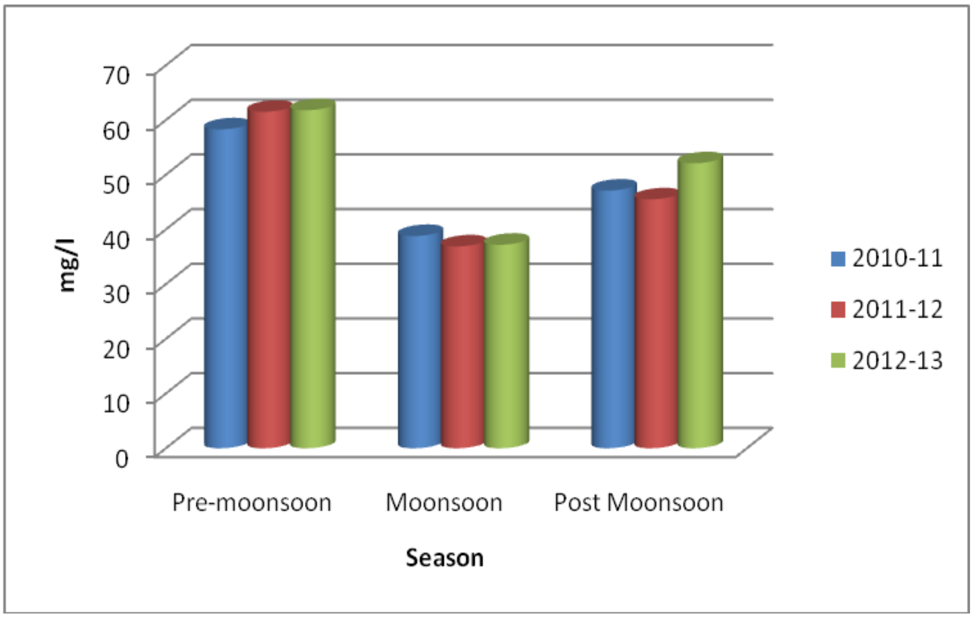


Figure 27. Average Chemical Oxygen Demand of Gulshan lake water

COD of Gulshan lake water varied from 32.5 mg/l to 62.4 mg/l. In first year average was 48.1±9.8 mg/l, in second year 48.0±12.9 mg/l and third year was 50.4±12.4 mg/l. First and second year had no significant difference.

Third year data show statistically significant difference than two years of the Gulshan lake water. ($P=0.012$, $P<0.05$). [Table 2]. In pre monsoon average COD was 60.5±0.1 mg/l in monsoon 36.6±0.4 mg/l and in post monsoon 49.0±1.7 mg/l. COD of the Gulshan lake water show statistically significant difference among three seasons. ($P=0.000$, $P<0.01$). [Table 4].

COD of the Dhanmondi lake water varied from 17.6mg/l to 32.7mg/l In first year average was 24.3±4.6 mg/l, in second year was 23.5±4.0 mg/l and third year was 25.6±0.5 mg/l.

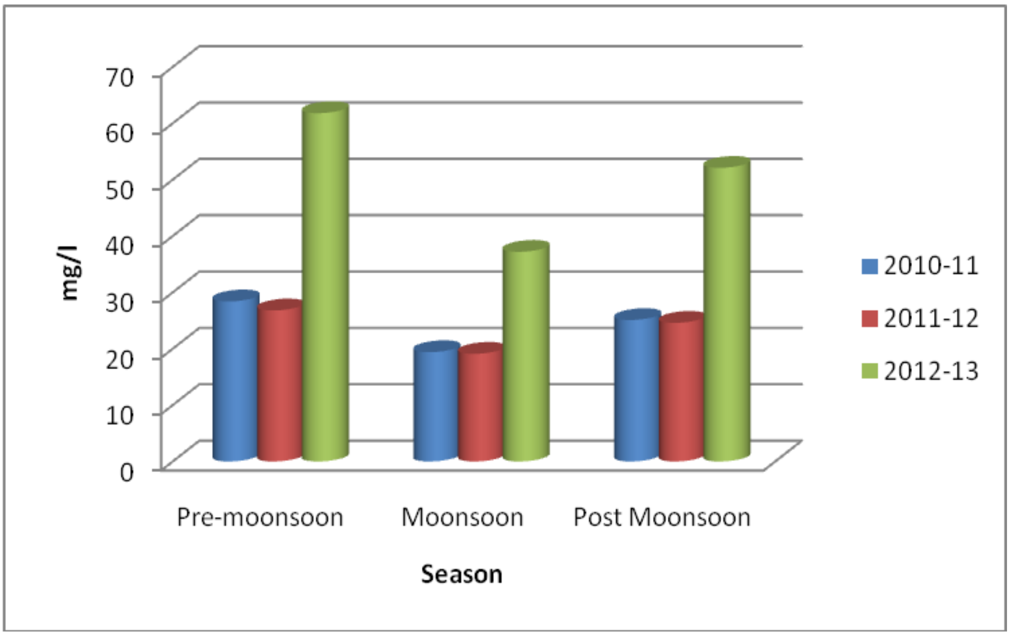


Figure 28. Average Chemical Oxygen Demand of Dhanmondi lake water

COD values of the Dhanmondi lake water was observed in below than acceptable range throughout the season and years. COD of the Dhanmondi lake shows no significant differences in three years. (Table 3). In pre monsoon average COD was 26.9±1.4 mg/l in monsoon was 20.1±0.9 mg/l and in post monsoon was 25.1±0.3 mg/l. [Table 3]. COD of the Dhanmondi lake water show statistically significant difference among three seasons. (P=0.006, P<0.01). [Table 5].

In comparison between the two lakes water COD values showed strongly significant differences in three years data (t=17.79 in year 1, t=16.50 in year 2 and t=15.43 in year 3, df=142, p<0.001) [Table 6-8].

4.3. Heavy metals of water:

Heavy metals are among the most common environmental pollutants and their occurrence in water indicates the presence of natural or anthropogenic sources. Heavy metals like chromium, lead, cadmium, arsenic, etc. exhibit extreme toxicity even at trace levels. Water is a dominant pathway for metals transport and heavy metals become significant pollutants of many open water systems. The behavior of metals in natural waters is a function of the substrate sediment composition the suspended sediment composition and the water chemistry. During their transport the heavy metals undergo numerous changes in their speciation due to dissolution, precipitation, absorption and complication phenomena. In this study key heavy metals viz., Zinc (Zn), Chromium (Cr), Cadmium (Cd), Lead (Pb), Copper (Cu), Nickel (Ni) and Manganese (Mn) of water samples collected during pre monsoon, monsoon and post monsoon were analysed. The results so far obtained during the period of investigation in the Dhanmondi and Gulshan lakes are briefly discussed below.

4.3.1 Zinc (Zn):

Zinc plays a biochemical role in the life processes of all aquatic plants and animals therefore they are essential in the aquatic environment in trace amounts.

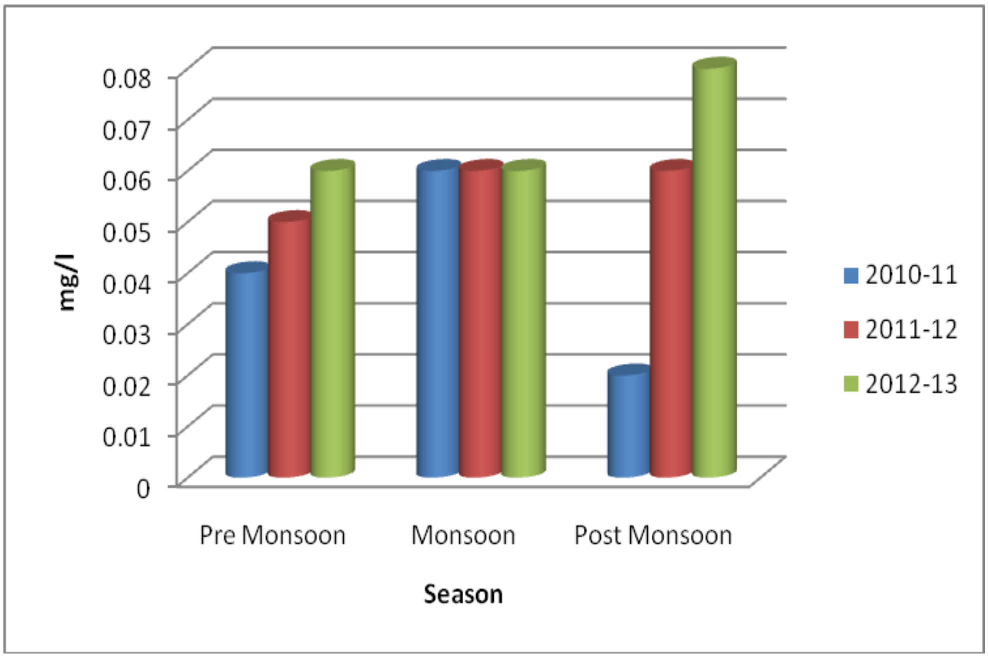


Figure 29. Average Zinc of Gulshan lake water

Zinc level in water of the Gulshan lake was varied from 0.02 mg/l to 0.08 mg/l.(Table A7-A9). No specific relation was found among the three seasons. Increasing trends of Zn concentrations were found in successive year.

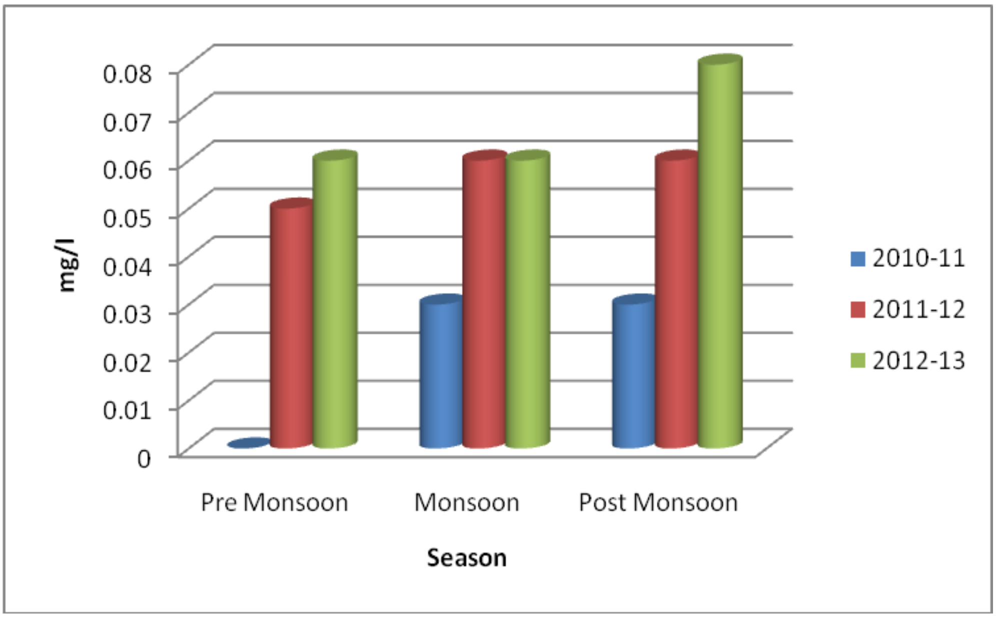


Figure 30. Average Zinc of Dhanmondi lake water water

In the Dhanmondi lake it was ranges from 0.00 mg/l to 0.04 mg/l. (A10-A12). No specific relation was observed between the three seasons. Zinc concentration of Dhanmondi lake water was not changed with years. Higher concentrations were recorded in the Gulshan lake water compare to the Dhanmondi lake water.

4.3.2 Chromium (Cr):

Chromium level of water of the Gulshan lake was recorded below detected level (BDL) water during the entire study period. (Table A7-A9).

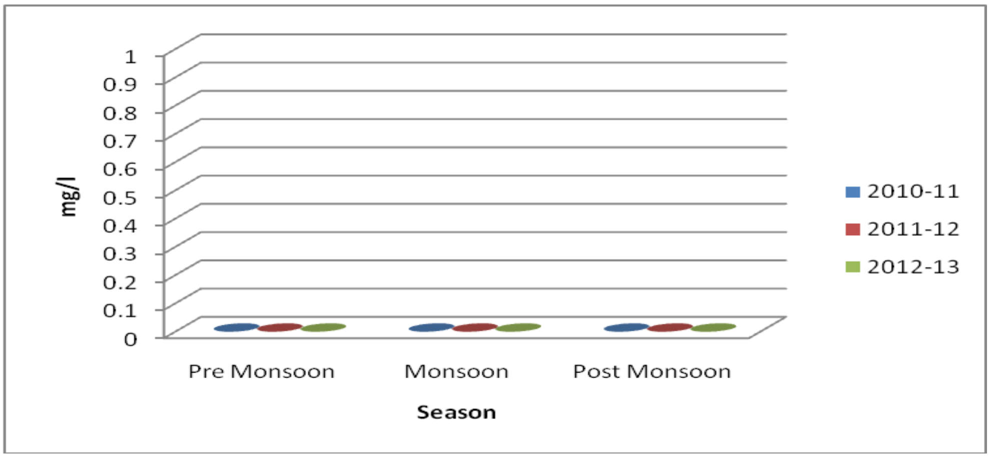


Figure 31. Average Chromium of Gulshan lake water

Chromium level of water of the Dhanmondi lake was also recorded below detected level (BDL) during the entire study period. (Table A10-A12).

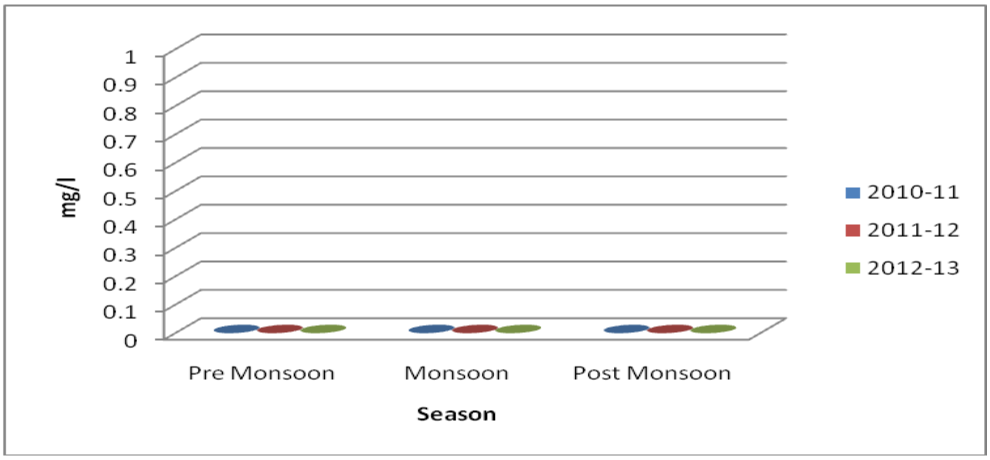


Figure 32. Average Chromium of Dhanmondi lake water

4.3.3 Cadmium (Cd):

Cadmium level of water in the Gulshan lake was ranged from 0.00 mg/l to 0.07 mg/l. (Table A7-A9). In the Gulshan lake no specific relation was observed between the seasons but increasing tendency was recorded with the year succeeding.

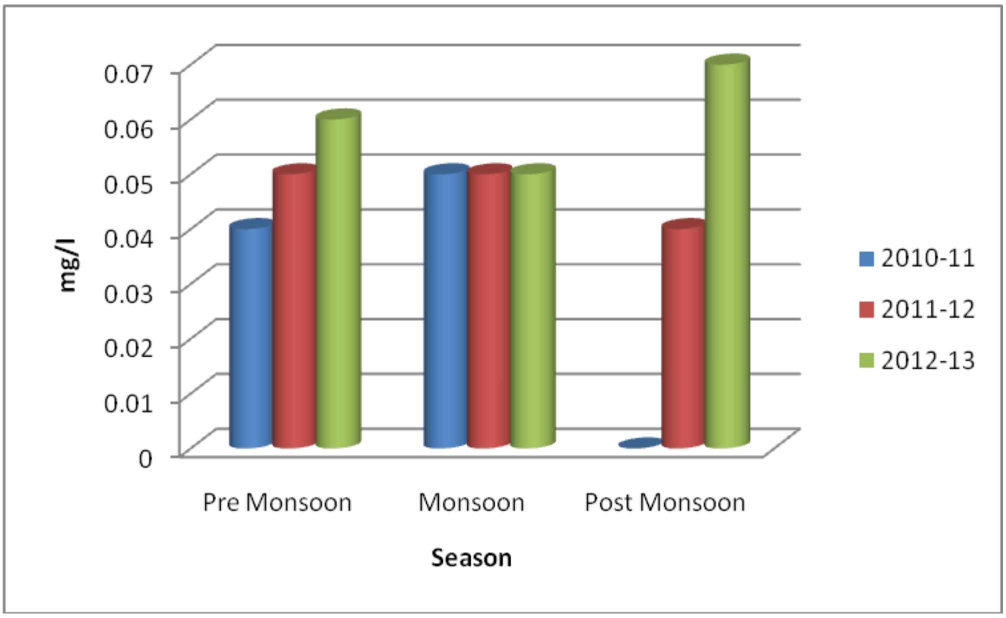


Figure 33. Average Cadmium of Gulshan lake water

In the Dhanmondi lake it was recorded 0.01mg/l to 0.04mg/l. (Table A10-A12).There was no specific relation was found in cadmium concentration with the season and year in the Dhanmondi lake.

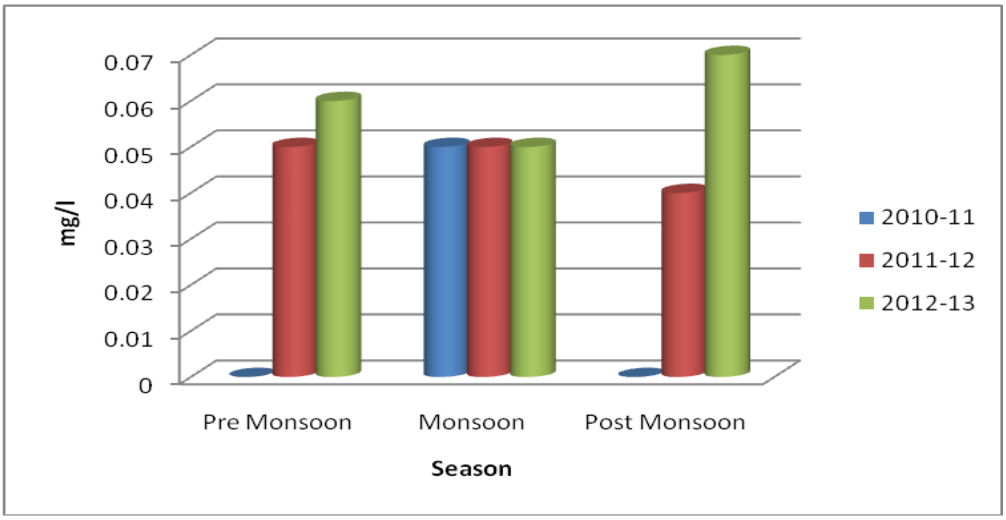


Figure 34. Average Cadmium of Dhanmondi lake water

4.3.4 Lead (Pb):

The Lead concentration of the Gulshan and Dhanmondi lake are shown in Figure 35 and Figure 36. Average value of lead of the Gulshan lake varied between 0.02 mg/l and 0.08 mg/l (Table A7-A9) and in the Dhanmondi lakes varied between 0.00 mg/l and 0.06 mg/l. (Table A10-A12).

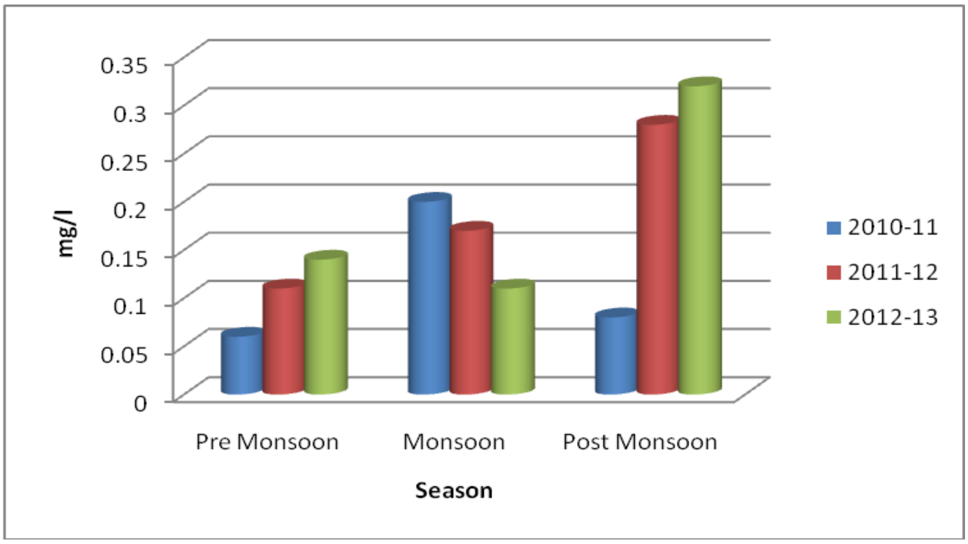


Figure 35. Average Lead of Gulshan lake water

Lead is soft malleable metal also considered to be one of heavy metals. The aqueous form of a contaminant may significantly affect environmental physicochemical behavior and bioavailability of toxic metals.

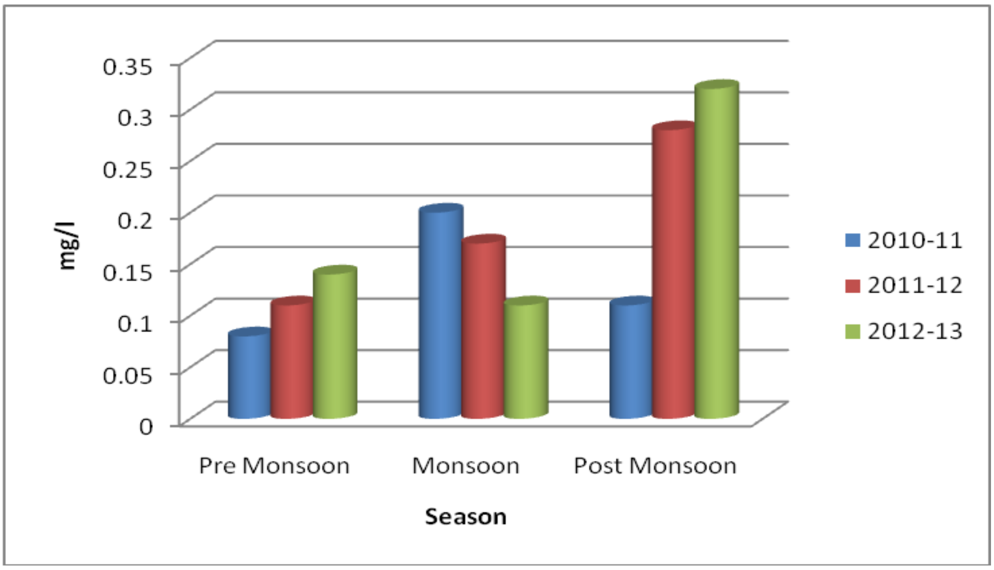


Figure 36. Average Lead of Dhanmondi lake water

Lead may be present in ionic state or as soluble complexes or in sorbet state in an aquatic system. Toxicity of lead depends on the chemical form in which it exists in the system.

4.3.5 Copper (Cu):

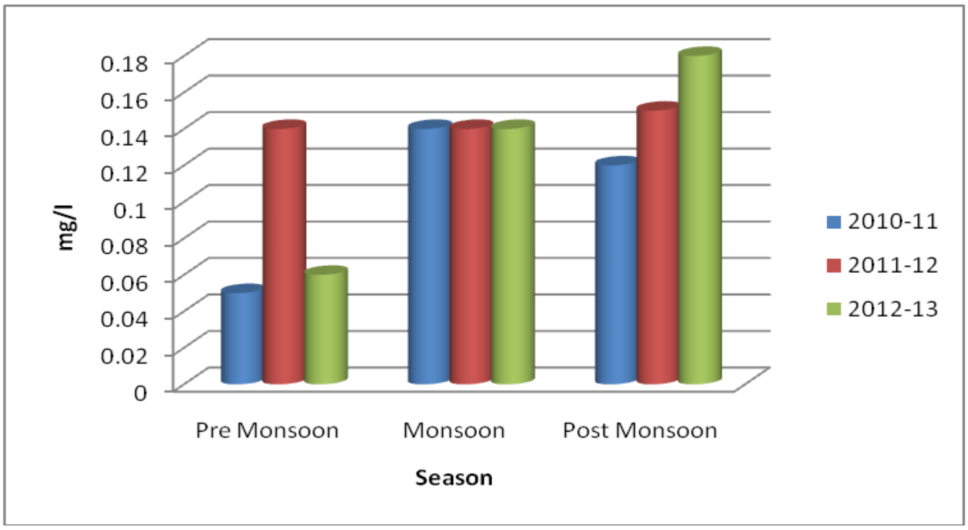


Figure 37. Average Copper of Gulshan lake water

Average Copper in the Gulshan lake water was ranged from 0.05mg/l to 0.14mg/l (Table A7-A9) and in the Dhanmondi lake water was 0.06 mg/l to 0.14 mg/l. (Table A10-A12). The results revealed that no specific relation was observed between the seasons and increasing trends was observed with the following years.

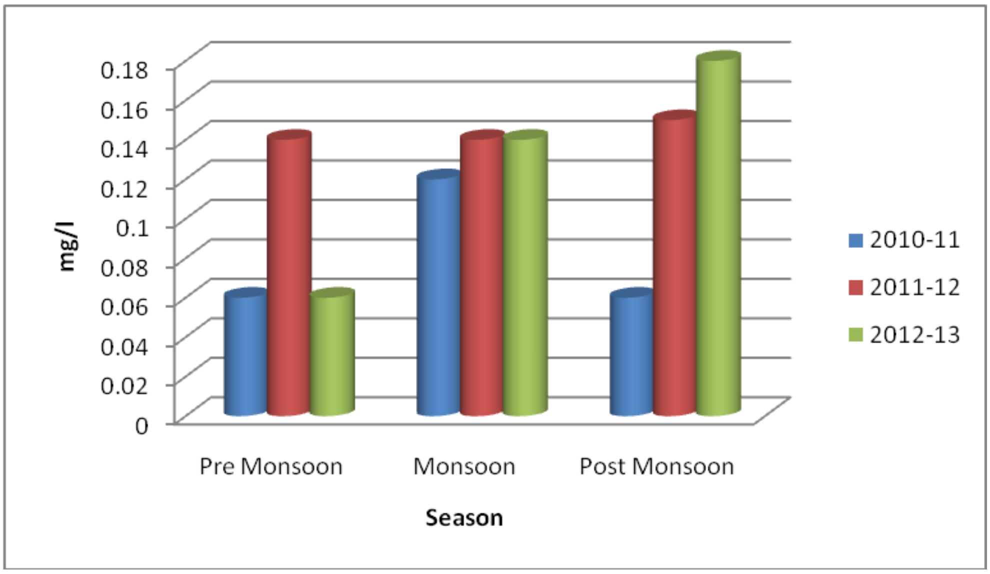


Figure 38. Average Copper of Dhanmondi lake water

Copper is a vital element necessary for normal organism growth and metabolism and its uptake are regulated by physiological mechanisms according to nutritional demand. At high concentrations copper becomes toxic to the body.

4.3.6 Nickel (Ni):

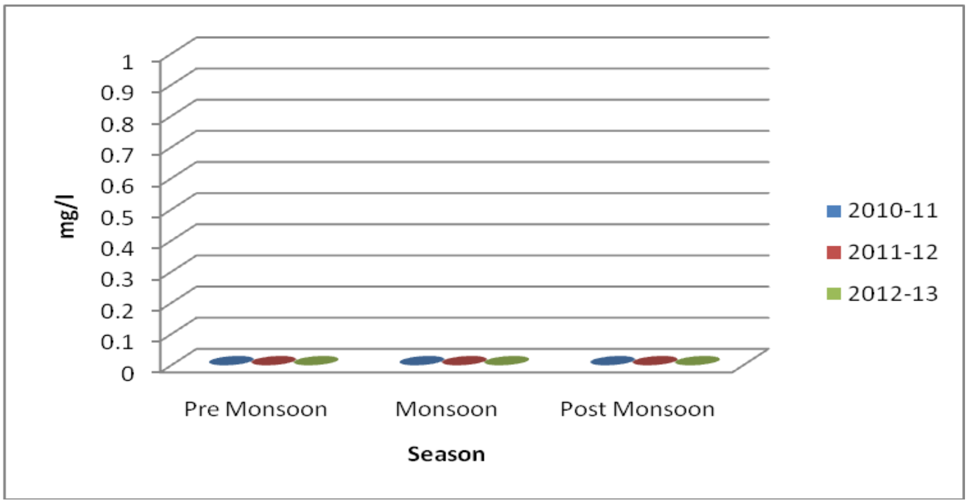


Figure 39. Average Nickel of Gulshan lake water

Nickel level of water of the Gulshan and Dhanmondi lakes was recorded below detected level (BDL) (Table A7-A12).

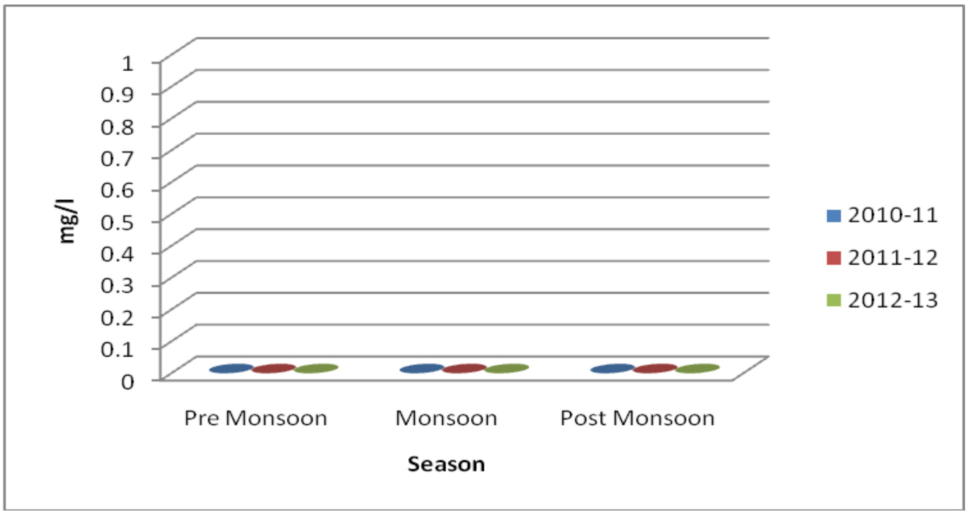


Figure 40. Average Nickel of Dhanmondi lake water

4.3.7 Manganese (Mn):

Average value of Mn of the Gulshan and Dhanmondi lakes are presented below. Mn in the Gulshan lake water was 0.40mg/l and 0.48 mg/l. (Table A7-A9). In Dhanmondi lake it was varied between 0.30mg/l and 0.48 mg/l. (Table A10-A12).

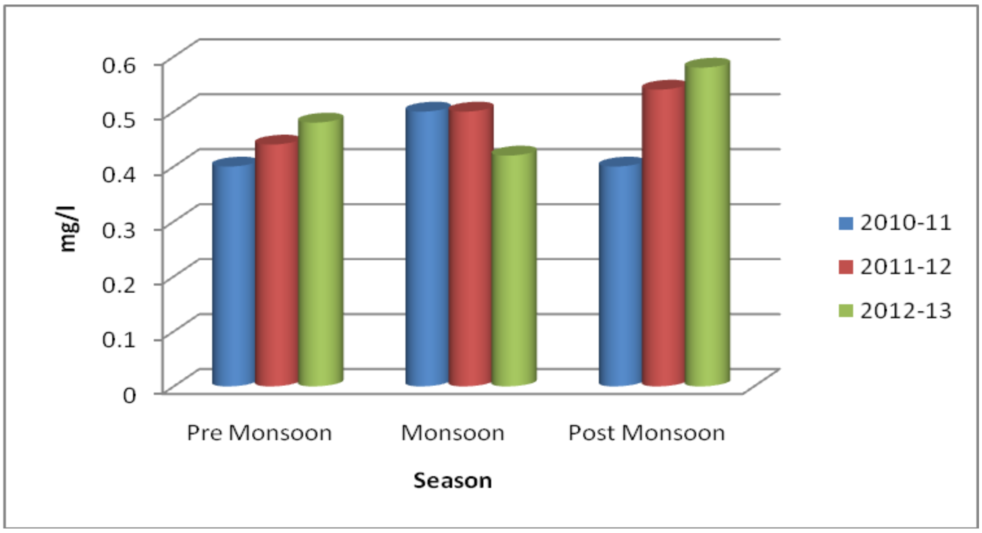


Figure 41. Average Manganese of Gulshan lake water

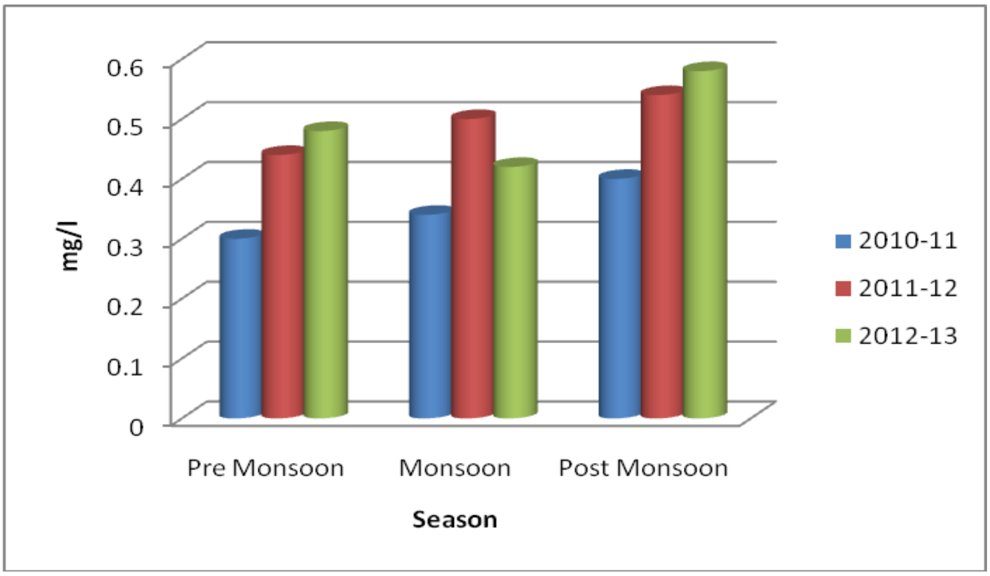


Figure 42. Average Manganese of Dhanmondi lake water

4.4. Sediment quality:

The sediment quality of two lakes was analyses on seasonal basis. Pre monsoon, monsoon and post monsoon. Details results are describe below.

4.4.1. pH:

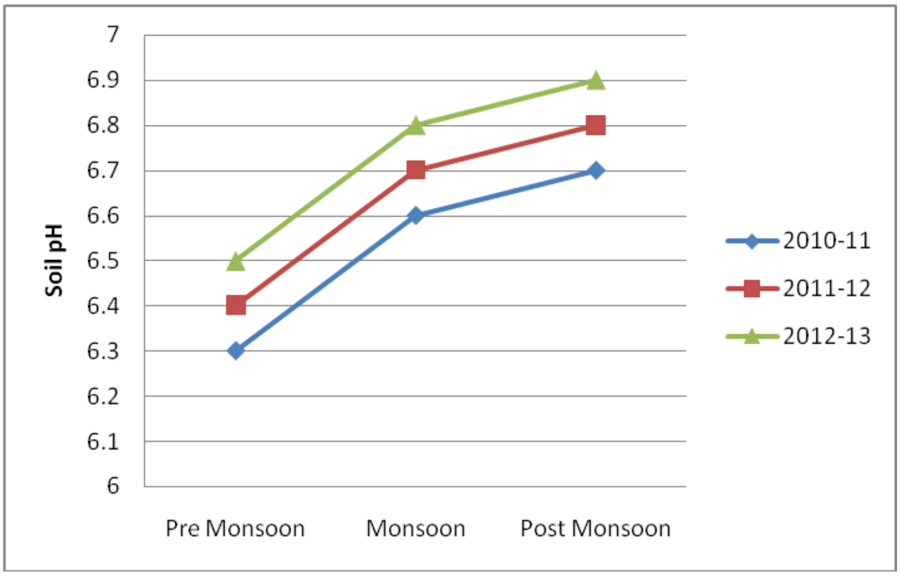


Figure 43. Average pH value of Gulshan lake sediment

Average pH value of sediment of the Gulshan lake was 6.3 to 6.5. (Table A13-A15). In the Dhanmondi lake sediment was also 6.1 to 6.5. (Table A16-A18). The pH values were indicates that sediments of both lakes were acidic in nature.

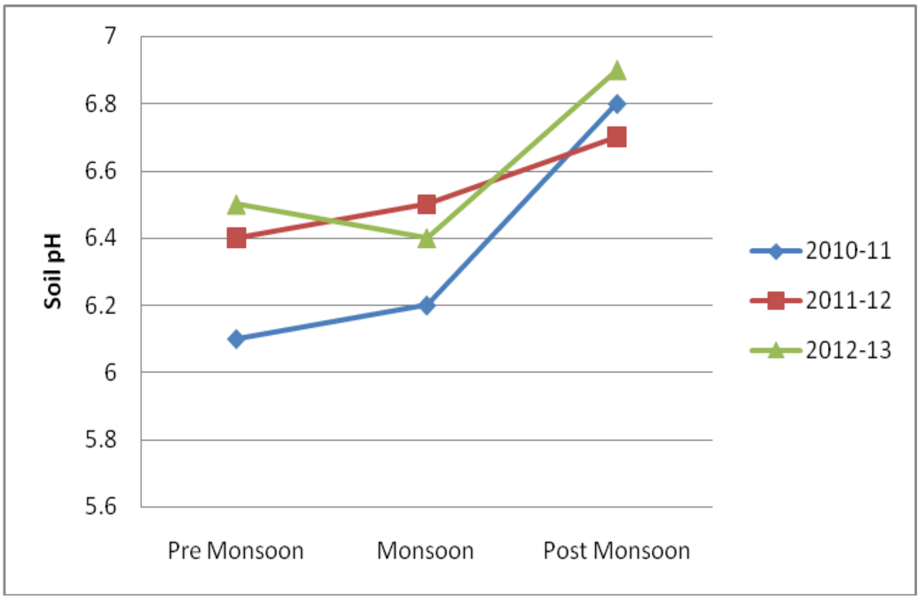


Figure 44. Average pH value of Dhanmondi lake sediment

4.4.2. Organic matter:

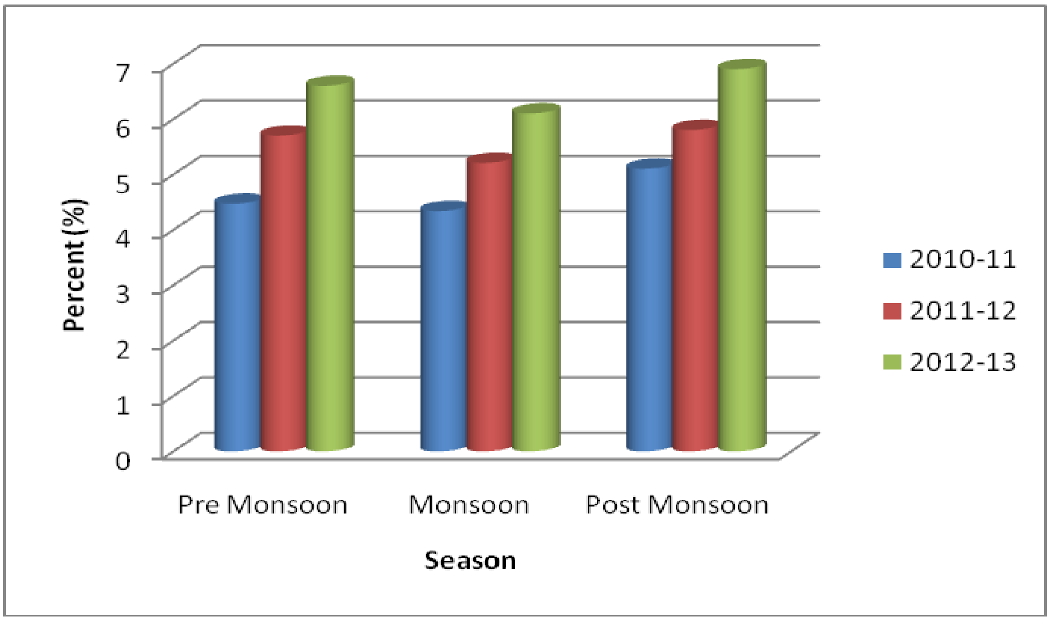


Figure 45. Average Organic matter of Gulshan lake sediment

Average organic matter range was found 4.5% to 6.6% in sediment of the Gulshan lake. (Table A13-A15). In the Dhanmondi lake average sediment range was 3.05% to 3.64%. (Table A16-A18). Almost double the values of organic matter were recorded in the Gulshan lake sediment than the Dhanmondi lake which is apparently resulted the sediment of the Gulshan lake was polluted.

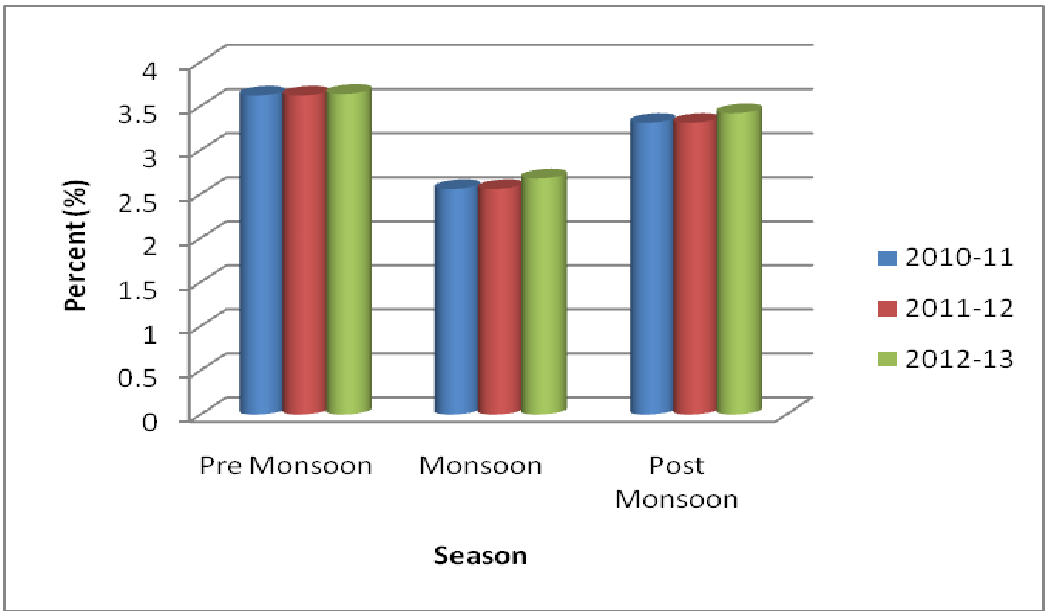


Figure 46. Average Organic matter of Dhanmondi lake sediment

4.4.3. Acidity:

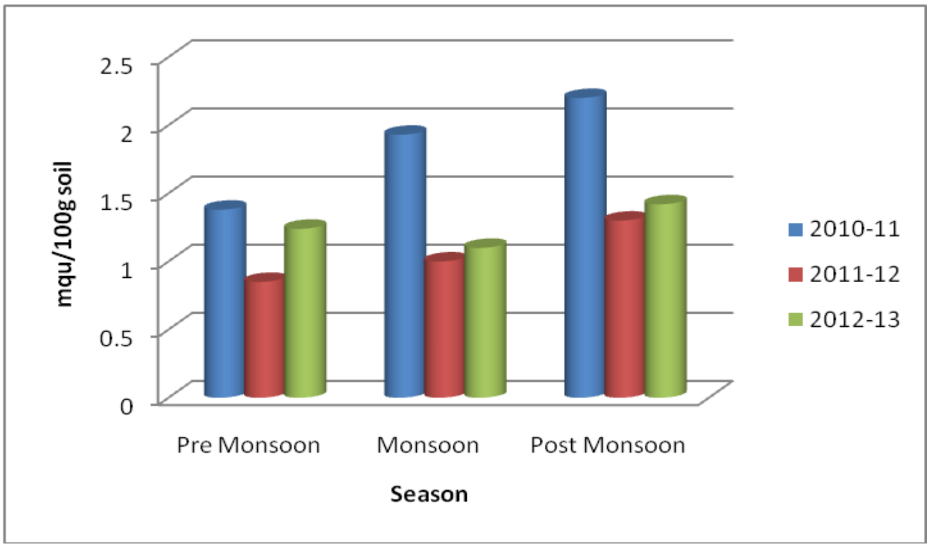


Figure 47. Average Acidity of Gulshan lake sediment

Average acidity of the Gulshan lake was estimated between 0.85 mequ/100g and 1.38 mequ/100g (Table A13-A15) and in the Dhanmondi lake sediment was 0.62 mequ/100g and 0.68 mequ/100g. (Table A16-A18). No specific relationship of sediment acidity within the season and years in both of the lakes. Apparently the Gulshan lakes showed higher values over the season and years in compared to the Dhanmondi lake.

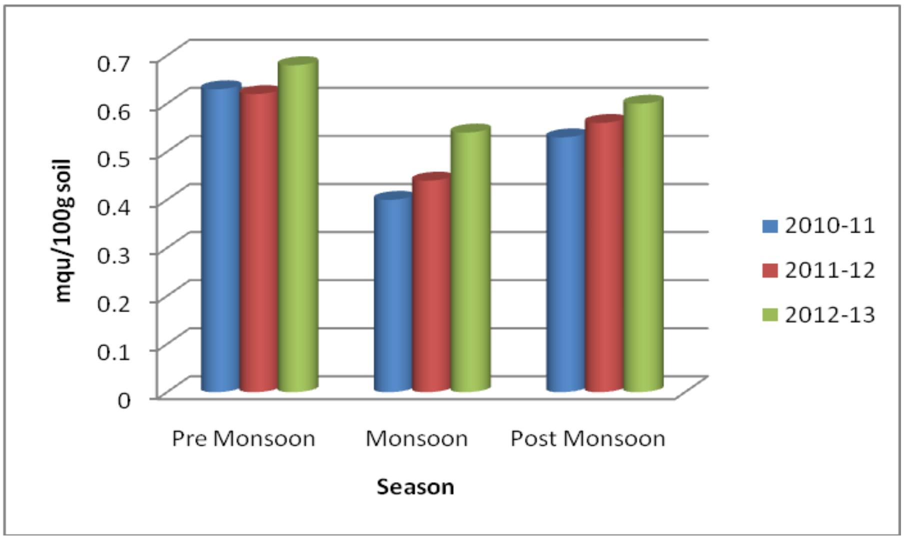


Figure 48. Average Acidity of Dhanmondi lake sediment

4.4.4. Total Nitrogen:

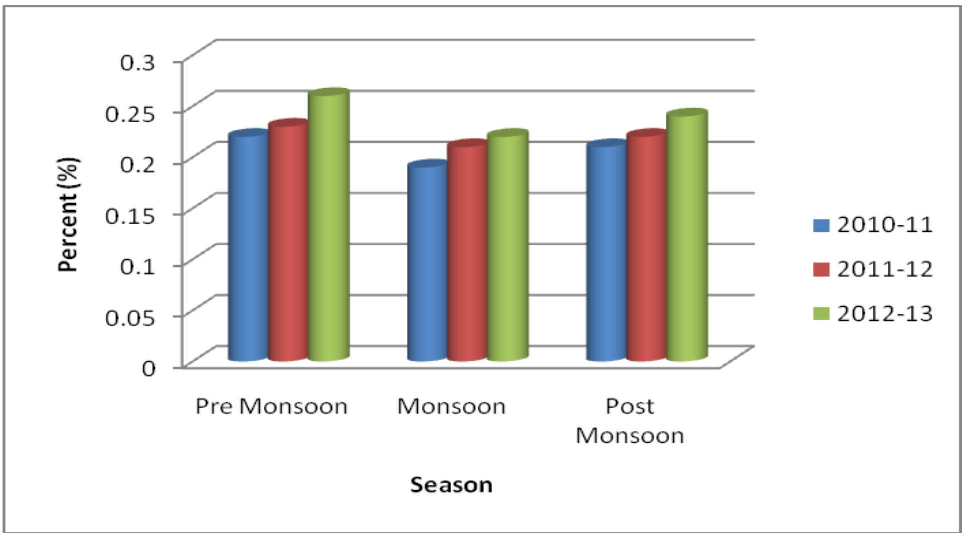


Figure 49. Average Total Nitrogen of Gulshan lake sediment

Average total nitrogen of sediment of the Gulshan lake was ranged from 0.22% and 0.26% (Table A13-A15) and in the Dhanmondi lake sediment was ranged 0.14% to 0.19%. (Table A16-A18).

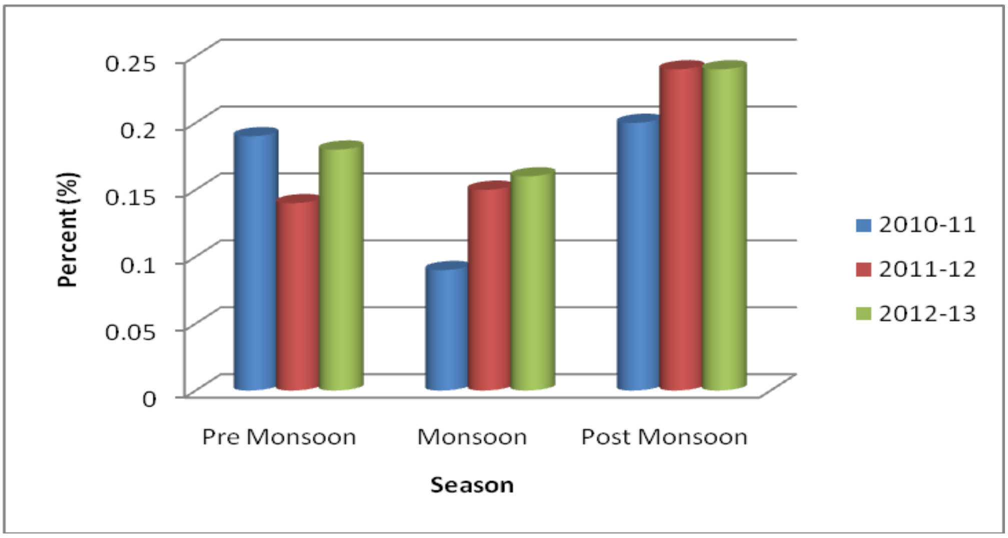


Figure 50. Average Total Nitrogen of Dhanmondi lake sediment

Dhanmondi lake sediment total nitrogen was less in compared to Gulshan lake which may be due to the lower debris materials in the sediment in Dhanmondi lake also re excavated in recent years. There is no specific relation found in sediment nitrogen within the season and years in the sediment of the both lakes.

4.4.5. Calcium:

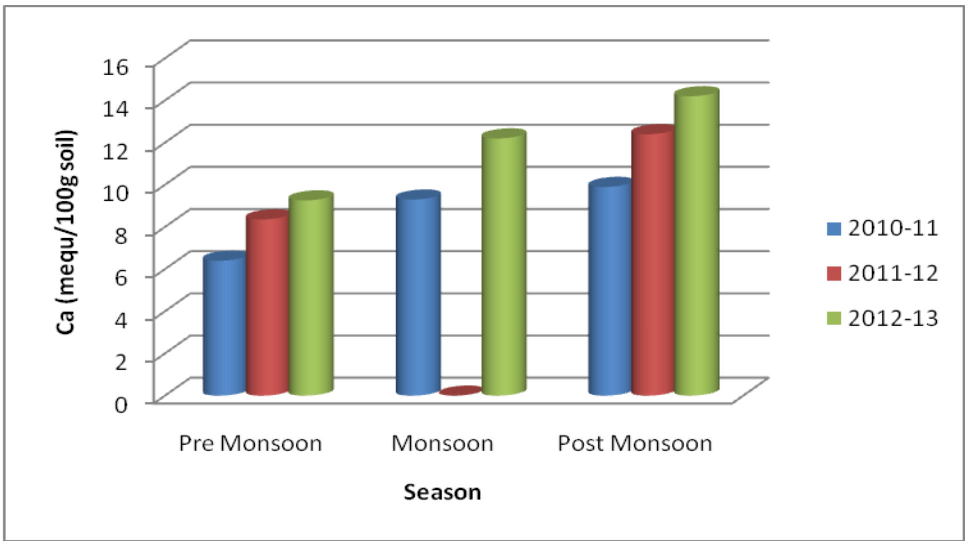


Figure 51. Average Calcium of Gulshan lake sediment

Average calcium level of sediment of the Gulshan lake was 6.4 mequ/100g and 9.6 mequ/100g (Table A13-A15) and in the Dhanmondi lake sediment was 12.86 mequ/100g and 13.80 mequ/100g. (Table A16-A18).

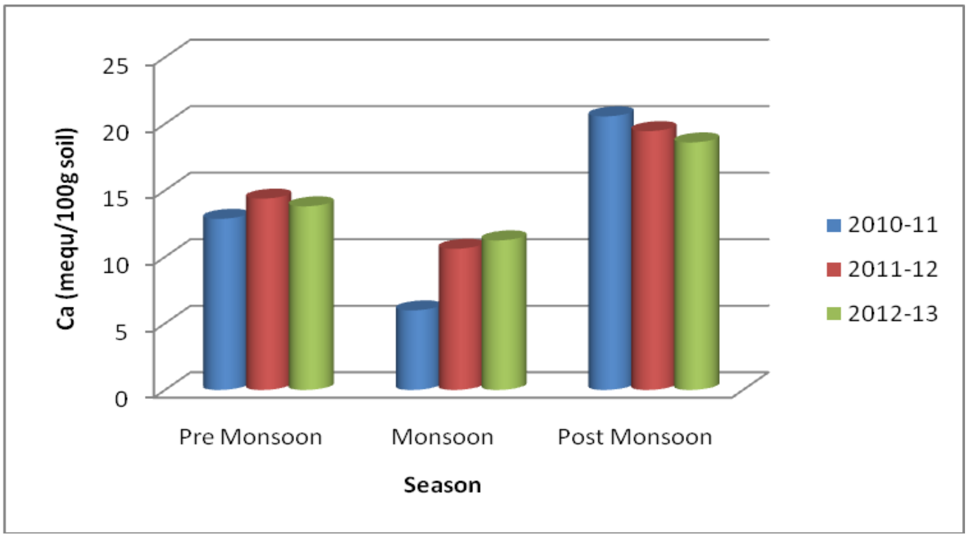


Figure 52. Average Calcium of Dhanmondi lake sediment

No specific relation found in season and year in the both lakes sediment calcium values. Calcium found higher values in the Dhanmondi lake sediment in all season.

4.4.6. Magnesium:

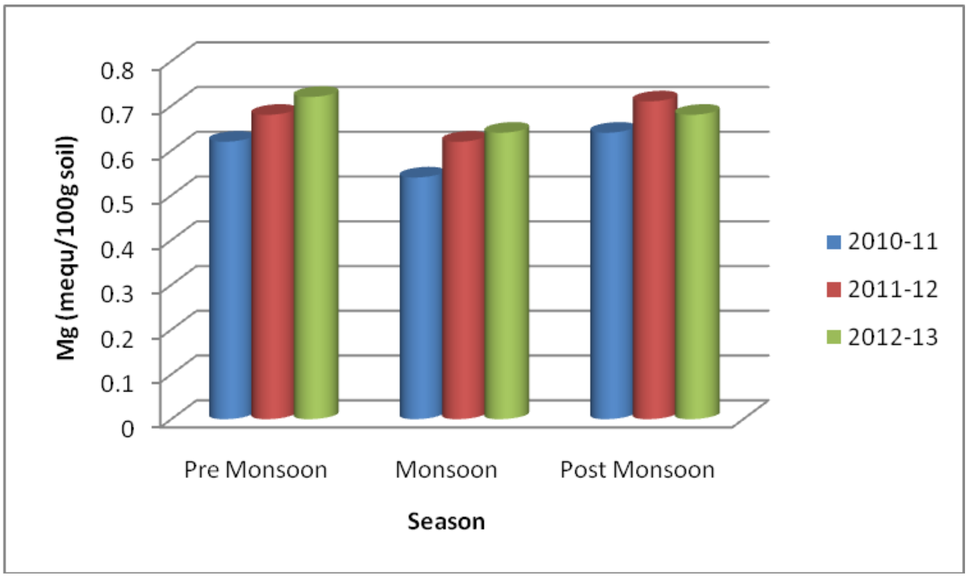


Figure 53. Average Magnesium of Gulshan lake sediment

Average magnesium level of sediment of the Gulshan lake was 0.62 mg/100g to 0.72 mequ/100g (Table A13-A15) and in the Dhanmondi lake sediment it was 1.49 mg/100g to 1.72 mequ/100g. (Table A16-A18).

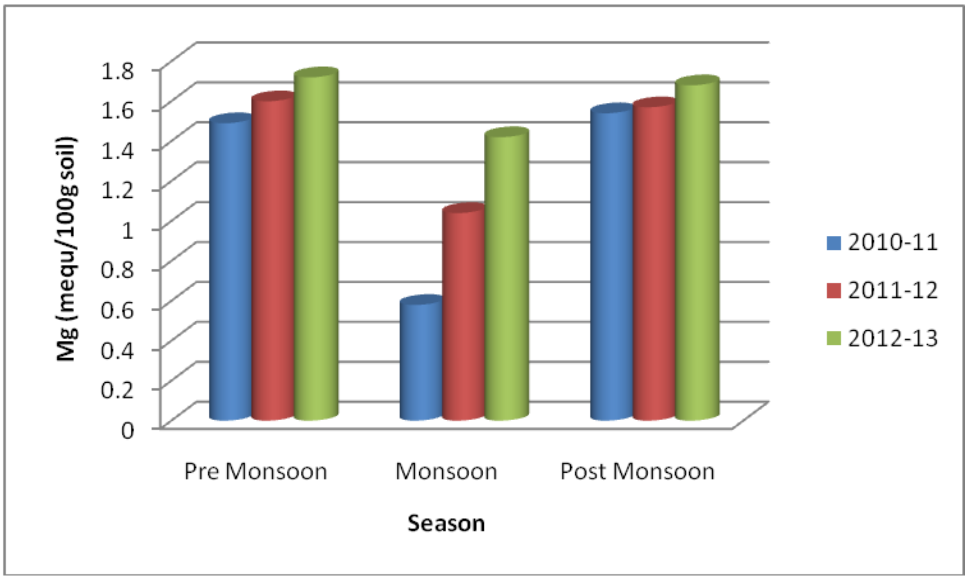


Figure 54. Average Magnesium of Dhanmondi lake sediment

4.4.7. Potassium:

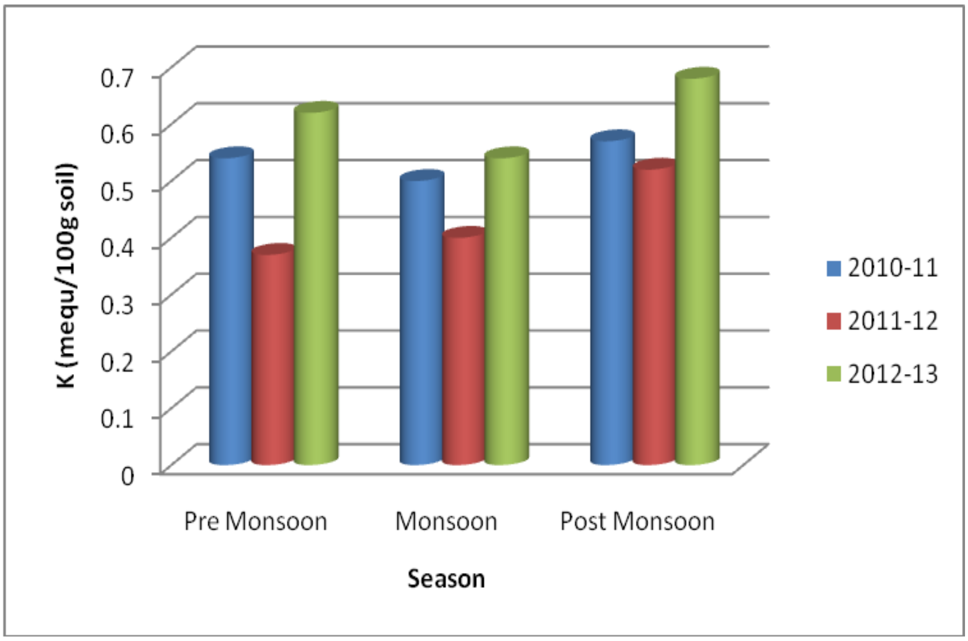


Figure 55. Average Potassium of Gulshan lake sediment

Average potassium of the Gulshan lake was ranged from 0.37 mequ/100g to 0.62 mequ/100g (Table A13-A15) and in the Dhanmondi lake sediment was 0.31 mequ/100g to 0.50 mequ/100g. (Table A16-A18).

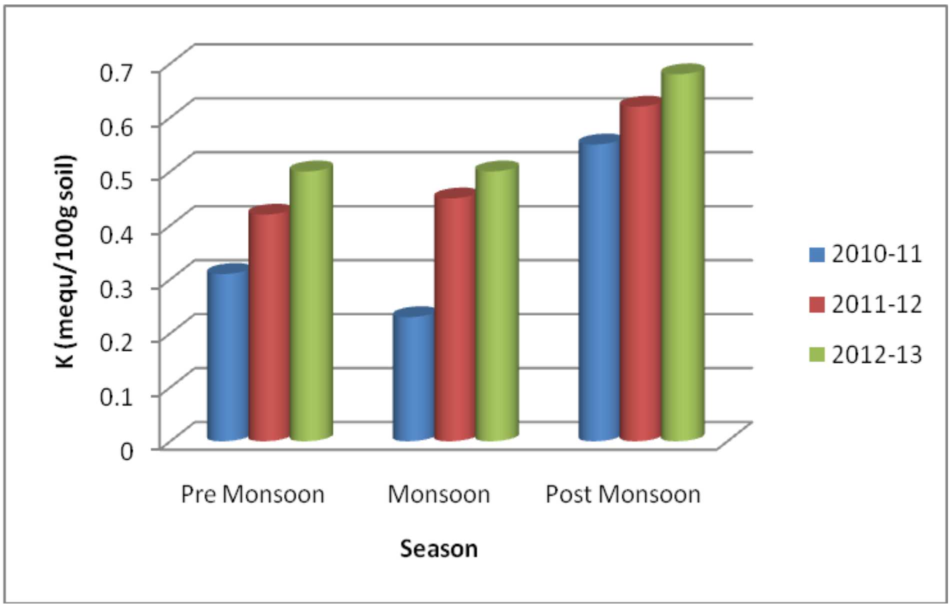


Figure 56. Average Potassium of Dhanmondi lake sediment

4.4.8. Phosphorus:

Average phosphorus of the Gulshan lake sediment phosphorus was 1.4 mequ/100g to 1.64 mequ/100g (Table A13-A15) and in the Dhanmondi lake sediment was 9.47 mequ/100g to 11.24 mequ/100g. (Table A16-A18)

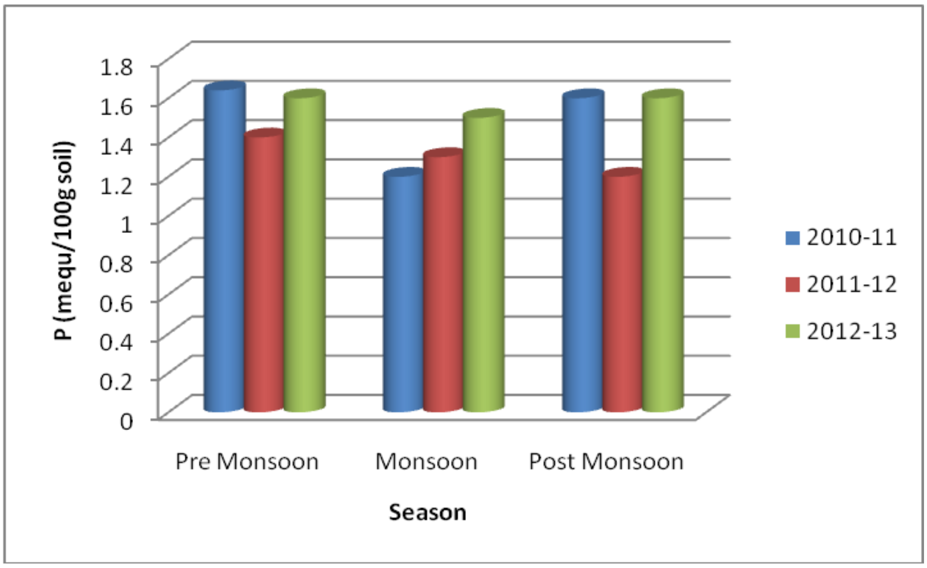


Figure 57. Average Phosphorus of Gulshan lake sediment

No specific relation found in season and year in both the lakes sediment. Dhanmondi lake sediment shows exceptionally higher values than the Gulshan lake sediment.

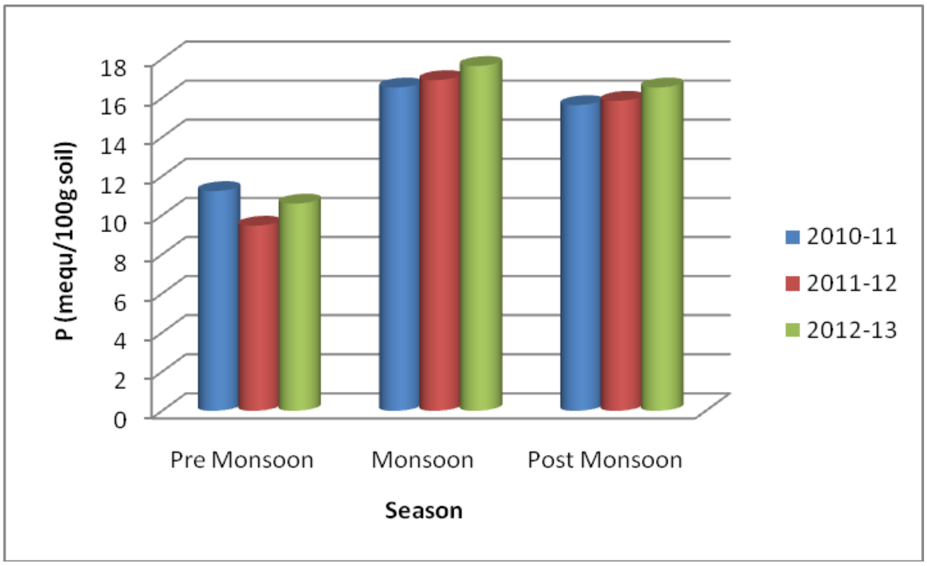


Figure 58. Average Phosphorus of Dhanmondi lake sediment

4.5. Heavy metals of lake sediment:

4.5.1 Zinc (Zn):

Average zinc level of sediment of the Gulshan lake was ranged from 8.25 mg/kg to 18.6 mg/kg (Table A19-A21) and in the Dhanmondi lake sediment it was 6.48 mg/kg to 16.40 mg/kg. (Table A22-A24).

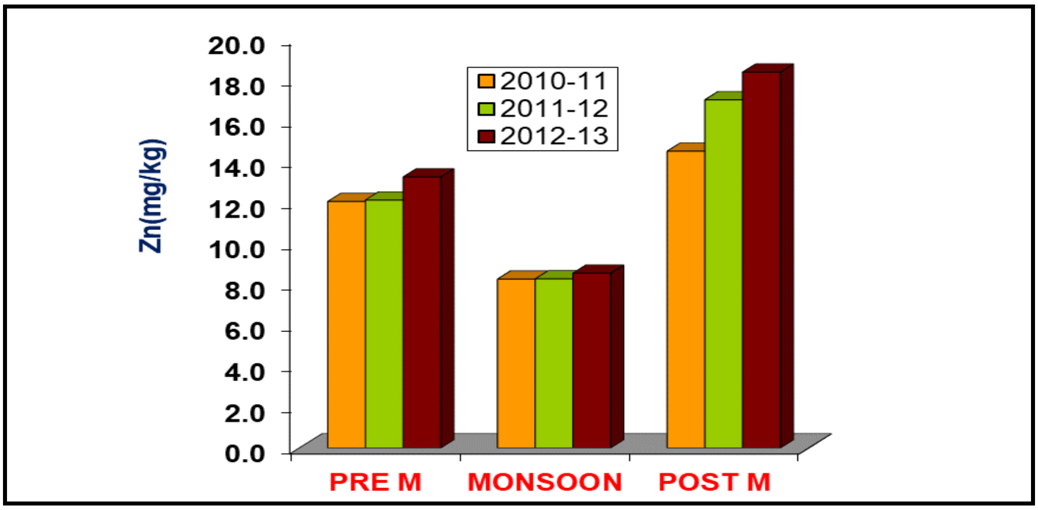


Figure 59. Average Zinc concentration of Gulshan lake sediment

Lowest values recorded in monsoon of Gulshan lake sediment and highest found in post monsoon. Increasing values recorded as following the years. Same results also observed in case of the Dhanmondi lake sediment.

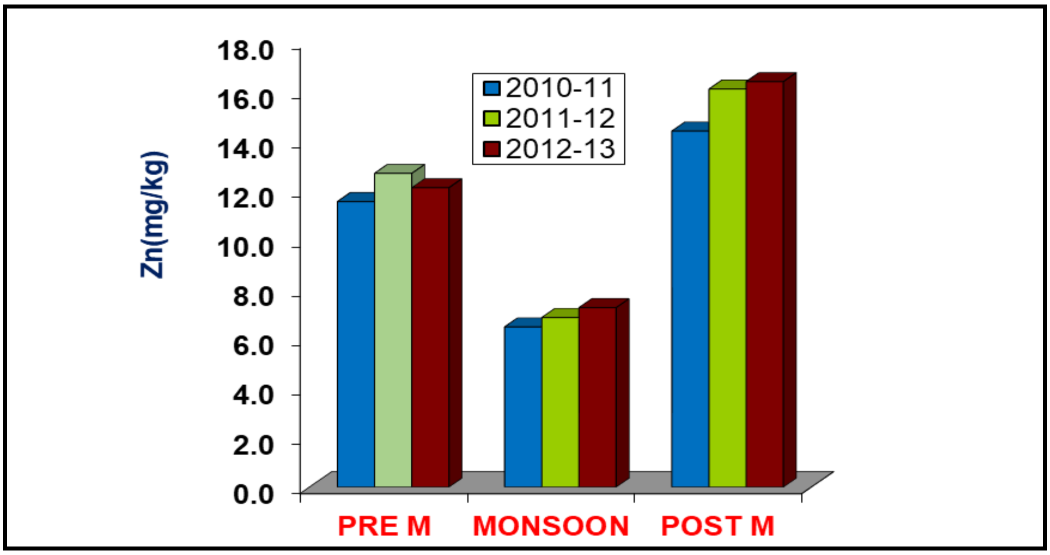


Figure 60. Average Zinc concentration of Dhanmondi lake sediment

4.5.2 Chromium (Cr):

Average chromium level of sediment of the Gulshan lake was ranged from 30.80 mg/kg to 66.24 mg/kg (Table A19-A21) and in the Dhanmondi lake sediment it was 15.20 mg/kg to 20.40 mg/kg. (Table A22-A24).

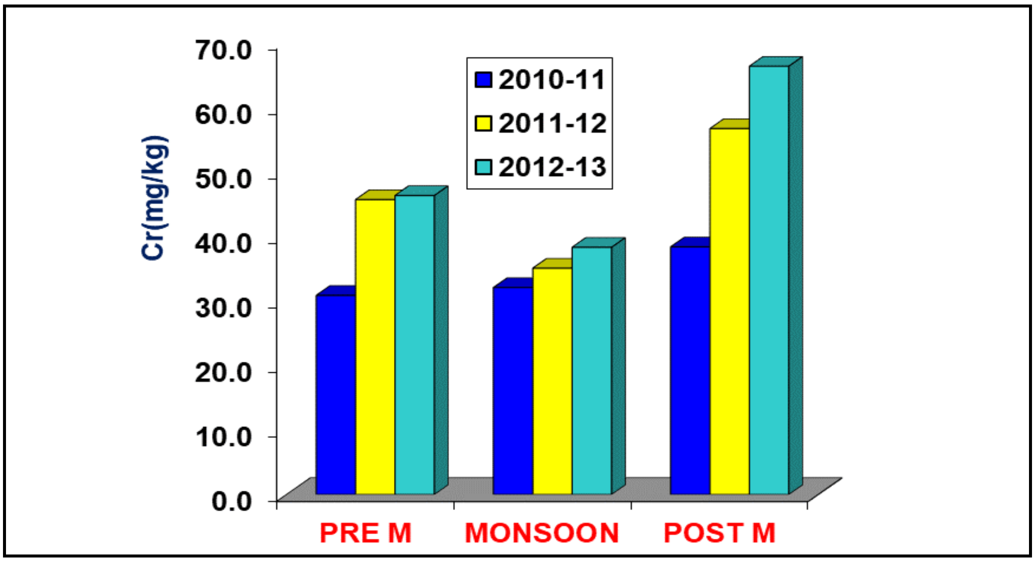


Figure 61. Average Chromium concentration of Gulshan lake sediment

In Gulshan lake sediment chromium shows lowest values during monsoon and highest in post monsoon. Increasing values were recorded as years succeeding. Dhanmondi lake sediment chromium was found lowest in monsoon and highest in pre monsoon. Values of chromium were increasing following the year in both lake sediment. Higher chromium value recorded in Gulshan lake sediment than Dhanmondi lake.

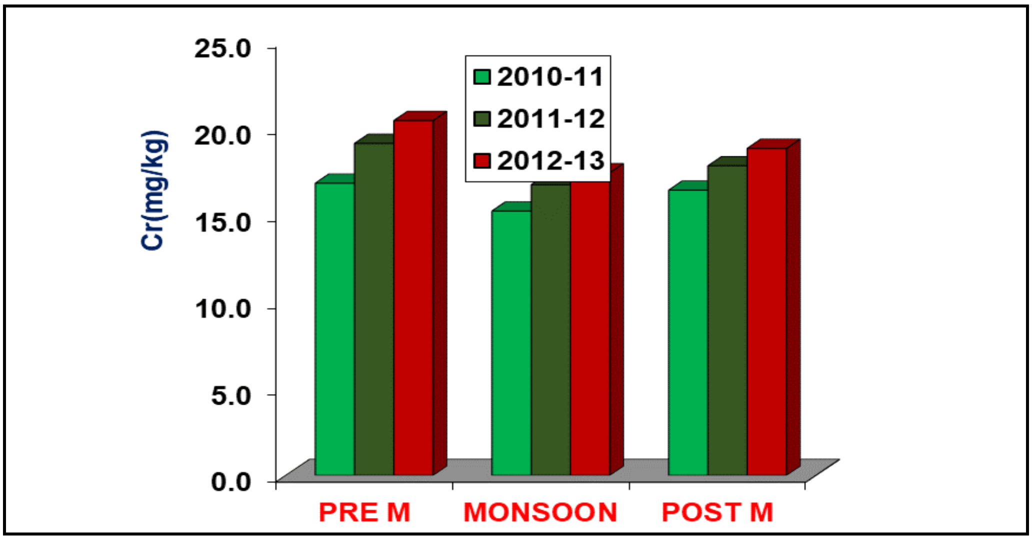


Figure 62. Average Chromium concentration of Dhanmondi lake sediment

4.5.3 Cadmium (Cd):

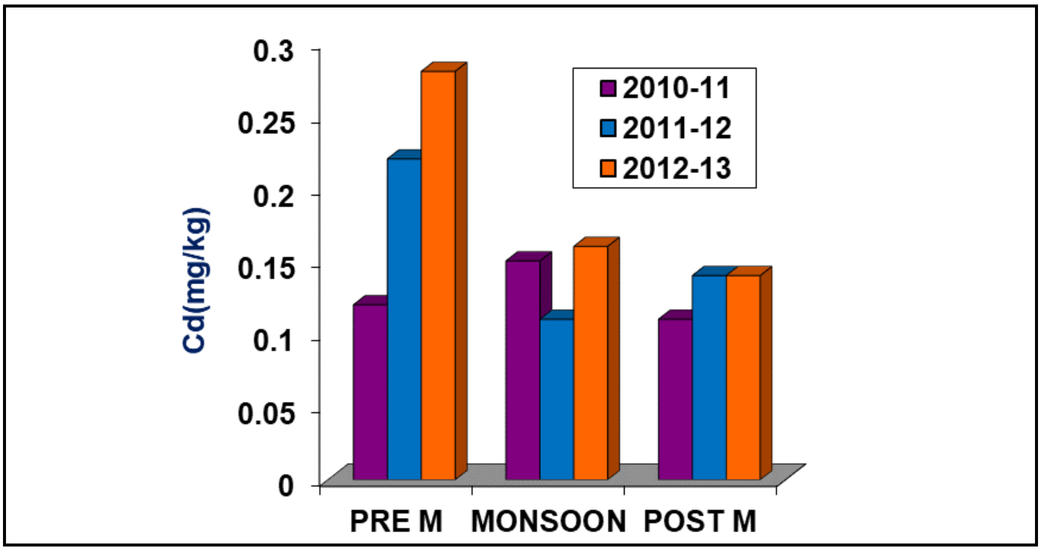


Figure 63. Average Cadmium concentration of Gulshan lake sediment

Average cadmium of the Gulshan lake sediment was ranged from 0.11 mg/kg to 0.28 mg/kg (Table A19-A21) and in the Dhanmondi lake sediment it was 0.08 mg/kg to 0.14 mg/kg. (Table A22-A24). There was no specific relation found in season and year in the both lakes sediment. Gulshan lake sediment shows more or less double concentrations of cadmium compare to Dhanmondi lake sediment. The higher levels of Cd obtained in sediments might be due to contribution from other source such as agricultural runoff where fertilizers are used in addition to possible release of sediment bound metal

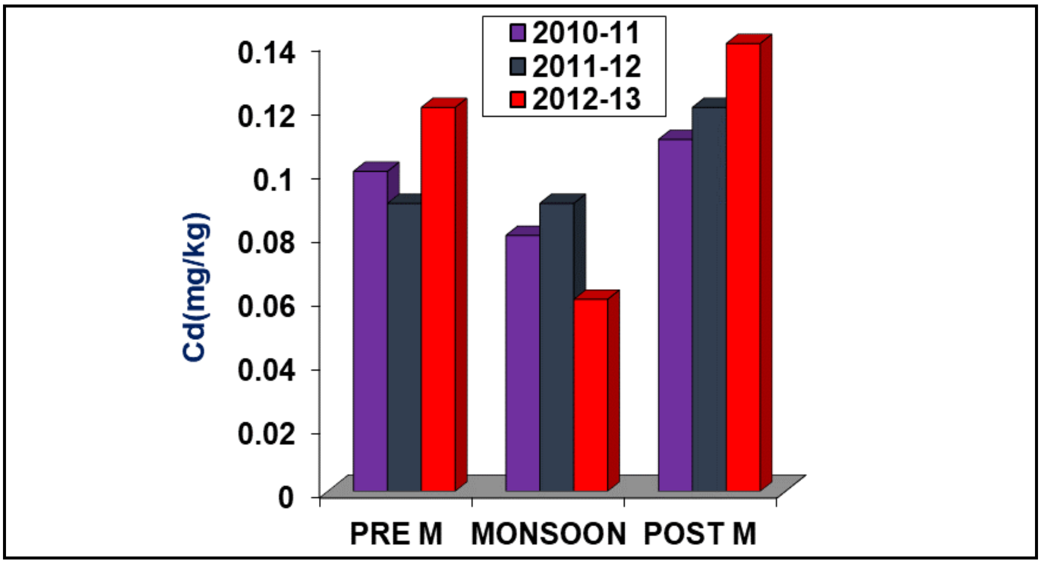


Figure 64. Average Cadmium concentration of Dhanmondi lake sediment

4.5.4 Lead (Pb):

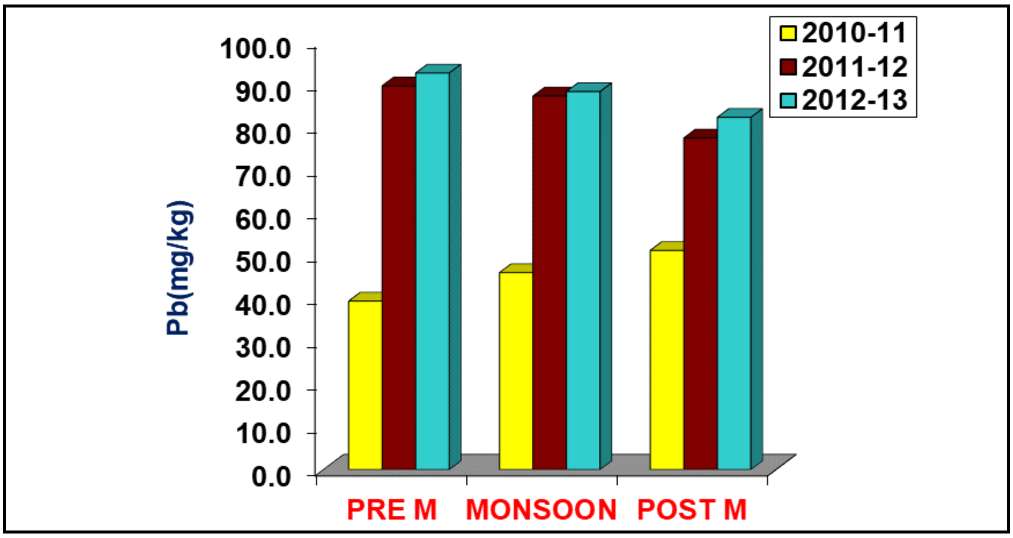


Figure 65. Average Lead concentration of Gulshan lake sediment

Average lead in the Gulshan lake sediment was ranged from 39.28 mg/kg to 92.46 mg/kg (Table A19-A21) and in the Dhanmondi lake sediment it was 16.87 mg/kg to 76.80 mg/kg. (Table A22-A24). There was no specific relation found in case of lead with season and year in both lakes sediment. Gulshan lake sediment lead shows comparatively higher concentrations than Dhanmondi lake.

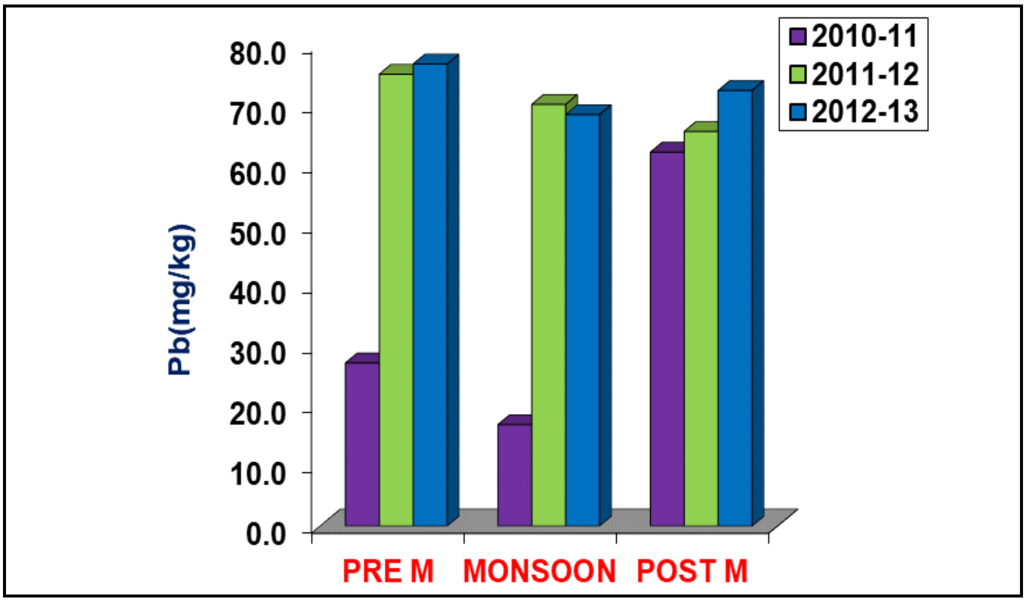


Figure 66. Average Lead concentration of Dhanmondi lake sediment

4.5.5 Copper (Cu):

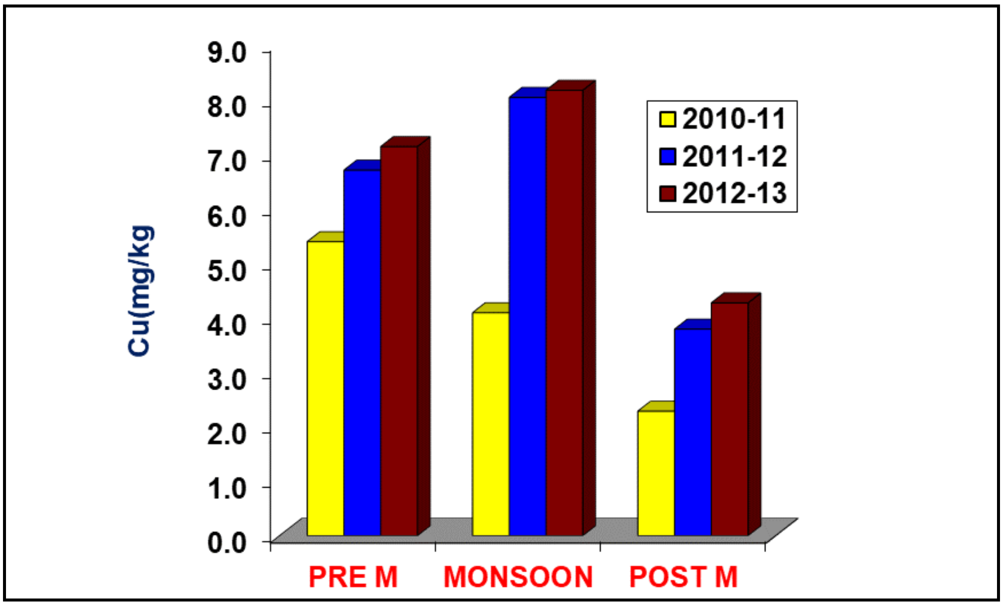


Figure 67. Average Copper concentration of Gulshan lake sediment

Average copper of the Gulshan lake sediment was ranged from 2.28 mg/kg to 8.15 mg/kg (Table A19-A21) and in the Dhanmondi lake sediment it was ranged from 2.07 mg/kg to 3.16 mg/kg. (Table A22-A24). Both lake sediment samples contained excessive Copper.

No specific relation found in case of copper with season but increasing values recorded following years in both lakes sediment. Gulshan lake soil shows extremely higher concentrations of copper compare to Dhanmondi lake sediments.

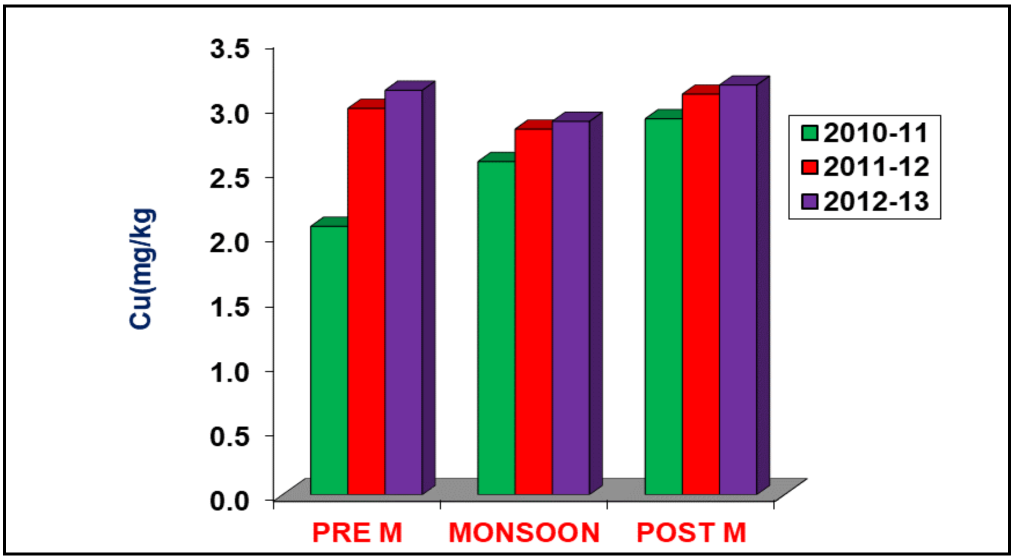


Figure 68. Average Copper concentration of Dhanmondi lake sediment

4.5.6 Nickel (Ni):

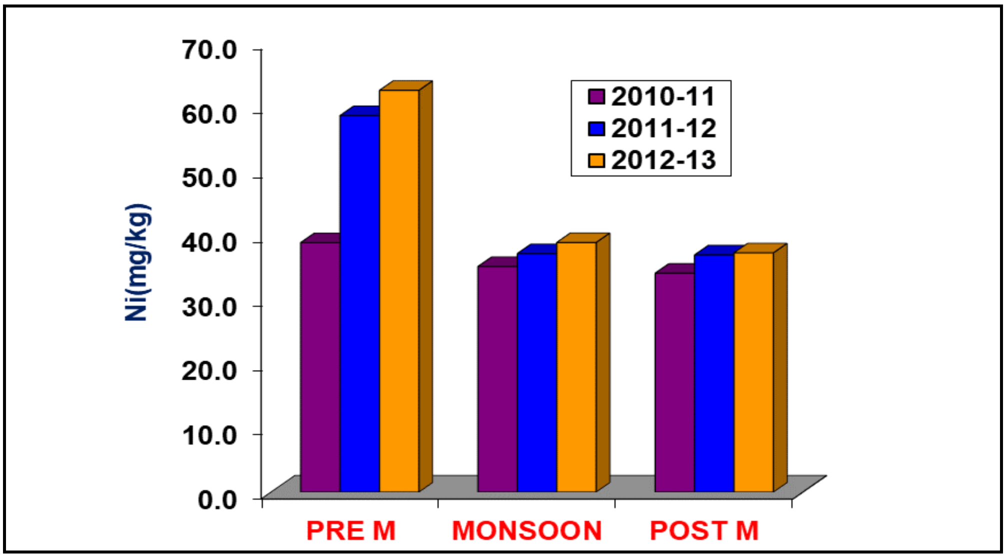


Figure 69. Average Nickel concentration of Gulshan lake sediment

Average Nickel of the Gulshan lake sediment was ranged from 34.08 mg/kg to 62.54 (Table A19-A21) mg/kg and in the Dhanmondi lake sediment it was 14.21 mg/kg to 21.20 mg/kg. (Table A22-A24).

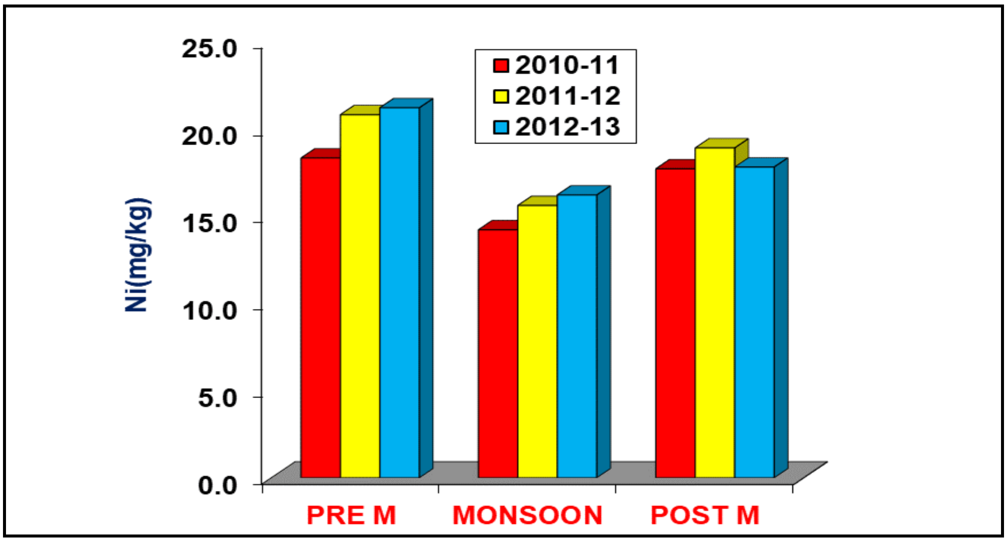


Figure 70. Average Nickel concentration of Dhanmondi lake sediment

Nickel in sediment of both the lakes higher than reference values. In Gulshan lake higher values of nickel was found in pre monsoon and lowest in post monsoon. In Dhanmondi lake lowest nickel was recorded during monsoon and highest in pre monsoon. Increasing values recorded following years in both lakes sediment. Gulshan lake sediment show remarkably higher nickel than Dhanmondi lake sediment.

4.5.7 Manganese (Mn):

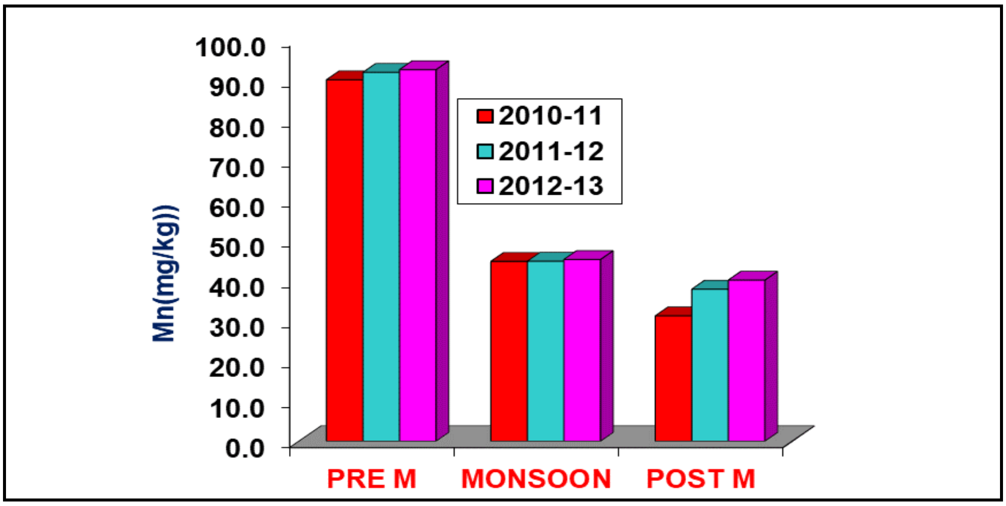


Figure 71. Average Manganese concentration of Gulshan lake sediment

In the Dhanmondi lake lowest average manganese was recorded during monsoon and highest in pre monsoon. Increasing values recorded following the years in both lakes sediment. Gulshan lake sediment shows higher values of manganese than the Dhanmondi lake sediment.

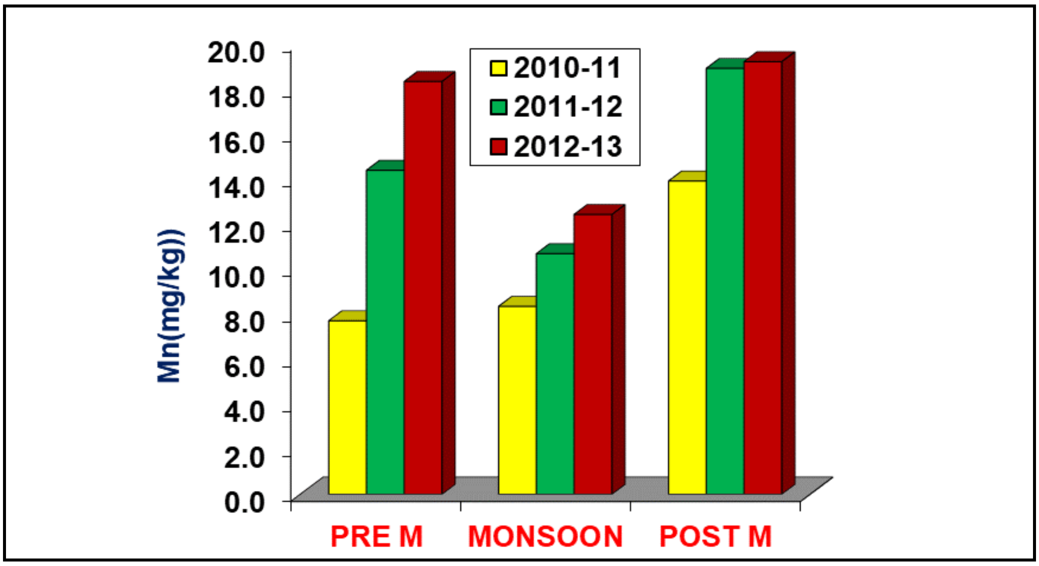


Figure 72. Average Manganese concentration of Dhanmondi lake sediment

4.5.8 Iron (Fe):

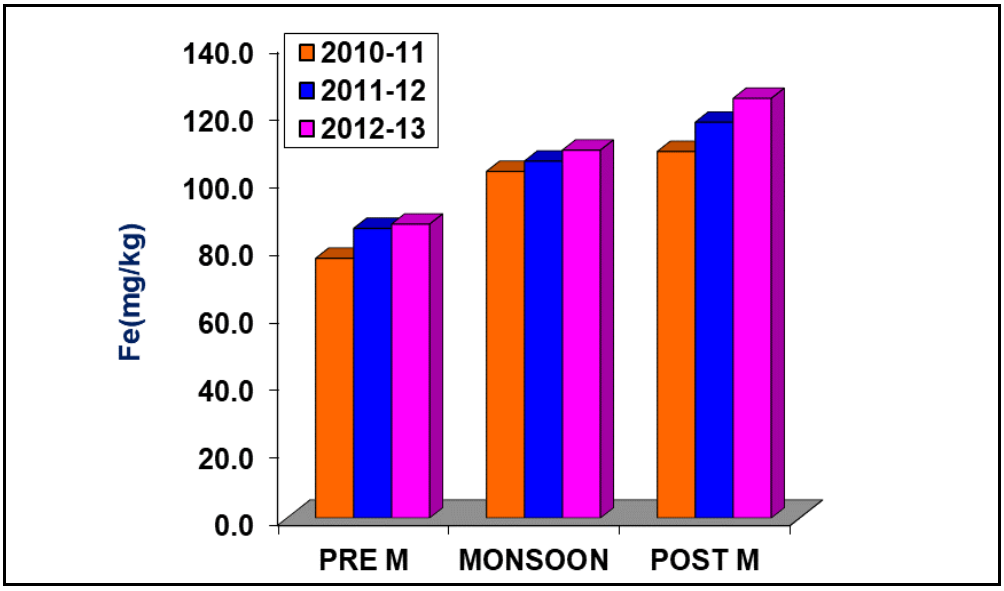


Figure 73. Average Iron concentration of Gulshan lake sediment

Average Iron of the Gulshan lake sediment was ranged from 76.80 mg/kg to 124.12 mg/kg (Table A19-A21) and in the Dhanmondi lake sediment it was 53.60 mg/kg to 114.32 mg/kg. (Table A22-A24). Lowest iron in the Gulshan lake sediment was found during pre monsoon and highest in post monsoon. In the Dhanmondi lake sediment lowest iron was recorded during monsoon and highest in post monsoon. Increasing values recorded following years in both lakes sediment. Gulshan lake sediment shows slightly higher values iron compare to Dhanmondi lake sediment.

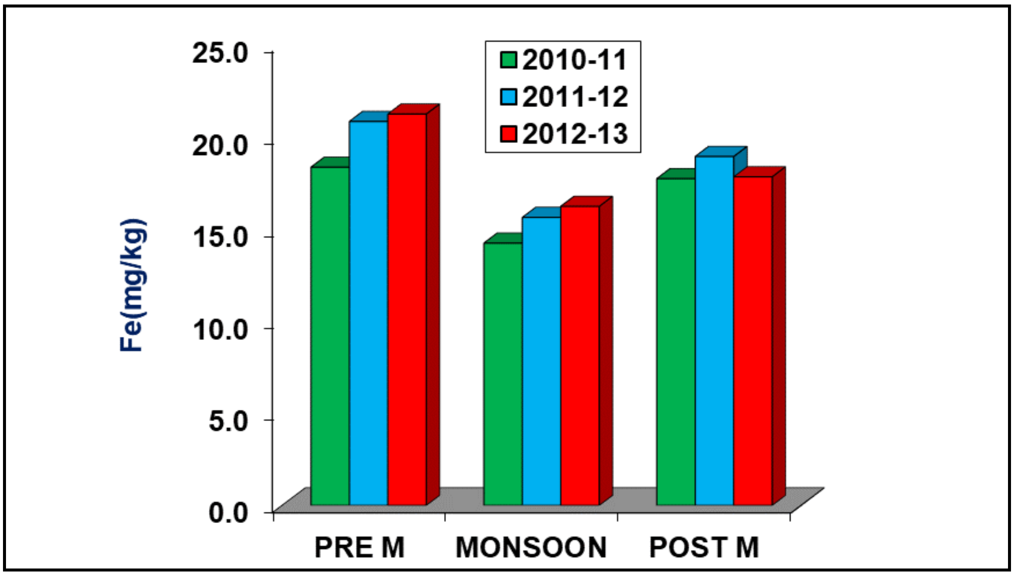


Figure 74. Average Iron concentration of Dhanmondi lake sediment

4.6 Plankton diversity:

4.6.1. Phytoplankton:

In Gulshan lake Phytoplankton comprises around 80% and zooplankton was around 20%. In Dhanmondi lake Phytoplankton comprises 55% and zooplankton was 45%. During first year the abundance of phytoplankton in the Gulshan lake ranged from 14532 ind/L in August 2010 to 33299 ind/L in May 2010 with mean value of 22100±5526 ind/L [Table B-1]. In the Dhanmondi lake ranged from 1112 ind/L in October 2010 to 1656 ind/L in April 2010 with mean value of 1312±178 ind/L. [Table B-4].

In second year the abundance of phytoplankton in the Gulshan lake ranged from 17340 ind/L in July 2011 to 43415 ind/L in April 2011 with mean value of 30554±9411 ind/L [Table B-2]. In the Dhanmondi lake ranged from 822 ind/L in December 2011 to 2386 ind/L in May 2011 with mean value of 1381±473 nos/L. [Table B-5].

During third year the abundance of phytoplankton in the Gulshan lake ranged from 18600 nos/L in April 2012 to 42200 ind/L in February 2013 with mean value of 30268±8759 nos/L [Table B-3]. In the Dhanmondi lake ranged from 821 ind/L in November 2012 to 2100 ind/L in August 2012 with mean value of 1379±391 ind/L. [Table B-6].

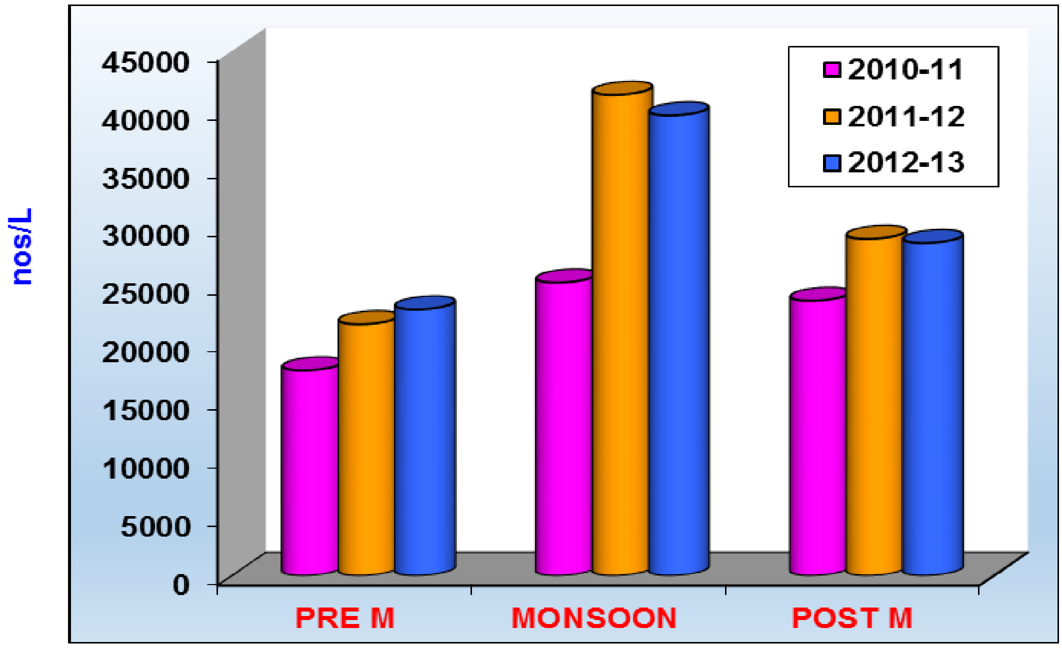


Figure 75. Average Phytoplankton density of Gulshan lake

In both the lakes phytoplankton were identified as six species of Cyanophyceae, nine species of Chlorophyceae. Seven species of Bacillariophyceae in Gulshan lake and six species of Bacillariophyceae in Dhanmondi lake. Phytoplankton data showing that members belonging to Chlorophyceae recorded the highest population density followed by Bacillariophyceae and Cyanophyceae. A total of twenty two species of phytoplankton were recorded during the study period. Phytoplankton species are found in following groups.

Cyanophyceae group: *Microcystis sp, Polycistis sp, Spirulina sp, Anabaena sp, Nostoc sp and Oscillatoras sp.*

Chlorophyceae group: *Spirogyra sp, Pediastrum sp, Actinastrum sp, Scenedesmus sp, Microspora sp, Synedra sp, Ulothrix sp, Oedogonium sp and Closterium sp.*

Bacillariophyceae group: *Tabellaria sp, Gomphonema sp, Navicula sp, Ditoma sp, Nitzchia sp, Anomoeoneis sp and Cystodinium sp***.**

Abundance of different phytoplankton groups describes below.

Cyanophyceae:

In first year five species of Cyanophyceae from Gulshan lake and six species from Dhanmondi lake were identified. The highest average number of Cyanophyceae in Gulshan lake was in the pre monsoon (21438±7643) ind/L followed by post monsoon (17963±1954) ind/L and monsoon (15143±4348) ind/L [Table A-27]. The highest average value of Cyanophyceae in Dhanmondi lake was in the pre monsoon (596±105) ind/L followed by monsoon (525±76) ind/L and post monsoon (397±36) ind/L [Table A-30]. The Cyanophyceae abundance between two lakes in first year shows statistically significant differences ($t=5.82$, $df=23$, $p=0.000$). [Table 9].

During second year six species of Cyanophyceae from Gulshan lake and six species from Dhanmondi lake were recorded. The highest average number of Cyanophyceae in Gulshan lake was in the pre monsoon (33763±5272) ind/L followed by post monsoon (24655±5242) ind/L and monsoon (18711±3677) ind/L [Table A-28]. The highest average number of Cyanophyceae in Dhanmondi lake was in the monsoon (836±183) ind/L followed by pre monsoon (699±333) ind/L and post monsoon (342±82) ind/L [Table A-31]. The Cyanophyceae abundance between Gulshan and Dhanmondi lakes in second year shows statistically significant differences ($t=4.64$, $df=23$, $p=0.000$). [Table 10].

During third year six species of Cyanophyceae from Gulshan lake and six species from Dhanmondi lake were recorded. The highest average number of Cyanophyceae in Gulshan lake was in the pre monsoon (32625±1325) ind/L followed by post monsoon (24613±6504) ind/L and monsoon (19175±5141) ind/L [Table A-29]. The highest average number of Cyanophyceae in Dhanmondi lake was in the monsoon (519±263) ind/L followed by pre monsoon (506±180) ind/L and post monsoon (349±42) ind/L [Table A-32]. The Cyanophyceae abundance between Gulshan and Dhanmondi lakes in third year also shows statistically significant differences (t=8.53, df=23, p=0.000). [Table 11].

Chlorophyceae:

In first year nine species of Chlorophyceae from the Gulshan lake and eight species from the Dhanmondi lake were identified. The highest average number of Chlorophyceae in the Gulshan lake was in the pre monsoon (4791±2640) ind/L followed by post monsoon (3053±1269) ind/L and monsoon (1761±1812) ind/L. [Table A-27]. The highest average number of Chlorophyceae in the Dhanmondi lake was in the monsoon (428±30) ind/L followed by pre monsoon (403±74) ind/L and post monsoon (409±82) ind/L [Table A-30]. The Chlorophyceae abundance between the two lakes in first year shows statistically significant differences (t=22.17, df=23, p=0.000). [Table 9].

During second year nine species of Chlorophyceae from the Gulshan lake and nine species from the Dhanmondi lake were recorded. The highest average number of Chlorophyceae in the Gulshan lake was in the pre monsoon (6689±3389) ind/L followed by post monsoon (3648±1586) ind/L and monsoon (2376±1098) ind/L. [Table A-28]. The highest average number of Chlorophyceae in the Dhanmondi lake was in the pre monsoon (435±188) ind/L followed by monsoon (378±102) ind/L and post monsoon (360±74) ind/L. [Table A-31]. The Chlorophyceae abundance between the Gulshan and Dhanmondi lakes in second year also shows statistically highly significant differences (t=4.12, df=23, p=0.000). [Table 10].

During third year nine species of Chlorophyceae from the Gulshan and Dhanmondi lake were recorded. The highest average number of Chlorophyceae in the the Gulshan lake was in the pre monsoon (5944±2308) ind/l followed by post monsoon (3065±772) ind/L and monsoon (2747±644) ind/L [Table A-29]. The highest average number of Chlorophyceae in the Dhanmondi lake was in the monsoon (591±109) ind/L followed by pre monsoon (527±153) ind/L and post monsoon (443±68) ind/L.

[Table A-32]. The Chlorophyceae abundance between the two lakes in third year also shows statistically significant differences (t=14.73, df=23, p=0.000). [Table 11].

Bacillariophyceae:

In first year seven species of Bacillariophyceae from Gulshan lake and six species from Dhanmondi lake were identified. The highest average number of Bacillariophyceae in Gulshan lake was in the post monsoon (763±217) ind/L followed by pre monsoon (749±777) ind/L and monsoon (412±230) ind/L. [Table A-27]. The highest average number of Bacillariophyceae in Dhanmondi lake was in the pre monsoon (500±183) ind/L followed by post monsoon (407±122) ind/L and monsoon (643±269) ind/L. [Table A-30].The Bacillariophyceae abundance between Gulshan and Dhanmondi lakes in first year shows statistically significant differences (t=5.67, df=23, p=0.026). [Table 9].

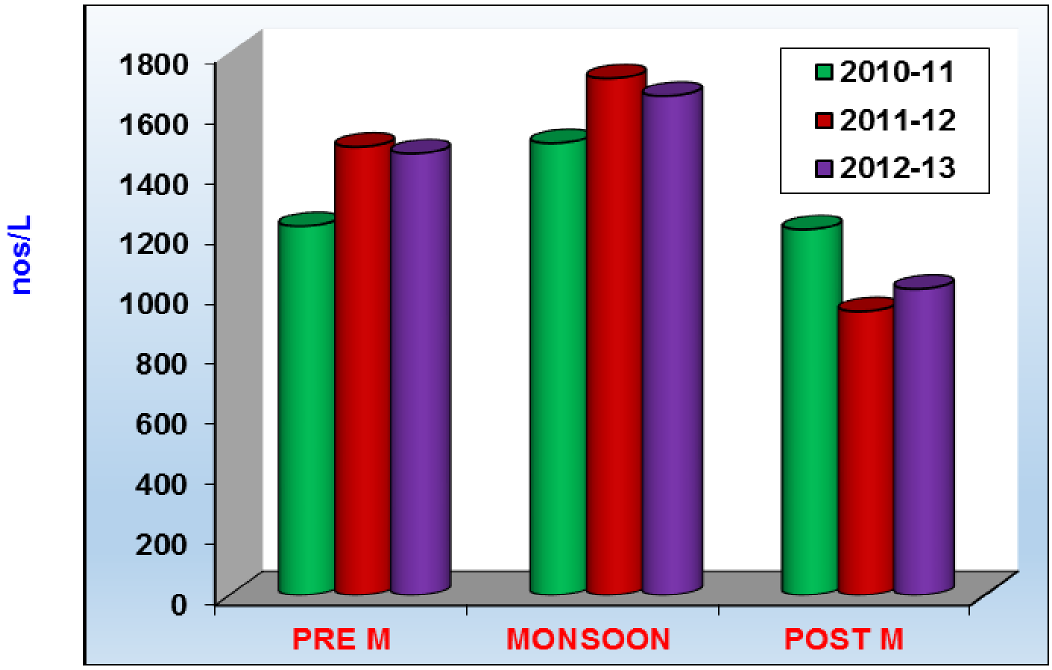


Figure 76. Average Phytoplankton density of Dhanmondi lake

During second year seven species of Bacillariophyceae from the Gulshan lake and six species from the Dhanmondi lake were recorded. The highest average number of Bacillariophyceae in the Gulshan lake was in pre monsoon (778±449) ind/L followed by post monsoon (574±268) ind/L and monsoon (472±95) ind/L [Table A-28]. The highest average number of Bacillariophyceae in the Dhanmondi lake was in pre monsoon (580±118) nos/L followed by monsoon (274±183) ind/L and post monsoon (241±71) ind/L [Table A-31]. Bacillariophyceae abundance between two lakes in this year shows statistically significant differences (t=6.20, df=23, p=0.012). [Table 10].

During third year seven species of Bacillariophyceae from the Gulshan lake and six species from the Dhanmondi lake were recorded. The highest average number of Bacillariophyceae in the Gulshan lake was in the monsoon (903±399) ind/L followed by pre monsoon (897±166) ind/L and post monsoon (835±123) ind/L [Table A-29]. The highest average number of Bacillariophyceae in the Dhanmondi lake was in the pre monsoon (623±358) nos/L followed by monsoon (354±74) ind/l and post monsoon (224±79) ind/L [Table A-32]. Bacillariophyceae abundance between the Gulshan and Dhanmondi lakes in third year shows statistically significant differences (t= 5.31, df=23, p=0.020). [Table 11].

4.6.2. Zooplankton:

The Zooplankton concentration of the the Gulshan and Dhanmondi lakes are presented in Figure 77 and 78 respectively. Fifty eight species of Zooplankton were identified from the Gulshan lake of which fifteen species were Protozoans, nine were Copepods, seven were Cladocerans and twenty seven were Rotifers. [Table B7-9]. In the Dhanmondi lake fifty eight species were recorded of which fifteen belonged to Protozoans, nine were Copepods, seven were Cladocerans and twenty seven were Rotifers. [Table B 10-12].

In first year the abundance of Zooplankton in the Gulshan lake ranged from 4720 ind/L in July 2010 to 6540 ind/L in January 2011 with mean value of 5804±660 ind/L. [Table B-7]. In the Dhanmondi lake ranged from 791 ind/l in August 2010 to 1149 ind/l in April 2010 with mean value of 980±135 ind/l. [Table B-10].

In second year the abundance of Zooplankton in the Gulshan lake ranged from 4826 ind/L in October 2011 to 9827 ind/L in May 2011 with mean value of 7021±1735 ind/L. [Table B-8]. In the Dhanmondi lake ranged from 710 ind/l in July 2011 to 1580 ind/l in February 2012 with mean value of 1132±272 ind/l. [Table B-11].

In third year the abundance of Zooplankton in the Gulshan lake ranged from 5827 ind/L in October 2012 to 10515 ind/L in May 2012 with mean value of 7834±1480 ind/L. [Table B-9]. In the Dhanmondi lake ranged from 795 ind/l in July 2012 to 1460 ind/l in February 2013 with mean value of 1435±499 ind/l. [Table B-12].

Protozoa group: Major species identified are in *Euglena acus, E. oxyuris, E. clavata, E. fusca, E. spathyrhynchus, E. sanguinea, E. mainxi, Euglena sp, Phacus longicaudatus, P. pleuronectus, Phacus sp, Difflugia sp. Volvox sp, Epistylis sp and Arcella sp.*

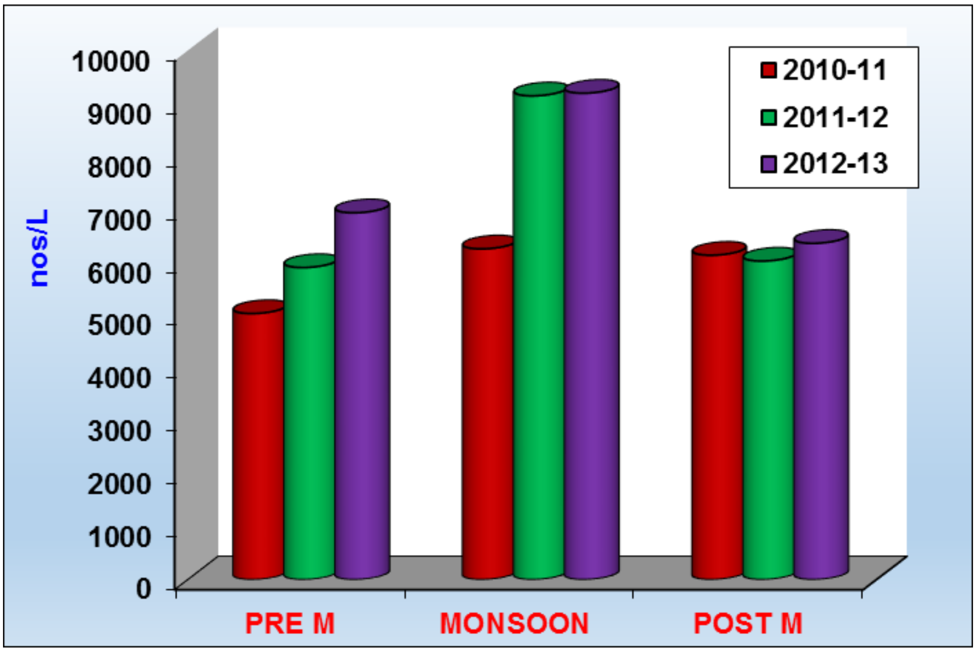


Fig 77. Average Zooplankton density of Gulshan lake

Copepods group: *Mesocyclops edax, M. varicans, Cyclops sp, Diaptomus gracilis, Diaptomus sp. Naupleus sp, Metanaupleus sp, Bryocamptus sp and Mysis larva*.

Cladocera group: *Diaphanosoma brachyurum, Moina brachiata, Skapholebaris kingi, Polyphemus sp and Cydorus sp*. and *Bosmina sp.*

Rotifers group: *Brachionus angularis B. diversicornis B. caudatus B. calicyflorus B. falcatus B. forficula B. plicatilis B. quadridentata B. rubens B. budapestinensis Keratella vulga, Keratella cochlearis, Filinia longiseta, F. terminalis, Rotaria neptunia , Asplanchna priodonta, Asplanchna herricki, Asplanchna sp, Anuraeopsis fissa, Monostylla bula, Trichocerca pocellus, T. cylindrical, T. braziliensis, Lindia sp., Epiphenes sp, Cephalodella incilla, Synchaeta sp, Dicranophorus sp, Mytilina sp Chromogaster sp, Lecane sp, Hexarthra sp, Ascomorpha sp, Colurella bicuspidata.*

Copepods group: *Mesocyclops edax, M. varicans, Cyclops sp, Diaptomus gracilis, Diaptomus sp. Naupleus sp, Metanaupleus sp, Bryocamptus sp and Mysis larva.*

Cladocera group: *Diaphanosoma brachyurum, Moina brachiata, Skapholebaris kingi, Polyphemus sp and Cydorus sp.* and *Bosmina sp.*

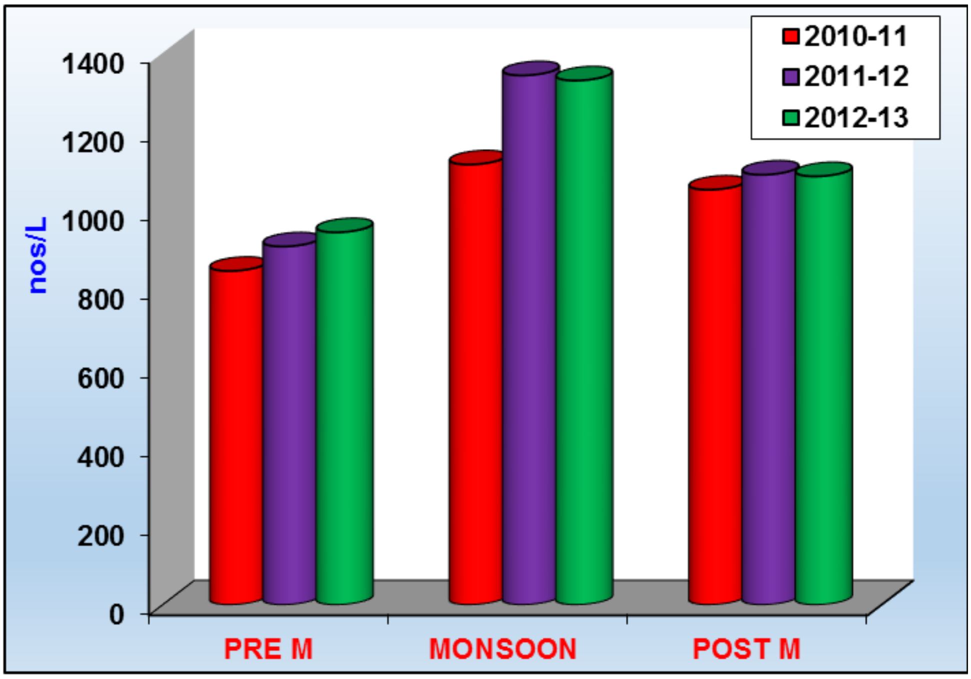


Figure 78. Average Zooplankton density of Dhanmondi lake

Rotifers group: *Brachionus angularis B. diversicornis B. caudatus B. calicyflorus B. falcatus B. forficula B. plicatilis B. quadridentata B. rubens B. budapestinensis Keratella vulga, Keratella cochlearis, Filinia longiseta, F. terminalis, Rotaria neptunia , Asplanchna priodonta, Asplanchna herricki, Asplanchna sp, Anuraeopsis fissa, Monostylla bula, Trichocerca pocellus, T. cylindrical, T. braziliensis, Lindia*

sp., Epiphenes sp, Cephalodella incilla, Synchaeta sp, Dicranophorus sp, Mytilina sp Chromogaster sp, Lecane sp, Hexarthra sp, Ascomorpha sp, Colurella bicuspidata.

Protozoans:

In first year fifteen species of Protozoans from the Gulshan lake and fourteen species from the Dhanmondi lake were identified. [Table B-7 and B-10]. The highest average number of Protozoans in the Gulshan lake was in the post monsoon (1453±114) ind/L followed by monsoon (1306±469) ind/L and pre monsoon (1065±472) ind/L. [Table A-31] The highest number of Protozoans in the Dhanmondi lake was in the post monsoon (98±15) ind/L followed by pre monsoon (97±68) ind/L and monsoon (84±29) ind/L. [Table A-34]. The Protozoan abundance between the two lakes in first year shows statistically significant differences ($t = 5.06$, $df=23$, $p=0.000$). [Table 12].

During second year fifteen species of Protozoans from the Gulshan lake and thirteen species from the Dhanmondi lake were recorded [Table B-8 and B-11]. The highest average number of protozoans in Gulshan lake was in the 5monsoon (2738±690) ind/L followed by monsoon (2043±861) ind/L and post monsoon (1838±436) ind/L. [Table A-32]. The highest number of protozoans in Dhanmondi lake was in the post monsoon (80±35) ind/L followed by pre monsoon (74±33) ind/L and monsoon (73±40) ind/l. [Table A-35]. The protozoan abundance between two lakes in second year shows statistically significant differences ($t=4.68$, $df=23$, $p=0.000$). [Table 13].

During third year fifteen species of Protozoans from the Gulshan lake and Dhanmondi lake were recorded (Table B-9 and B-12]. The highest average number of protozoans in the Gulshan lake was in the pre monsoon (2568±455) ind/L followed by monsoon (2465±343) nos/L and post monsoon (2010±406) nos/L. [Table A-33]. The highest average number of Protozoans in the Dhanmondi lake was in the post monsoon (349±42) ind/l followed by pre monsoon (64±11) ind/L and monsoon (58±9) ind/L. [Table A-36]. The Protozoan abundance between the two lakes in third year also shows statistically significant differences ($t=4.89$, $df=23$, $p=0.000$). [Table 14].

Copepods:

In first year seven species of Copepods from the Gulshan lake and ten species from the Dhanmondi lake were identified. [Table B-7 and B-10]. The highest average number of Copepods in the Gulshan lake was in the post monsoon (508±86) ind/L followed by monsoon (308±156) ind/L and pre monsoon (265±44 ind/L. [Table A-31]. The highest average of Copepods in the Dhanmondi lake was in the pre monsoon (332±124) ind/L followed by monsoon (157±23) ind/L and post monsoon (114±34) ind/L.[Table A-34]. The copepods abundance between the two lakes in first year shows highly statistically significant differences (t=8.92, df=23, p=0.00). [Table 12].

During second year six species of Copepods from the Gulshan lake and nine species from the Dhanmondi lake were recorded. [Table B-8 and B-11]. The highest average number of Copepods in the Gulshan lake was in the post monsoon (270±119) ind/L followed by pre monsoon (264±45) ind/L and monsoon (180±58) ind/L. [Table A-32]. The highest average number of Copepods in the Dhanmondi lake was in pre monsoon (401±272) ind/L followed by post monsoon (122±74) ind/L and monsoon (103±34) ind/L. [Table A-35]. The Copepods abundance between the two lakes in second year shows highly statistically significant differences (t=7.08, df=23, p=0.000). [Table 13].

During third year seven species of Copepods from the Gulshan lake and seven species from the Dhanmondi lake were recorded. [Table B-9 and B-12]. The highest average number of Copepods in the Gulshan lake was in the post monsoon (256±151) ind/L followed by pre monsoon (251±83) ind/l and monsoon (211±76) ind/l. [Table A-33]. The highest average number of Copepods in the Dhanmondi lake was in the post monsoon (443±68) ind/l followed by monsoon (263±162) ind/l and pre monsoon (190±56) ind/L. [Table A-36]. The Copepods abundance between the two Gulshan and Dhanmondi lakes in third year also shows highly statistically significant differences (t=12.4, df=23, p=0.000). [Table-14].

Cladocera:

In first year five species of Cladocera from the Gulshan lake and six species from the Dhanmondi lake were identified. [Table B-7 and B-10]. The highest average number of Cladocera in the Gulshan lake was in the post monsoon (654±202) ind/L followed by monsoon (258±85) ind/L and pre monsoon (233±132) ind/L. [Table A-31]. The highest number of Cladocera in the Dhanmondi lake was in the post monsoon (73±19) ind/l followed by pre monsoon (59±37) ind/L and monsoon (42±28) ind/L. [Table A-34]. The Cladocera abundance between the two lakes in first year shows statistically significant differences (t=4.56, df=23, p=0.000). [Table 12].

During second year five species of Cladocera from the Gulshan lake and six species from the Dhanmondi lake were recorded. [Table B-8 and B-11]. The highest average number of Cladocera in the Gulshan lake was in the post monsoon (346±144) ind/L followed by pre monsoon (219±57) ind/L and monsoon (206±93) ind/L. [Table A-32]. The highest number of Cladocera in the Dhanmondi lake was in the post monsoon (62±34) ind/L followed by pre monsoon (38±21) ind/L and monsoon (32±15) ind/L. [Table A-35]. The Cladocera abundance between the two lakes in second year shows statistically significant differences (t=5.42, df=23, p=0.000). [Table 13].

During third year five species of Cladocera from the Gulshan lake and seven species from the lake were recorded. [Table B-9 and B-12].The highest average number of Cladocera in the Gulshan lake was in the post monsoon (286±62) ind/L followed by monsoon (203±55) ind/L and pre monsoon (200±85) ind/L. [Table A-35]. The highest average number of Cladocera in the Dhanmobdi lake was in the post monsoon (224±79) ind/l followed by monsoon (45±7) ind/L and pre monsoon (40±15) ind/L. [Table A-36]. The Cladocera abundance between the two lakes in third year also shows statistically significant differences (t= 6.17, df=23, p=0.000). [Table 14].

Rotifers:

In first year thirty three species of Rotifers from the Gulshan lake and twenty four species from the Dhanmondi lake were identified. [Table B-7 and B-10]. The highest average number of Rotifers in the Gulshan lake was in the pre monsoon (4406±989) ind/L followed by post monsoon (3517±597) ind/L and monsoon (3443±505) ind/L. The highest number of Rotifers in the Dhanmondi lake was in the post monsoon (768±134) ind/L followed by pre monsoon (630±84) ind/L and monsoon (564±106) ind/L. The Rotifers abundance between the two lakes in first year shows statistically significant differences (t= 6.41, df=23, p=0.000). [Table 12].

During second year thirty one species of Rotifers from the Gulshan lake and twenty six species from the Dhanmondi lake were recorded. [Table B-8 and B-11]. The highest average number of Rotifers in Gulshan lake was in the pre monsoon (5923±873) ind/L followed by post monsoon (3568±591) ind/L and monsoon (3471±1122) ind/L. [Table A-32]. The highest average number of Rotifers in the Dhanmobdi lake was in the post monsoon (882±242) ind/L followed by pre monsoon (830±339) ind/L and monsoon (702±163) ind/L. [Table A-35]. The Rotifers abundance between the two lakes in second year shows statistically significant differences (t= 5.10, df=23, p=0.000). [Table 13].

During third year thirty four species of Rotifers from the Gulshan lake and twenty seven species from the Dhanmondi lake were recorded. [Table B-9 and B-12]. The highest average number of Rotifers in the Gulshan lake was in the pre monsoon (6726±407) ind/L followed by monsoon (4599±1140) ind/L and post monsoon (4410±353) ind/L. [Table A-33]. The highest average number of rotifers in the Dhanmobdi lake was in the post monsoon (1016±145) ind/L followed by pre monsoon (963±145) ind/L and monsoon (653±97) ind/L. [Table A-36]. In third year Rotifers abundance between two the lakes in third year also shows statistically significant differences (t= 6.13, df=23, p=0.000). [Table 14].

4.7. Benthic organism:

Qualitative and quantitative estimation of Benthic organism was also done during the study. Benthic organisms of the the Gulshan and Dhanmondi lakes are presented in Figure 79 and 80 respectively. Eighteen species of Benthos were identified from the Gulshan lake of which five species were Chironomids, ten were Oligochates and three Molluscs. [Table B13-15]. In the Dhanmondi lake twelve species of Benthos were identified from the Dhanmondi lake of which one species were Chironomids, seven were Oligochates and four Molluscs. [Table B16-18]. The following groups and species were identified from Benthic organism:

Chironomids: *Chironomus sp, Pantala(Odonata), Nepa elongate, Nepa (Hemiptera), larvae (Red blood), Chironomus* larvae (others)

Oligochaets: *Lumbriculus, Nais sp, Tubifex sp, Chaetogaster sp, Branchiodrillus semperi, B. hortensis, Dero sp, Aulopherus sp, Branchiura sowerbyi, Aelosoma sp;*

Molluscs: *Lamellidens, Bellamya bengalensis. Brotia costula and Terabia.*

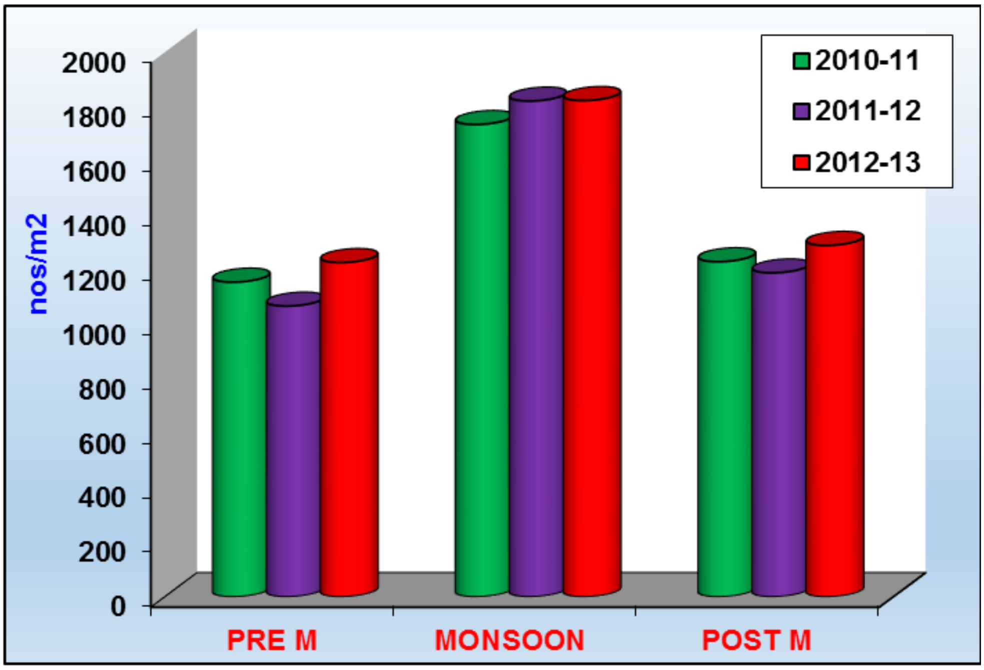


Figure 79. Average Benthos density of Gulshan lake

During first year abundance of Benthos in the Gulshan lake ranged from 950 nos/m^2 in November 2010 to 1971 ind/m^2 in August 2010 with mean value was 1374±340 ind/m^2 m^2. [Table B-13]. In the Dhanmondi lake ranged from 866 ind/m^2 in November 2010 to 1539 ind/m^2 in September 2010 with mean value was 1126±247 ind/m^2. [Table B-16]

In second year abundance of Benthos in the Gulshan lake ranged from 943 ind/m^2 in December 2011 to 2237 ind/m^2 in August 2011 with mean value was 1360±450 ind/m^2. [Table B-14]. In the Dhanmondi lake Benthos ranged from 610 ind/m^2 in March 2012 to 1869 ind/m^2 in September 2011 with mean value was 1232±430 ind/m^2. [Table B-17].

During third year abundance of benthos in the Gulshan lake ranged from 1020 ind/m^2 in March 2013 to 2222 ind/m^2 in August 2012 with mean value was 1447±402 ind/m^2. [Table B-15]. In the Dhanmondi lake ranged from 927 ind/m^2 in December 2012 to 1930 ind/m^2 in September 2012 with mean value was 1230±344 ind/m^2. [Table B-18].

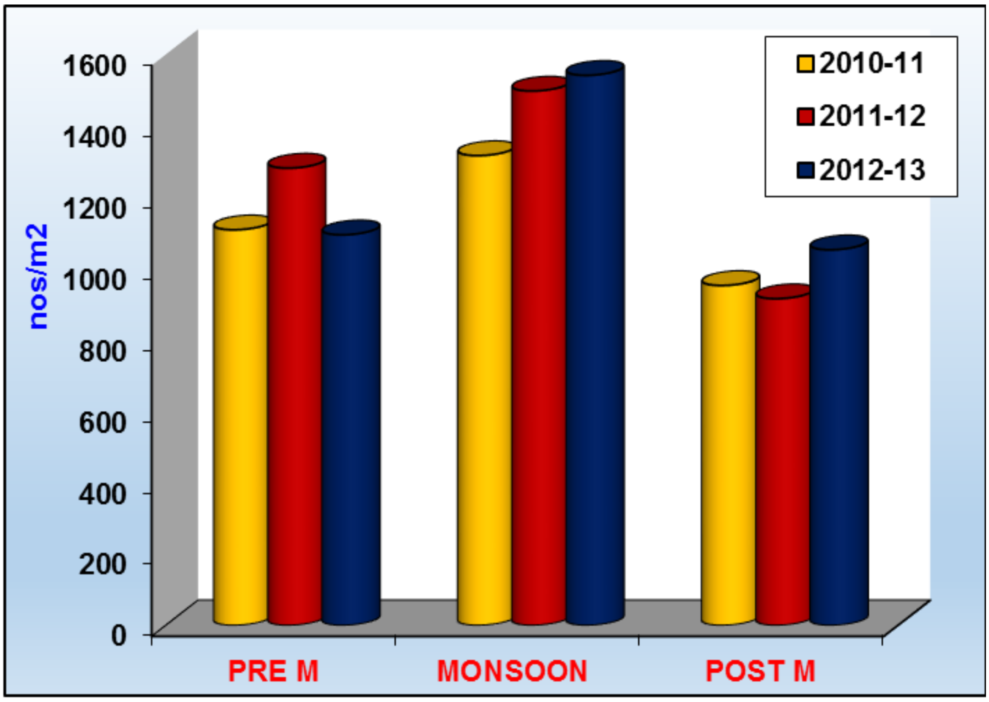


Figure 80. Average Benthos density of Dhanmondi lake

Abundance of different Benthos groups describes below:

Chironomids:

In first year four species of Chironomids from the Gulshan lake and one species from the Dhanmondi lake were identified. The highest average number of Chironomids in the Gulshan lake was in the monsoon (811±195) ind/m^2 followed by pre monsoon (768±297) ind/m^2 and post monsoon (545±487) ind/m^2. [Table A-37]. The highest average value of Chironomids in the Dhanmondi lake was in post monsoon (211±159) ind/m^2 followed by monsoon (121±168) ind/m^2 and pre monsoon (71±56) ind/m^2. [Table A-40]. The Chironomids abundance between the two lakes in the first year shows statistically highly significant differences ($t=3.35$, $df=23$, $p=0.006$). [Table 15].

During second year three species of Chironomids from the Gulshan lake and one species from the Dhanmondi lake were recorded. The highest average number of Chironomids in Gulshan lake was in the pre monsoon (826±451) ind/m^2 followed by monsoon (810±203) ind/m^2 and post monsoon (554±614) ind/m^2. [Table A-38]. The highest average number of Chironomids in the Dhanmondi lake was in the monsoon (212±296) ind/m^2 followed by post monsoon (136±102) ind/m^2 and pre monsoon (78±55) ind/m^2. [Table A-41]. The Chironomids abundance between the two lakes in second year shows statistically significant differences (t= 2.80, df=23, p=0.017). [Table 16].

During third year five species of Chironomids from the Gulshan lake and one species from the Dhanmondi lake were recorded. The highest average number of Chironomids in Gulshan lake was in the pre monsoon (707±222) ind/m^2 followed by monsoon (637±193) ind/m^2 and post pre monsoon (476±128) ind/m^2. [Table A-39] The highest average number of Chironomids in Dhanmondi lake was in the post monsoon (155±60) ind/m^2 followed by monsoon (150±146) ind/m^2 and pre monsoon (147±70) ind/m^2. [Table A-42]. The Chironomids abundance between two lakes in third year also shows statistically significant differences (t= 6.69, df=23, p=0.000). [Table 17].

Oligochaets:

In first year nine species of Oligochaets from the Gulshan lake and seven species from the Dhanmondi lake were identified. The highest number of Oligochaets in Gulshan lake was in the pre monsoon (962±467) ind/m^2 followed by post monsoon (682±274) ind/m^2 and monsoon (340±194) ind/m^2. [Table A-37]. The highest average number of Oligochaets in the Dhanmondi lake was in the pre monsoon (386±226) ind/m^2 followed by monsoon (244±144) ind/m^2 and post monsoon (241±195) ind/m^2. [Table A-40]. The Oligochaets abundance between the two lakes in first year shows statistically significant differences (t= 5.38, df=23, p=0.000). [Table 15].

During second year ten species of Oligochaets from the Gulshan lake and seven species from the Dhanmondi lake were recorded. The highest average number of

Oligochaets in Gulshan lake was in the pre monsoon (992±584) ind/m^2 followed by post monsoon (632±397) ind/m^2 and monsoon (254±216) ind/m^2. [Table A-38]. The highest average number of Oligochaets in Dhanmondi lake was in the pre monsoon (428±234) ind/m^2 followed by post monsoon (262±183) ind/m^2 and monsoon (214±129) ind/m^2. [Table A-41]. The Oligochaets abundance between two lakes in second year shows statistically significant differences (t= 5.37, df=23, p=0.000). [Table 16].

During third year ten species of Oligochaets from the Gulshan lake and seven species from the Dhanmondi lake were recorded. The highest average number of Oligochaets in the Gulshan lake was in the pre monsoon (1112±300) ind/m^2 followed by post monsoon (811±193) ind/m^2 and monsoon (587±389) ind/m^2. [Table A-39]. Average highest number of Oligochaets of the Dhanmondi Lake was in the pre monsoon (568±145) nos/m^2 followed by monsoon (380±114) nos/m^2 and post monsoon (374±93) nos/m^2. [Table A-42]. The Oligochaets abundance between the two lakes in third year also shows statistically significant differences (t=9.39, df=23, p=0.000). [Table 17].

Molluscs:

In first year three species of Molluscs from the Gulshan lake and four species from the Dhanmondi lake were identified. The highest average number of Molluscs in Gulshan lake was in the pre monsoon (5±1) ind/m^2 followed by monsoon (5±1) ind/m^2 and post monsoon (5±1) nos/m^2. [Table A-37]. The highest average value of Molluscs in the Dhanmondi lake was in the pre monsoon (861±302) ind/m^2 followed by monsoon (744±222) ind/m^2 and post monsoon (502±109) ind/m^2. [Table A-40]. Molluscs abundance between the Gulshan and Dhanmondi lakes in first year shows statistically significant differences (t=9.47, df=23, p=0.000). [Table 15].

During second year three species of Molluscs from the Gulshan lake and three species from the Dhanmondi lake were recorded. The highest average number of Molluscs in Gulshan lake was in monsoon (5±1) ind/m^2 followed by post monsoon (4±1) ind/m^2 and post monsoon (3±2) ind/m^2. [Table A-38]. The highest average number of Molluscs in the Dhanmondi lake was in pre monsoon (991±396) ind/m^2

followed by monsoon (754±243) ind/m^2 and post monsoon (518±90) ind/m^2. [Table A-41] The Molluscs abundance between the two lakes in second year shows statistically significant differences (t= 8.35, df=23, p=0.000). [Table 16].

During third year three species of Molluscs from the Gulshan lake and three species from the Dhanmondi lake were recorded. The highest average number of Molluscs in Gulshan lake was in the monsoon (5±3) ind/m^2 followed by pre and post monsoon (4±2) ind/m2. [Table A-39]. The highest average number of Molluscs in the Dhanmondi lake was in the pre monsoon (827±293) ind/m^2 followed by monsoon (567±204) ind/m^2 and post monsoon (524±85) ind/m^2. [Table A-42]. The Molluscs abundance between two lakes in third year also shows statistically significant differences (t=17.15, df=23, p=0.000). [Table-17].

CHAPTER 5
DISCUSSION

5.1. Physico-chemical parameters:

Limnology is the comprehensive study of fresh water bodies. Water has two dimensions that are closely linked-quantity and quality. Water quality means the physical, chemical and biological properties of water. The proper balance of physical, chemical and biological qualities of water in lakes is an essential ingredient for successful production of fish and other aquatic resources. Lakes are great importance as they uses in fish culture and provided water for domestic, industrial and agricultural practices.

A large number of people use these surface water sources for bathing, cleaning and other requirements. The quality of water is characterized by various physico-chemical parameters. These parameters change widely due to many factors like source of water, type of pollution, seasonal fluctuations and adjacent human intervention. The maintenance of a healthy aquatic ecosystem is dependent on physico-chemical properties of water and its biological diversity. Water quality also affected by pollutants which act on elements existing in water such as dissolved oxygen or produce substances such as ammonia, nitrates etc. It is not possible to understand biological phenomena fully without the knowledge of water chemistry of the ecosystem. The present studies were provided detailed information on physico-chemical parameters of the water and sediment of two urban lakes. Assess the Biological diversity of plankton and benthos. Comparison of limnological parameters among the two lakes was also determined.

5.1.1. Water quality:

Water depth also a factor for fish culture and should be maintained between 1.5 to 2m. Generally in lakes higher water depth were reported. Gulshan lake water depth lowest recorded in 2.9m in February 2011 and highest was 4.2m in August 2010 with mean value of 3.6±0.3. In Dhanmondi lake it was 3.5m in March 2013 and 5.0m in September

2013 with a mean of 4.1m±0.4. The trend of increasing in depth is related to the monsoon months. These results were supported by Hossain *et al.*, (1997). They found maximum depth in monsoon months and minimum in winter months from Basukhali-Salimpur-Kola-Barnal (BSKB) beel, Bangladesh. Twombly and Lewis, 1987 also recorded highest water depth in early September and it gradually decreased from mid-summer until October from the Venezuelan floodplain lake. Water depth showed positive relations with secchi depth from both lakes (Gulshan lake: r=0.483, p<0.01 and Dhanmondi lake: r=0.493, p<0.01). [Table 18-19]. Similar observation was reported by Dewan (1973). Sharma et al. (2009) also reported similar findings in Mahi dam.

Temperature is vital element for aquatic ecosystem as it affects the organisms as well as the chemical and physical properties of water. All biological and chemical activities in aquaculture are influenced by temperature. At temperature above or below optimum, fish growth is decreased. Sometimes mortalities may occur at higher temperature. Results from April 2010 to March 2013, air temperature ranged from 17.80^{0}C to 32.1^{0}C with mean value of (28.0±4.5^{0}C) in Gulshan lake and 17.7^{0}C to 33.30^{0}C with mean value of (28.1^{0}C±4.5) in Dhanmondi lake. The results revealed that the air temperature values of both lakes were within the acceptable levels for survival and growth of aquatic organism**.** Kabir and Naser (2011) reported same results from two baors of Meherpur district Bangladesh. Rajvanshi (2010) also reported similar result from Duhamel river at Saharanpur District, India. Hasan *et al*., (1994) found similar results from the Dhanmondi lake. Dewan (1973) also reported highest temperature in summer months and the lowest in winter months.

Water temperature ranged from 18.20 ^{0}C to 31.4^{0}C (27.7±4.0^{0}C) in the Gulshan lake and 17.90 ^{0}C to 32.40 ^{0}C (27.7±4.1^{0}C) in the Dhanmondi lake. Low temperature was recorded during winter and higher in monsoon. Water temperature of the Gulshan lake showed significant difference (P<0.01) in first year data but in second and third year results showed no significant difference [Table 2]. No significant difference was reported from water temperature in the Dhanmondi lake among the three years [Table 4]. The variation in the water temperature may be due to different timing of collection and influence of season. Water temperature showed close relationship with the air temperature during the present study. Water temperature showed almost an increasing and decreasing trend with air temperature. The water temperature was found to decrease gradually from November to January from both the lakes for three sampling year. It increased slowly from February to March and then sharp rise in April which increases up to September and gradually decreased from October to December and then slightly increased in January to March. Chowdhury and Mazumder (1981) reported same results. Varunprasath *et. al.* (2010) noted that the temperature variation between 22^{o}C to 29.5^{o}C in Bhavani river, Tamilnadu.

During entire sampling period from both the lake air temperature showed positive relations with water temperature (Gulshan lake: $r=0.971$, $p<0.01$, Dhanmondi lake: $r=0.994$, $p<0.01$). [Table 18-19]. Identical correlation also reported by Chowdhury and Mazumder (1981) and Patra and Azadi (1985). This result also coincide with Oppenheimer *et al*. (1978) and Hassan *et al.*(2008).

The secchidisc depth is a reliable method of examining light penetration in a water body. Secchi depth transparency between 30 and 40 cm indicates optimum productivity of a lake or pond (Santhosh and Singh 2007). Rahman *et.al.* (1992) reported that transparency of productive water bodies should be 40 cm or less. It gives an idea about the productivity nature of the water body. During entire study period secchidisc depth in Gulshan lake varied from 28.0cm to 38.8cm and mean values were 34.1 ± 3.3 cm and in Dhanmondi lake 70.2cm to 87.0cm and mean values were 78.5 ± 4.2cm. Khondaker *et al.* (1988) noted related result from Dhanmondi lake. Chowdhury and Mazumder (1981) and Halder *et al.*(1992) and Ahmed *et al*. (1999a) also observed high value of secchidisc depth in the Kaptai lake during monsoon period. This range of secchidisc transparency is also low compared to other aquatic habitats of Bangladesh. In Kaptai lake, 40-340 cm (Chowdhury and Mazumder 1981). Ameen *et al.* (1986) found higher in fish pond of Raipur (58-76 cm). Choubey (1990) observed transparency variation between 30 cm to

220 cm in Gandhi sagar reservoir. Saksena et al. (2008) recorded minimum turbidity in the month of March and maximum turbidity in the month of August in Chambal river in National Chambal sanctuary, Madhya Pradesh. Sharma and Chowdhary (2011) noticed that transparency variation between 12.5 to 40.75 cm in Tawi river of Jammu and Kashmir. Tamot and Awasthi (2012) found fluctuations in the transparency between 20 cm to 60 cm in Shahapura lake of Madhya Pradesh.

The suitable pH range for fish culture is between 6.7 and 9.5. Ideal pH for the growth of fishes is between 7.5 and 8.5. WHO has recommended maximum permissible limit of pH from 6.5 to 9.2 (De, 2002). The survival and growth of the fish is also depending on pH of the water. It acts as an index of several aquatic conditions such as free CO_2 concentration, DO contents, nutrient concentrations and acidity-alkalinity. During the entire sampling period pH of water always found slightly alkaline in both lakes and it ranged from 7.3 to 7.9 (7.6 ± 0.14) in Gulshan lake and in Dhanmondi lake it ranged from 7.3 to 7.8 (7.6 ± 0.10). In three years data no significant differences was recorded in Gulshan lake (P=0.300) and Dhanmondi lake (P=0.549) [Table 6-8]. Present findings were closest with Halder *et. al*., (1992). Hossain *et. al.*, (2010) found pH values in Dhanmondi and Gulshan Lake waters were 6-7. Chinnaiah *et al*, (2011) reported pH value ranged from 7.0-7.4 in Khajana lake and Darmasagar lake in Adilabad, AndhraPradesh, India. Patil *et.al.,* (2012) reported pH 6.8-7.8 from Music department lake of Kolhapur, India. Moniruzzaman *et.al.* (2009) In the study area the pH of water collected at different points and at different times of year ranged from 7.1 to 7.6 in Buriganga river

It reveals that both lake water were slightly alkaline in nature. Ahmed *et al*. (2004) also found alkaline pH values (7.4-8.4) of water near surface (up to 1.5 m depth) in March 2002. The results revealed that the water pH of the Gulshan and Dhanmondi lakes were remain desirable and suitable level for aquaculture. Nusrat *et. al*., (2013) also reported the similar findings that pH of Gulshan Lake in winter and summer period are almost equal but the water of the Gulshan lake are more turbid and colorful in winter season compare with spring season. It is concluded that during the present study almost all pH values recorded were within the USEPA (1986) standards (6.0 to 9.0) and within Bangladesh Environmental Conservation Rules, 1997 standard (6.5 to 8.5) for water in natural lake usable mainly for fish culture.

During the entire study period water pH showed negative correlation with Secchidisc depth (Gulshan lake: r=-0.116, Dhanmondi lake: r=-0.303), Positive correlation were found with water depth in Gulshan lake: r=0.152, but negative correlation was observed in Dhanmondi lake: r=-0.489. Significant differences was found with free CO_2, (Gulshan lake: r=0.229, $p<0.01$; otherwise Dhanmondi lake shows negative correlation with free CO_2: r=-0.013. Dissolved Oxygen shows positive correlation with pH (Gulshan lake: r= 0.002; Dhanmondi lake resulted significantly negative correlation: r=-0.315, $p<0.05$). [Table 18-19]. Similar results were made by Munawar (1970) and Miah *et al*. (1981). The lower value of water pH during high value of free CO_2 was also observed by Ameen *et. al*., (1986) in fish ponds of Raipur, Bangladesh. Direct relationship between dissolved oxygen (DO) and water pH was also observed by Dewan (1973).

Dissolved oxygen content is one of the most important factors in lake and its deficiency directly affects the ecosystem of a lake. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. Oxygen is the single most important gas for most aquatic organisms; free oxygen (O_2) or DO is needed for respiration. DO levels below 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. Air and aquatic plants are the major source of oxygen in the water. A minimum value of 5 mg/l would be satisfactory for most stages and activities as well as survival of the cultured fish (Alabaster and Loyd, 1982).

During three years dissolved oxygen varied from 3.2 to 6.1 mg/l (5.0 ± 0.7) in Gulshan lake and 5.4 to 7.7 mg/l (6.5 ± 0.6) in Dhanmondi lake [Table-3]. Gulshan Lake was found in September 2010, July and August 2012 and the lowest value in January 2011. In Dhanmondi lake the highest value was found in August 2010 and the lowest value in January 2011. Dissolved oxygen values of water during three years in the Gulshan and

Dhanmondi lake did not show significant differences (P=0.128 and P=0.126 respectively) [Table 6-8]. Begum *et. al.,* (2012) reported from Shafipur ansar academy lake (4.98-9.66 mg/l). Ahmed *et. al.,* (1999a) reported from Kaptai lake highest concentration of dissolved oxygen (DO) during monsoon months.

During the entire sampling period dissolved oxygen showed significant correlation with air temperature (Gulshan lake: r=0.500, $p<0.05$; Dhanmondi lake: r=0.320, $p<0.05$), water temperature (Gulshan lake: r=0.482, $p<0.05$; Dhanmondi lake: r=0.316, $p<0.05$) in both lakes [Table 18-19]. Shafi *et al*. (1978) observed dissolved oxygen inversely correlated with temperature from the Meghna river, Bangladesh. Munawar (1970) observed inverse relationship between dissolved oxygen of water and free CO_2.

Dissolved CO_2 in water bodies may cause severe impact to the water quality. Higher value of free CO_2 can cause the respiring problem and it becomes worse during summer when temperature goes up**.** Free carbon dioxide in water is the by-product of metabolism. Free carbon dioxide (CO_2) is an extremely necessary constituent in an aquatic environment. Free carbon dioxide content of water is of great importance in understanding its pH as well as in many other ways (Hutchinson 1975). Free CO_2 value of Gulshan lake ranged from 13.7 to 33.4 mg/l with mean value of 19.3 ± 3.90 mg/l. Free CO_2 content more than 20 mg/l may be harmful to fish and even lower concentration may be equally harmful when dissolved oxygen contents are less than 3 mg/l (Lagler 1972). In Dhanmondi lake the free CO_2 value varied from 11.4 to 33.3 mg/l to with mean value of (20.2 ± 3.6 mg/l) [Table-2]. Similar observation was also made by Patra and Azadi (1987) from Halda river and Miah *et. al*.(1983) from one year old fish pond in Bangladesh. The highest value of free CO_2 of water in monsoon from both lakes may be due to the rain and inflow of flood water. The higher CO_2 may be due to decomposition of organic matters or its production during respiration by aquatic organisms, which is greater than its uptake by phytoplankton and macrophytes during photosynthesis. Similar observation was recorded from Indian reservoirs by Mathew (1975). Dewan (1973) stated that the high values of free CO_2 in monsoon were due to the release of CO_2 as a product of decomposition of organic matter carried into the water bodies and the reduced photosynthetic activities of phytoplankton during cloudy weather. The lower values of free CO_2 during winter were probably due to lower decomposition of organic matters associated with the cold weather. The lower CO_2 in the water indicated the higher rate of its consumption during photosynthesis by algae. Saha *et al*. (1971) also observed similar observation from a freshwater fish pond.

During the entire sampling period in Gulshan lake free CO_2 showed significant positive correlation with air temperature ($r=0.175$, $p<0.01$) and water temperature ($r=0.239$, $p<0.05$) [Table 18]. Munawar (1970) reported direct relationship between temperature and free CO_2 of water. Naser *et al*. (1990) also found same relationship. In Dhanmondi lake showed no significant correlation. [Table 19].

Alkalinity is a measurement of carbonate and bicarbonate ions dissolved in the water. Alkalinity is the estimate of ability of water to resist change in pH upon addition of acid. Alkalinity has significant impact on fish and aquatic life since it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. Total alkalinity of Gulshan lake was 122.4 mg/l and 216.7 mg/l with an average of 173.2 ± 29.6mg/l while in Dhanmondi lake it varied from 87.5 mg/l to 123.1 mg/l with an average value of 103.2 ± 8.6 mg/l. The higher concentration was observed during February to April in Gulshan lake while in Dhanmondi lake the higher concentration was found in February and March. Rahman *et al. (*2006) reported similar results from the Hamil beel, Bangladesh. Jhingran (1989) reported that alkalinity values of more than 50 mg/l are more productive and those of less than 10 mg/l do not produce large aquatic crops. He added that total alkalinity values up to 20 mg/l indicate poor production and values above 40-90 mg/l show high production. Accordingly, these two lakes are productive. Seasonally, the highest values of alkalinity were observed in Post monsoon months. Ali *et. al*.(1980) in pond and Chowdhury and Mazumdar (1981) in Kaptai lake found similar findings.

The average value of alkalinity was found higher in Gulshan lake (173.2 ± 29.6 mg/l) than Dhanmondi lake (103.2 ± 8.6 mg/l). Thus it is clear that alkalinity of Gulshan lake has already caused a threat to the protection of aquatic species. The alkalinity varies in accordance with the fluctuation in the pollution load. This difference may be due to removal of bottom sediments from Dhanmondi lake. Ohimain *et al.* (2008) showed that the dredging triggered physico-chemical changes of the water body.

In the entire sampling period in the Gulshan lake and Dhanmondi lake water alkalinity showed significant negative correlation with water depth (r=-0.411, p<0.05; r=-0.298, p<0.05), air temperature (r=-0.407, p<0.05; r=-0.469, p<0.05), water temperature (r=- 0.411, p<0.05; r=-0.460, p<0.05) and dissolve oxygen (r=-0.174, p<0.01, r=-0.224, p<0.05) [Table 18-19]. Chinnaiah *et al*, (2011) reported alkalinity value ranged from 206 mg/l to 240 mg/l in Khajana lake. Maximum (240 mg/l) and minimum (206 mg/l) were seen in the summer and monsoon respectively. In Darmasagar it is varied from 210 mg/l to 232 mg/l, minimum in winter (210 mg/l) and maximum in summer (232 mg/l).

Hardness of water is an important consideration in determining the suitability of water for domestic and industrial uses. Water hardness is commonly reported aspect of water quality and significant impact on fish culture. Generally hardness of water is due to the presence of calcium, magnesium, chloride, sulfate, carbonate, bicarbonate etc. Hardness of water is directly related to the biological productivity. Hardness of water depends on the dissolved solids and pH. Hardness gives a measure of the total concentration of the divalent metallic cations calcium, magnesium and strontium. Proper liming can reinstate the hardness. The ideal value of hardness for fish culture is 30-180 mg/l. There may be sudden variations in the hardness due to heavy rainfall (Santhosh and Singh 2007).

During the entire sampling period total hardness value of Gulshan lake was varied between 85.70 and 130.0 mg/l with mean value of (104.5 ± 9.1 mg/l). In Dhanmondi lake it ranged from 87.5–123.1 mg/l with mean value of (103.2 ± 8.6 mg/l). The highest value of hardness (130.0 mg/l) was found in March 2012 and the lowest value (85.7 mg/l) in September 2010 from the Gulshan lake. In the Dhanmondi lake the highest value (115.0

mg/l) was found in April 2010 and the lowest value (83.0 mg/l) was recorded in Octobor 2010. Total hardness was found relatively higher in post monsoon months and lower in monsoon months and this finding was supported by Chowdhury and Mazumder (1981). In monsoon months lower level of hardness may be due to heavy rainfall resulting in dilution of water. Water of Dhanmondi lake could be classified as soft since its average hardness value did not exceed 120 mg/l. The value of total hardness of water of Gulshan lake was found higher than Dhanmondi lake. This difference may be due to removal of bottom sediments in Dhanmondi lake. These changes appeared to be the causal factors for the reduction in the population density and zooplankton taxa which was confirmed by Ohimain *et al*. (2002).

During the entire sampling period in Gulshan lake total hardness inversely significant correlated with water depth ($r=-0.274$, $p<0.05$), transparency ($r=-0.307$, $p<0.05$) and dissolved oxygen ($r=-0.344$, $p<0.05$) and significant positive correlation with ammonia ($r=0.308$, $p<0.05$) and alkalinity ($r=0.355$, $p<0.05$) [Table 18]. In Dhanmondi lake also shows negative significant correlated with water depth ($r=-0.281$, $p<0.05$) and dissolved oxygen ($r=-0.174$, $p<0.05$) and significantly positive correlation with ammonia ($r=0.272$, $p<0.05$) and alkalinity ($r=0.328$, $p<0.05$) [Table 19]. Positive correlation between alkalinity and hardness was reported by Boyd (1982). Direct relation between total alkalinity and hardness from high altitude rivers of India also found Ayoade *et al.* (2009).

Fish is very sensitive to ammonia in lake. Ammonia is the most toxic form of inorganic nitrogen produced in water. The ammonia nitrogen content in water in an index of the level of its pollution. Ammonia may be produced from the waste products of fish and fish secretions which may cause fish mortalities, therefore the ammonia content in running water culture systems should be low. It is suggested that concentration of ammonia in running water pond should not be more than 1.0 ppm. The harmful effects of ammonia on fish are related to the pH value and the temperature of water. Ammonia-nitrogen is mainly found in water as ammonium ion (NH_4) through the bacterial breakdown of protein and through bacterial de nitrification. It is also formed through nitrogen fixation by certain bacteria, molds and blue green algae which is used by plants as the nutrient. In unpolluted water body its concentration is low (1 ppm or less). Due to organic pollution, pollution by gasses work and very high decomposition, high concentration of ammonia (12 ppm or more) occurs in water which may become lethal to fishes and other animals.

During the entire study period the ammonia-nitrogen concentration in Gulshan lake found too high concentration. Concentrations were gradually increasing with the year. Ammonia was exceptionally higher in Gulshan lake water. The high values of ammonia of Gulshan lake water was may be due to sewage contamination from surrounding areas. It ranged from 4.7 to 18.4 mg/l (10.5±3.3mg/l) with the maximum in winter and summer period while in Dhanmondi lake it ranged from 0.30 to 2.3 mg/l (0.9±0.4 mg/l) with the maximum in winter. Stavroulakis *et al.* (2007) found the maximum ammonia-nitrogen concentration in December and August from the lake Kournas, Greece. Madkour *et al.* (2007) observed the notable increase of ammonia-nitrogen in March and the lowest in May from Suez canal. The lowest ammonia-nitrogen was observed in monsoon month due to heavy rainfall resulting in dilution of water. The ammonia-nitrogen was observed high in summer months which were supported by Welch (1952). Jhingran (1989) reported dissolved ammonia-nitrogen concentration of 0.2-0.5 mg/l is favorable for fish life. On the basis of above mentioned conditions Gulshan lake water was found highly polluted and Dhanmondi lake was found suitable for fish culture.

In Gulshan lake the values of ammonia-nitrogen showed significantly inverse relationship with water depth ($r=-0.483$, $p<0.05$), air temperature ($r=-0.260$, $p<0.05$) water temperature ($r=-0.273$, $p<0.05$) and positive significant correlation with alkalinity ($r= 0.549$, $p<0.05$), hardness ($r=0.308$, $p<0.05$), conductivity ($r=0.526$, $p<0.05$), TDS ($r= 0.616$, $p<0.05$), BOD ($r=0.586$, $p<0.05$) and COD ($r=0.643$, $p<0.05$) [Table 18]. In Dhanmondi lake it also showed negative correlation with water depth ($r=-0.309$, $p<0.05$), air temperature ($r=-0.308$, $p<0.05$), water temperature ($r=-0.340$, $p<0.05$), transparency ($r=-0.363$, $p<0.05$), dissolve oxygen ($r=-0.243$, $p<0.05$) and pH ($r=-0.372$, $p=0.05$) [Table 19]. Negative correlation between ammonia-nitrogen and water depth and secchidisc depth may be due to the heavy rainfall which diluted the water. Ammonia-nitrogen of Dhanmondi lake water showed significant positive correlation with alkalinity ($r=0.318$, $p<0.05$), hardness ($r=0.272$, $p<0.05$), conductivity ($r=0.280$, $p<0.05$), BOD ($r=0.326$, $p<0.05$) and COD ($r=0.572$, $p<0.05$) [Table 19].

The mean values for conductivity in the Gulshan lake during the whole study period was found between 421 and 590 µs/cm which is the higher than the standard value of 350 µs/cm. In pre monsoon it was 563.2±19.7 µs/cm, during monsoon it was 432.3±13.7 µs/cm and post monsoon it was 471.4±29.2 µs/cm. In the wet season, as the flow of the lake increases which may cause the dilution of the water, while in the dry season, the flow of the lake decreases, as a result the conductivity increases. Nevertheless, these values indicate that the Gulshan lake may receive the wastewater (sewage effluent) that contains high ionic concentration, which is eventually harmful for the aquatic life. Increasing trends were recorded with the following years that are one indicators for pollution.

Other hand, the mean values for conductivity in the Dhanmondi lake during the wet season at all six different sampling stations were found 350 µs/cm which is below than the DOE standard. However, the results revealed that distribution of these values in some occasions was slightly exceeding the standard level during the dry season. Increasing trends also observed according to year passing. The minimum values were observed in monsoon of first year (2010-11) and the maximum was in pre monsoon of third year (2012-13). Earlier Begum *et. al*., (2012) reported that the annual average conductivity of Shafipur Ansar and VDP lake showed minimal value (162.65 µ S/cm) than the Dhanmondi lake (565.42 µS/cm), Gulshan lake (196.1 µS/cm) and Banani lake (337.23 µ S/cm) (340.10 µ S/cm). The conductivity value of this lake is closer to Crescent lake (158.57µS/cm) and the Gulshan lake (196.1µS /cm). Highest conductivity was obtained in summer which indicates that the highest free ionic load occurs during this period. This may be a result of crucial breakdown of organic and inorganic matters in the water body and this was followed by high phytoplankton densities in dry months.

In the Gulshan lake conductivity showed significantly positive relation with hardness (r=-0.471, p<0.01), ammonia-nitrogen (r=0.526, p<0.01), alkalinity (r=0.462, p<0.01) and negative significant correlation with water depth (r=-0.350, p<0.01), transparency (r=-0.363, p<0.01) and Dissolved Oxygen (r=-0.205, p<0.05) [Table 18]. In the Dhanmondi lake it also showed positive correlation with ammonia-nitrogen (r=0.280, p<0.01), alkalinity (r=0.220, p<0.01) and hardness. (r=0.206, p<0.05) and negative significant correlation shows with water depth (r=-0.314, p<0.01) and dissolved oxygen (r=-0.217, p<0.01). [Table 19]

Total dissolved solids (TDS) analysis has great implications in the control of biological and physical waste water treatment processes. TDS in surface waters come from the solvent action of water in contact with minerals in the earth, agricultural and residential runoff, leaching of soil contamination, and used water from industrial or sewage treatment plants. Common chemical constituents are calcium, sodium, chloride, potassium, phosphates and nitrates. The increasing trends of TDS were recorded with the following years in both the lakes.

In the Gulshan lake TDS showed significantly positive correlation with ammonia (r=-0.616, p<0.01), carbon dioxide (r=0.194, p<0.05), alkalinity (r=0.472, p<0.01), hardness (r=0.465, p<0.01) and conductivity (r=0.713, p<0.01) and negative significant correlation with water depth (r=-0.643, p<0.01), air temperature (r=-0.280, p<0.01), water temperature (r=-0.274, p<0.01), transparency (r=-0.449, p<0.01) and Dissolved Oxygen (r=-0.267, p<0.01) [Table 18]. In the Dhanmondi lake TDS showed significantly positive correlation with air temperature (r=-0.294, p<0.01), water temperature (r=0.310, p<0.01), pH (r=0.182, p<0.05), and conductivity (r=0.682, p<0.01). Negative significant correlation shows with water depth (r=-0.391, p<0.01) and transparency in the Dhanmondi lake (r=-0.170, p<0.05) [Table 19]

Biological Oxygen Demand (BOD) is the measure of the oxygen required by microorganisms while breaking down organic matter. BOD determines the strength of sewage, effluents and other polluted waters and provides data on the pollution load in all natural waters. The biodegradation of organic materials exerts oxygen tension in the water and increases the biological oxygen demand (Abida, 2008). BOD directly affects the amount of dissolved oxygen (DO) in lakes. The greater the BOD the more rapidly oxygen is depleted in the water. Lakes with low BOD have low nutrient level therefore much of the oxygen remains in the water. Unpolluted natural waters have a BOD of 5 mg/l or less. The greater the BOD the more rapidly oxygen is depleted in the lakes. This means less oxygen is available to higher forms of aquatic life. Sources of BOD include leaves and woody debris, dead plants and animals, animal manure, effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants, failing septic systems and urban storm water runoff.

The BOD_5 is a measure of the amount of oxygen that bacteria consume in five days at 20°C while decomposing organic matter under aerobic conditions. In case of BOD the standard for aquatic life is 6mg/l which has been exceeded in case of Gulshan lake in all the sampling stations. Reason of high values of BOD in the Gulshan lake may be due to domestic discharge during rainy season. Higher BOD values were observed in pre monsoon and low BOD values recorded during monsoon season. These results partially agreed with findings of Chatterjee (1992) who has recorded higher BOD values during northeast monsoon and attributed to the enhanced biological activity at higher temperature.

BOD values of Gulshan lake recorded above acceptable level in all the season and years. Increasing trend also recorded in Gulshan lake water following the years. This value one of the indicators of pollution. The high level of BOD particularly during the dry season in the Gulshan lake also indicates the presence of excessive amount of bacteria in the water which consume the oxygen levels in the river. Nusrat et. al., (2013) also found quite higher BOD in Gulshan lake water only exception in the north direction of this lake and BOD found acceptable level.

The BOD values of Dhanmondi lake water were found acceptable level in all the season and years. Therefore Dhanmondi lake water is suitable for aquatic life. Seasonal analysis reveals that BOD values are more during pre monsoon followed by monsoon and post monsoon. Similar treads also reported by Ahipathi (2006) open defecation nearby river and Discharging of Sewage waste water generated by Kollegala town and Harale village to upstream river resulting higher BOD values of 2.6 mg/L and 3.1 mg/L respectively and steadily reduced in the downstream sites of mixing zone. The yearly average BOD values range was 1.60 to 5.60 mg/L of the Dhanmondi lake indicates the absence of major organic pollution sources. Sinha and Biswas (2011) analyses physico-chemical characteristics of water of a lake in Kalyani, West Bengal. The BOD value of the lake throughout the year of survey fluctuated between 1.8 mg/L and 4.5 mg/L with highest and lowest values during December and May-June respectively and average BOD value was 2.8 mg/L.

In Gulshan lake BOD showed significantly positive correlation with ammonia ($r=-0.586$, $p<0.01$), carbon dioxide ($r=0.205$, $p<0.05$), alkalinity ($r=0.360$, $p<0.01$), hardness ($r=0.371$, $p<0.01$), conductivity ($r=0.613$, $p<0.01$) and TDS ($r=0.800$, $p<0.01$). [Table-18]. Negative significant correlation with water depth ($r=-0.607$, $p<0.01$), air temperature ($r=-0.239$, $p<0.01$), water temperature ($r=-0.228$, $p<0.01$) and transparency ($r=-0.460$, $p<0.01$) [Table 18. In Dhanmondi lake BOD showed significantly positive correlation with ammonia ($r=-0.326$, $p<0.01$), alkalinity ($r=0.185$, $p<0.05$) and hardness ($r=0.210$, $p<0.05$). [Table 19]. Negative significant correlation shows with water depth ($r=-0.209$, $p<0.05$) and water transparency ($r=-0.165$, $p<0.05$) [Table 19]

The chemical oxygen demand (COD) is measure of the oxygen equivalent of the organic matter content of the sample. High COD value indicates the toxic state of the waste water along with the presence of biologically resistant organic substances. It is commonly used to indirectly measure the amount of organic compounds in water. The measure of COD determines the quantities of organic matter found in water. This makes COD useful as an indicator of organic pollution in surface water (King *et al.*, 2003 and Faith, 2006). In the conjunction with the BOD test, the COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances (Sawyer *et al.*, 2003).

In Gulshan lake COD showed significantly positive correlation with ammonia (r=0.643, p<0.01), carbon dioxide (r=0.212, p<0.05), alkalinity (r=0.439, p<0.01), hardness (r=0.402, p<0.01), conductivity (r=0.634, p<0.01), TDS (r=0.859, p<0.01) and BOD (r=0.766, p<0.01). [Table 21]. Negative significant correlation with water depth (r=-0.664, p<0.01), air temperature (r=-0.215, p<0.01), water temperature (r=-0.224, p<0.01) and transparency (r=-0.419, p<0.01) [Table 18]. In Dhanmondi lake COD showed significantly positive correlation with pH (r=0.503, p<0.01), ammonia (r=0.572, p<0.01), alkalinity (r=0.231, p<0.01), hardness (r=0.166, p<0.05), conductivity (r=0.410, p<0.01), TDS (r=0.237, p<0.01) and BOD (r=0.232, p<0.01). [Table 19]. Negative significant correlation shows with water depth (r=-0.498, p<0.01), air temperature (r=-0.269, p<0.01), water temperature (r=-0.274, p<0.01), transparency (r=-0.492, p<0.01) and dissolved oxygen (r =-0.340, p<0.01) [Table 19].

The COD is another important parameter for lake water quality assessment. This measures the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. High values of COD indicate water pollution which linked to sewage effluents discharged from town, industry or agricultural practice. The minimum COD of Gulshan lake water was observed in monsoon as below acceptable level (>40mg/L) and the maximum in pre monsoon as above acceptable level (<40mg/L). The higher values of COD compared to the BOD values indicate the presence of inert organic material in the lake water during dry season. COD of Khajana Lake varied from minimum (28.88 mg/l) in monsoon to maximum (32.10mg/l) in summer. Chinnaiah *et al*, (2004). Where as in the lake of Darmasagar the COD varied from 22.14 mg/l to 24.10 mg/l in monsoon (22.14 mg/l) Venkatesharaju *et, al.*, (2010).

5.1.2. Heavy Metals of Water:

The relatively high Zinc level is suggestive of the influence of refuse dump and domestic sewage sources. It could also be attributed to the intense anthropogenic influence due to industrialization and urbanization within the catchments of the lakes. Zn is an essential nutrient for body growth and development however drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. Sources of Zn into aquatic ecosystems include urban runoff and municipal sewages.

Zinc level in water of the Gulshan lake was varied from 0.02mg/l to 0.08mg/l. In the Dhanmondi lake, it was ranges from 0.00mg/l to 0.04 mg/l. Mokades et. al., (2013) were also reported the similar findings that the average concentration of Zinc in Dhanmondi and Gulshan lakes water were varied between 0.016 and 0.040 ppm respectively. The concentration of Zn in surface water recorded in this study did not exceed the recommended limit of 3 mg/L for Zn levels in drinking water (WHO, 2008). Similar studies done in Lake Victoria, Kenya have recorded Zn levels as high as 0.220 mg/L (Lalah *et al.,* 2008 and Mwamburi, 2009). Also, Muiruri *et al.,* (2013) observed higher mean Zn levels (0.055–0.695 mg/L) in Athi River tributaries. Ochieng *et al.,* (2007) observed mean Zn levels ranging 0.029–0.235 mg/L in five rift valley lakes of Nigeria (Nakuru, Naivasha, Baringo, Elementaita and Bogoria). At Lake Kanyaboli mean Zn levels in surface water ranging from 0.015–0.056 mg/L have been recorded (Ochieng *et al.,* 2008). Olatunji and Osibanjo (2012) obtained higher mean Zn levels (1.98–4.03 mg/L) in the river Niger, Nigeria compared to those observed in Masinga reservoir.

Chromium level of water of Gulshan lake and Dhanmondi lake were recorded below detected level (BDL) during the whole study period. The main sources of Cr are industrial wastes such as Cr pigment, tannery wastes, leather manufacturing wastes and municipal sewage sludge (Rahman *et al.,* 2012). The mean Cr levels obtained in this study did not exceed the recommended limit of 0.05 mg/L for Cr in drinking water (WHO, 2008). Compared to other studies the mean Cr levels in surface water of Masinga reservoir were lower than 0.23–0.79 mg/L recorded in Lake Victoria (Oyoo-Okoth *et al.,* 2010), 0.025–0.188 mg/L in five rift valley lakes (Ochieng *et al.*, 2007) and 0.068 mg/L in Athi River tributaries (Muiruri *et al.*, 2013). Ochieng *et al.*, (2008) found mean Cr levels of 0.005–0.061mg/L at different sites in Lake Kanyaboli. Olatunji and Osibanjo (2012) recorded a much higher mean Cr levels of 1.19–3.16 mg/L in River Niger, Nigeria. A higher mean Cr level of 0.049±0.02 mg/L has been recorded in Owen multi-purpose dam water, Nigeria (Oyhakilome *et al.*, 2012). However mean Cr levels observed at Masinga reservoir were within the range of 0.003–0.088 mg/L recorded in River Nile, Egypt (Osman and Kloas, 2010).

Kar *et al*. (2008) found that Chromium concentration more than 92% of the samples in the range of 0.001-0.044 mg/L in Ganga river of West Bengal. Mohuya et al. (2010) studied on heavy metal contamination in Gulshan-Baridhara lake, Dhaka and found the concentrations of Cr was 0.048-0.225 mg/L. According to WHO (2008) the guideline value of Cr for drinking water is 0.05 μg/mL. The concentration of Cr not exceeds the drinking standard.

The Lead concentration of the Gulshan and Dhanmondi lakes varied between 0.06-0.32 mg/l; 0.00-0.08mg/l respectively. Lead concentration in natural water increases mainly through anthropogenic activities. Hence, likely source of Pb in water bodies is from soil erosion, municipal and industrial wastes and run off. Oyoo-Okoth *et al.*, (2010) found mean Pb levels ranging from 0.26–0.99 mg/L in Lake Victoria. Kenya. Muiruri *et al.*, (2013) also, recorded lower and higher mean Pb levels at different sites (0.00–0.047 mg/L) in surface water of Athi River tributaries. Other studies that recorded higher mean Pb levels include open waters of Winam gulf (0.2 mg/L), River Nyando (0.19 mg/L) and 0.015 mg/L in River Sondu Miriu (Tole and Shitsama, 2003). Ochieng *et al.*, (2007) obtained higher mean Pb levels ranging 0.025–0.563 mg/L in surface water of five Rift valley Lakes. Ochieng *et al.*, (2008) recorded Pb concentration levels of 0.006–0.048 mg/L in Lake Kanyaboli, Kenya. Olatunji and Osibanjo (2012) also recorded higher mean Pb levels (0.02–0.04 mg/ L) in surface water of River Niger, Nigeria.

Cadmium concentration in Gulshan lake water was ranged from 0.00-0.07mg/l. In Dhanmondi lake Cd was 0.01-0.04mg/l. The higher concentration of cadmium is extremely toxic to fish population. Its effects on the growth rate have been observed even for concentrations between 0.005 and 0.01 mg/L. The annual average Cd concentration in water samples of Gulshan and Dhanmondi lake was found to be above the permissible limit for consumption and domestic use. Probable sources of Cd in surface water include leaching from Ni-Cd based batteries, runoff from agricultural soils where phosphate fertilizers are used and other metal wastes. Mokades *et. al.*, (2013) reported average concentration of cadmium in the Dhanmondi and Gulshan were recorded 0.0097 ppm and 0.0277 ppm respectively. Recommended value for Cadmium in drinking water is 0.010 mg/l. (WHO, 2008). Values found in the Gulshan-Baridhara lake were well above the surface water criteria limits. Discharge from electro-plating units and zinc smelters are the main source of cadmium contamination in water. Metallic and plastic pipes can also contribute cadmium in water. High content of cadmium in the lake water might be due to discharge from the small electroplating industries in the catchments of the lake and also from the surface drain pipe or septic tank pipe connected to Gulshan-Baridhara lake.

In the Gulshan lake higher concentrations of lead found was recorded in post monsoon period (0.28±0.05 mg/l) and increasing tendency was recorded with the succeeding years. Similar results were observed from Dhanmondi lake water. In compared with two lakes comparatively higher concentrations were observed in Gulshan lake water. The high level of lead in water of the Gulshan and Dhanmondi lake can be attributed to heavily traveled roads that run along the lakes and agricultural runoff which contain fertilizers and pesticides. Mohuya et. al., (2010) found that lead concentration of Gulshan-Baridhara lake exceed the standard level during monsoon. Mokades *et. al*. (2013) reported lead concentrations varied from 0.151-0.210 mg/l during the dry period and from 0.030-0.120 mg/l during the wet period. Dixit and Tiwari (2008) found that in the Shahpura lake of Bhopal, India the highest value of Pb was 2.9 mg/l and the lowest value was 0.1 mg/l during the summer and monsoon respectively.

Concentration of copper in the Gulshan lake water was 0.05-0.18mg/L and in the Dhanmondi lake water was 0.06-0.11mg/l. Similar findings was reported by Mokades *et al.,* (2013) the average values of Copper for Tongi lake, Dhanmondi lake, Banani lake and Sangsad lake were 0.115ppm, 0.0211ppm, 0.0181ppm and 0.0194ppm respectively. Mohuya *et al.,* (2010) was found that copper concentration varied significantly during summer in the Gulshan lake and ranged between 0.101 and 6.135mg/l. They also stated that high content of Copper in the Gulshan lake might be due to various type of garbage, household materials, cans etc. which have been piled up near this spots of the lake. Copper concentrations in different seasons of the Gulshan lake were high. Lethal copper concentration for fish and aquatic invertebrates ranged from 0.02-3.0mg/l. In this respect high copper content in lake is also threat to its fish community and aquatic invertebrates.

Copper is a natural element which is widely distributed in soils, rocks and in rivers. It is released into water as a result of natural weathering of soil and discharges from industries and sewage treatment plants (Romo-Kroger *et al.,* 1994 and Hutchinson, 2002). Copper in surface water is from extensive use of pesticides sprays which contain Cu compounds for agricultural purposes (Al-Weher, 2008). In the dissolved form Cu is potentially very toxic to aquatic animals and plants especially to young life-stages such as fish larvae. However the toxicity is greatly reduced when Cu is bound to particulate matter in the river water and when the water is hard (Damodharan and Reddy, 2013).

Nickel of water in Gulshan and Dhanmondi lakes were recorded below detected level (BDL) throughout the study periods. Mohuya *et al.,*(2010) also found concentrations of nickel were below the detection limit at different sampling stations of the Gulshan-Baridhara lake water during the summer. However, at the sampling points close to Maddya Baddha area, the Nickel concentration was 0.623 mg/l. On the other hand, during the monsoon the values ranged from 0.007-0.159 mg/l except the Baridhara point, between Shahjadpur and middle Baddha point. In the rest of the sampling points the values were found the below the detection limit. They also reported that nickel contents obtained from the investigation were below the standard except the lower part of Uttar Baddha point during the monsoon.

Manganese in the Gulshan lake water was recorded 0.40-0.58 mg/L and in the Dhanmondi lake it was varied 0.30-0.41mg/L. Average manganese concentration in water samples of Gulshan and Dhanmondi lake was found above the permissible limit for drinking water. The permissible levels of Manganese in water used for domestic purposes are quite low (<0.05 mg/L) and the maximum acceptable concentration in water for continuous irrigation is 0.2 mg/L. (WHO, 2008). Manganese in water due to laundry and bathroom fixtures stained by very low levels of Manganese in water. The other study also revealed that the average values of manganese in the Dhanmondi, Ramna, Crescent, Samsad, Gulshan, Bonani, Rampura, Sutrapur, Airport and Tongi lake were 0.0528ppm, 0.0700ppm, 0.0798ppm, 0.0893ppm, 0.0904ppm, 0.0896ppm, 0.0916ppm, 0.1020ppm, 0.1085ppm and 0.0987ppm respectively (Mokades *et al.,* 2013). Comparable studies carried out in Kenya have recorded higher mean manganese values than observed in Masinga reservoir. These studies include those done by Lalah *et al.,* (2008) in Winam Gulf, Lake Victoria (0.05-3.276mg/L) and Ochieng *et al.,* (2008) in Lake Kanyaboli, Kenya (0.185–0.376mg/L). Also Ochieng *el al.,* (2007) obtained higher mean levels of Mn in five rift valley lakes (0.050–0.282mg/L). Akoto *et al.,* (2008) recorded similar mean Mn values ranging from 0.099–0.140mg/L in Owabi reservoir, Ghana while Mahadev and Gholami (2010) in KRS reservoir, India observed (0.0001–0.107mg/L) and Osman and Kloas (2010) in River Nile, Egypt (0.033–0.099mg/L). Oyhakilome *et al.,* (2012) recorded higher Mn values (0.346 ± 0.391mg/L) in Owen multi-purpose dam water, Nigeria.

5.2. Sediment quality:

Sediment is a habitat and major nutrient source for aquatic organisms. Sediment analysis is important in evaluating qualities of total ecosystem of a body of water in addition to water sample. Sediment comprise an important component of aquatic ecosystems, providing habitat for a wide range of benthic and epi-benthic organisms. Exposure to certain substances in sediment represents a potentially significant hazard to the health of these organisms. Effective assessment of this hazard requires an understanding of the relationships between concentrations of sediment associated chemicals and the occurrence of adverse biological effects. Sediment is the loose sand, clay, silt and other soil particles that settle at the bottom of lake. The erosion of bedrock and sediment leads to accumulation of soils of past or on-going natural and anthropogenic processes and components. Data from soils can provide information on the impact of distant human activity on the wider ecosystem. The composition of sediment sequences provides the best natural archives of recent environmental changes.

Sediment pH reflects the conditions associated with the availability of nutrients, physical conditions of sediment having a pronounced affect on the sediment biota including macrobenthos and microbial fauna. Jhingran (1989) stated that most of the bacterial growth occurs at pH 4 to 9 and the pond sediment which is slightly alkaline (ph 8.1) is good for bacterial and macro benthic growth.

The average pH value of soil of Gulshan lake was 6.3 to 6.9 and in Dhanmondi lake were also 6.1 to 6.9. Sediment pH was values indicate that soils of both the lake was acidic in nature. No specific relation was established among the season and year succeeding in both the lakes sediment. Organic matter act a reservoir of nutrients and it is indicated by plants microbes and other organisms inhabiting water body. Organic matter is also known to affect other properties of soil (Brady, 1994). The organic matter was found 4.3% to 6.9% in the sediment of Gulshan lake and in Dhanmondi lake sediment it was recorded 1.6% to 3.7%. The organic matter was higher in both the lakes sediment during pre and post monsoon in compared to monsoon period. Organic matter increased gradually in both the lakes sediment in the following years. Almost double values of organic matter were recorded in the Gulshan lake sediment than that of the Dhanmondi lake which is apparently significant resulted the sediment of Gulshan lake was polluted.

The total nitrogen of sediment of the Gulshan lake was ranged from 0.19% to 0.26% and in the Dhanmondi lake sediment was ranged 0.09% to 0.24%. Sediment nitrogen of the Dhanmondi lake was less in compared to the Gulshan lake which may be due to the lower debris materials in the sediment in Dhanmondi lake which was re excavated in recent years. Similar to sediment acidity no specific relation found in sediment nitrogen within the season and years in sediment of both the lakes. Total nitrogen content represents an important source of ammonium and a sink for nitrate (Seitzinger, 1988 and Kemp et. al.,1990) reported that in pond condition, total nitrogen was 0.140%. In aerobic conditions ammonium (produced as a byproduct of microbial degradation of organic matter and metabolism of benthic organisms) can undergo nitrification and form nitrate. Nitrates thus released are assimilated by bacteria and macro benthic organisms and later on released into bottom sediments by decay.

Calcium and magnesium is important exchangeable base in terms of physical, chemical and biological action in sediment. Calcium amendment stimulates microbial life too. The role of oxalic acid and bicarbonate in calcium cycling by fungi and bacteria: some possible implications for soil animals. Sediment calcium of the Gulshan lake was 6.4-14.2 mequ/100g and in the Dhanmondi lake was 6.0-20.6mequ/100g. No specific relation found in season and year in both lakes sediment calcium values. Calcium found higher concentration in Dhanmondi lake sediment in all season.

Magnesium level of the Gulshan lake sediment was 0.54-0.72mequ/100g and in the Dhanmondi lake was 0.58-1.72mequ/100g. There was no specific relation found in season and year in both lakes sediment magnesium values. Magnesium also found higher concentration in Dhanmondi lake sediment in all season. Potassium level of the Gulshan lake sediment was ranged from 0.37-0.68mequ/100g and in the Dhanmondi lake was 0.23-0.68 mequ/100g. There was no specific relation found in season and year in both lakes sediment potassium values. More or less same values were recorded in both the lakes. Phosphorus level of sediment of Gulshan lake was 1.2-1.6µg/g and in Dhanmondi lake sediment was 9.5-17.6µg/g. There was no specific relation found in season and year in both the lakes sediment. Dhanmondi lake sediment shows exceptionally higher in compare to the Gulshan lake sediment.

5.4. Heavy metals of sediment:

The mean concentration levels of Zinc (Zn) recorded during the study in different sites showed variations. The Zinc level of sediment of Gulshan lake was ranged from 8.25-18.6 mg/kg and in Dhanmondi lake sediment it was 6.48-16.40 mg/kg. [Table A 19-24]. Lowest values recorded in monsoon of Gulshan lake sediment and highest found in post monsoon. Increasing values recorded as following the years. Same results also observed in case of Dhanmondi lake sediment. Comparatively higher zinc value recorded in Gulshan lake sediment than Dhanmondi lake sediment. Identified domestic construction and car related source and untreated waste water as the main sources of Zinc. The source of Zn concentrations in sediments to reservoirs could be from a number of alloys including brass and bronze, batteries, fungicides and pigments (Akan *et al.*, 2010). Zinc is used in galvanizing steel and iron products hence a possible source from the urban areas. Another source could be Zn Carbonates used as pesticides (Anglin-Brown *et al.*, 1995). The elevated Zn values recorded at Kathini may be attributed to Zn which is used in printing and dyeing processes in textile industries located within the Thika sub catchment. The results obtained on mean Zn concentration levels in all the sampling sites did not exceed the WHO recommended limit of 123mg/kg (WHO, 2008). However, sediments have the capacity to accumulate more heavy metals with time and remobilize them back to water and the food chain (WHO, 2008). Compared to other studies mean Zn levels in Masinga reservoir were 96.2 to 229.6mg/kg recorded in five Rift Valley lakes, Kenya (Ochieng *et al.*, 2007). Mean Zn levels recorded 23.39–350.80 mg/kg at Winam gulf (Ochieng *et al.*, 2008).

The Chromium level of sediment of the Gulshan lake was ranged 30.80-66.24mg/kg and in the Dhanmondi lake sediment it was 15.20-20.40mg/kg. In the Gulshan lake sediment chromium shows lowest values during monsoon and highest in post monsoon. Increasing values were recorded in subsequent years. In the Dhanmondi lake sediment chromium was found lowest in monsoon and highest in pre monsoon. Values of chromium were increasing following the year in both the lake sediment. Exceptionally higher chromium value recorded in the Gulshan lake sediment than the Dhanmondi lake. Sources of Cr in aquatic ecosystems are attributed to industrial and sewage wastes (Akan *et al.,* 2010).

Cadmium of Gulshan lake sediment was 0.11-0.28mg/kg and in Dhanmondi lake sediment it was 0.08-0.14mg/kg. There was no specific relation found in season and year in both the lakes sediment. Gulshan lake sediment shows more or less double concentrations of cadmium compare to the Dhanmondi lake sediment. The higher levels of cadmium obtained in sediments might be due to contribution from other source such as agricultural runoff where fertilizers are possible release of sediment bound metal.

The Lead of sediment in the Gulshan lake was ranged 9.28-92.46 mg/kg and in the Dhanmondi lake sediment it was 16.87-76.80 mg/kg. There was no specific relation found in case of lead with season and year in both the lakes sediment. Gulshan lake sediment lead concentrations comparatively higher than the Dhanmondi lake sediment. The levels of Pb concentrations observed in both the lakes sediments were higher than the recommended limit of 35mg/kg for Pb in sediment (WHO, 2008). Mean Pb levels were recorded in Rift Valley lakes of 10.92–38.98 mg/kg (Ochieng *et al.,* 2007). Ochieng *et al.,* (2008) found higher mean levels of Pb in sediments of different sites within Lake Kanyaboli (11.42–153.90 mg/kg) and Winam Gulf (3.09–66.05 mg/kg).

Copper of sediment in Gulshan lake was ranged 2.28-8.15mg/kg and in Dhanmondi lake sediment it was 2.07-3.16mg/kg. Both lake sediment samples contained excessive Copper. No specific relation found in case of copper with season but increasing values recorded following years in both lakes sediment. Gulshan lake sediment shows extremely higher concentrations of copper compare to Dhanmondi lake sediments. High level of Copper indicates its higher input in these sites, which might be originated from urban and industrial wastes. Copper can get into aquatic ecosystems from diverse sources for example, from Cu compounds used in fungicides, algaecides, insecticides, wood preservatives, electroplating and azo dye manufacture (Akan *et al.,* 2010). The mean levels of Cu in both the lakes were below the WHO standard values of 25 mg/kg for the survival of aquatic organisms (WHO, 2004). Comparable mean Cu Concentration levels in surface sediments have been observed in five Rift Valley Lakes (Nakuru, Naivasha, Elementaita, Bogoria and Baringo) in Kenya with a mean ranging from 1.46–20.95 mg/kg (Ochieng *et al.*, 2007). In Lake Kanyaboli mean Cu concentration levels ranging from 1.80–30.27mg/kg have been observed (Ochieng *et al.*, 2008).

Nickel of sediment in the Gulshan lake was ranged 34.08-62.54 mg/kg and in the Dhanmondi lake sediment it was 14.21-21.20 mg/kg. However, Nickel in sediment of both the lakes higher than the reference values, 16 mg/kg (WHO, 2008). In the Gulshan lake higher concentrations of nickel was found in pre monsoon and lowest in post monsoon. In the Dhanmondi lake lowest nickel was recorded during monsoon and highest in pre monsoon. Increasing values recorded following years in both the lakes sediments. Gulshan lake sediment shows remarkably higher concentrations of nickel compare to the Dhanmondi lake sediment.

Manganese of sediment in Gulshan lake was ranged 31.22-92.54 mg/kg and in Dhanmondi lake sediment it was 7.70-19.20 mg/kg. In Gulshan lake higher concentrations of manganese was found in pre monsoon and lowest in post monsoon. In Dhanmondi lake sediment lowest manganese was recorded during monsoon and highest in pre monsoon. Increasing values recorded following years in both lakes sediment. Gulshan lake sediment shows extraordinarily higher concentrations of manganese compare to Dhanmondi lake sediment. Manganese is known to be a very abundant element widely distributed in the earth’s crust. It is used in manufacturing of dry cell batteries, glass and fertilizer and in the leather and textile industries. Also Mn is released into the atmosphere by both natural and anthropogenic processes mostly in form of coarse particles, through wind erosion and road dusts.

Iron of sediment in the Gulshan lake was ranged 76.80-124.12 mg/kg and in the Dhanmondi lake sediment it was 53.60-114.32 mg/kg. Lowest iron in the Gulshan lake sediment was found during pre-monsoon and highest in post monsoon. In the Dhanmondi lake sediment lowest iron was recorded during monsoon and highest in post monsoon.

Increasing values recorded following years in both the lakes sediment. Gulshan lake sediment shows slightly higher concentrations of iron compare to the Dhanmondi lake.

Phytoplankton:

The phytoplankton in a reservoir is an important biological indicator of the water quality. Phytoplankton is representing the microscopic algal communities of open water as a major element at primary level in aquatic biota. Phytoplankton is the pioneer of an aquatic food chain. The productivity of an aquatic environment is directly correlated with the density of phytoplankton. The phytoplankton population in any aquatic system is biological wealth of water for fishes and constitutes a vital link in the food chain. They form a bulk of food for zooplankton, fishes and other aquatic organisms. The maintenance of a healthy aquatic ecosystem depends on the abiotic properties of water and the biological diversity of the ecosystem (Harikrishnan *et al.*, 1999). The phytoplankton and zooplankton are always inversely proportional in an aquatic environment because the zooplankton feed on the phytoplankton. The planktonic study is very useful tool for the assessment of water quality and also contributes to understanding of the basic nature and general economy of the lake (Pawar *et al.*, 2006).

In the present study from April 2010 to March 2013, first year phytoplankton in Gulshan lake were twenty two species recorded of which six species belonged to Cyanophyceae, nine species were Chlorophyceae and seven species were Bacillariophyceae. In Dhanmondi lake recorded twenty one species recorded of which six species belonged to Cyanophyceae, nine species were Chlorophyceae and six species were Bacillariophyceae. Cyanophyceae, Chlorophyceae and Bacillariophyceae groups discrete data shows highly significant differences among Gulshan lake and Dhanmondi lake [Table 9-11].

During three sampling years phytoplankton abundance In Gulshan lake total phytoplankton showed peak in pre monsoon. Dhanmondi lake also in pre monsoon. Cyanophyceae, Chlorophyceae, Bacillariophyceae and total phytoplankton species abundance in comparison to Gulshan lake and Dhanmondi lake showed highly significant differences in all three years [Table 9-11]. Phytoplankton abundance of Gulshan lake showed negative correlation with hardness ($r=-0.807$, $p<0.01$) and positive correlation with Zooplankton ($r=0.842$, $p<0.01$) and Benthos ($r=0.792$, $p<0.05$). [Table 18]. In Dhanmondi lake Phytoplankton abundance also showed positive correlation with Zooplankton ($r=0.281$, $p<0.01$) and Benthos ($r=0.895$, $p<0.05$). [Table 19]. Total Phytoplankton among Gulshan and Dhanmondi lakes in all three years separately shows statistically highly significant differences. [Table 9-11].

Madkour *et. al.* (2007) reported the phytoplankton community was represented by a total of 151 species, including 76 diatom species, 61 dinoflagellates and a few representatives of different freshwater groups. Eighteen species appeared as dominant but most of them dominated once a year and the rest dominated intermittently 2-3 times except the dinoflagellate *Alexandrium minutum* which dominated five times over the year. As compared to the earlier records the present study reported serious changes in both the water fertility and the dynamics of the phytoplankton community in the Eastern Harbor.

Kumar and Oommen (2011) was carried out a limnological investigation in tropical community wetland, Kanewal, Gujarat, India from June 2007 to May 2008. Water quality parameters and phytoplankton composition were investigated during the study period. Correlation coefficients were calculated among the various physicochemical variables and phytoplankton groups. Pearson Product Analysis for phytoplankton at the two sites was performed and it showed a high significance of Bacillariophyceae members between both the sites than other two groups. A total of 45 species were identified belonging to Cyanophyceae, Chlorophyceae and Bacillariophyceae but members of Euglenophyceae were found to be absent indicating a lesser degree of organic pollution. Moreover, species of Bacillariophyceae were recorded to be the most occurred group compared to others throughout the study which shows relatively unpolluted nature of wetland.

Zooplankton:

In the present research from April 2010 to March 2013 in Gulshan lake sixty one species were recorded of which fifteen belonged to Protozoans, seven Copepods and five to Cladocerans and thirty four to rotifers. In Dhanmondi lake recorded fifty eight species of zooplankton of which fifteen were Protozoans, nine were Copepods, seven were Cladocerans and twenty seven were rotifers. Kabir and Naser (2008) identified a total of 59 taxa of which 13 species were Protozoans, 34 Rotifers, eight Copepods, three in Cladocerans, and one species belonged to Ostracods in Chandbill baor of Meherpur district, Bangladesh. Hasan *et al*. (2001) recorded 19 species of Rotifers from Dhanmondi lake of Dhaka, Bangladesh. Das and Bhuiyan (1974) recorded 55 species of planktonic organisms including 25 Rotifers, 14 Cladocerans, 10 Copepods, and 8 Ostracods from two ponds and two lakes of Dhaka city. Pliuraitae (2003) recorded 41 species of Zooplankton of which 11 taxa of Copepoda, 14 taxa of Cladocera and 16 taxa of Rotaria from Curonian Lagoon. Harding and Rayner (2001) also recorded 10 Rotifer species, 16 species of Cladocera, six Calanoid and six Cyclopoid species, three Ostracod species and a few insect larva from the lake Kariba.

The zooplankton population varied both qualitatively and quantitatively with months. The zooplankton are directly and indirectly subjected to the complex of influence which change with seasons and some effect might be made some of which result in the qualitative changes i.e. increase or decrease of size of population. Such variations in population may be due to variation in nutrient and other favorable conditions of water during plankton production. The present study showed that the abundance of zooplankton fluctuated distinctly in different months. During entire sampling period Zooplankton abundance from all the five showed one peak in the month of May 2011. Hossain *et al.* (1998) observed two peaks in zooplankton abundance from Bashukhali-Salimpur-Kola barnal (BSKB) *beel* in Bangladesh one in May and another in September. Patra and Azadi (1987) found only one peak which occurred in August from Halda river. Habib and Mohsinuzzaman (1986) stated that the abundance of zooplankton was the highest in

November. Ehsan *et al.* (1997) also showed two peaks of zooplankton in Chanda beel, first peak in October and second peak in January. The numerical variations in peak periods of zooplankton might be due to different physico-chemical and biological parameters and availability of nutrients in the water body. Total zooplankton abundance between two lakes showed significantly differences in three years [Table 12-14].

Zooplankton abundance of Gulshan lake was found about six times higher than Dhanmondi lake. This may be due to the result of drying and dredging effects in Dhanmondi lake. Lypsy and Malcom (1981) also found more species and higher zooplankton densities from older borrow-pit ponds than the newer ponds. Ohimain *et al.* (2005) assessed the impact of dredging on zooplankton community in a tropical mangrove ecosystem and found reduction in the population (by 91%) and taxa (72%).

In the present investigation four groups of zooplankton were recorded from Gulshan lake namely, Protozoa, Rotifera, Copepoda and Cladocera and four groups from Dhanmondi lake namely, Protozoa, Rotifera, Copepoda and Cladocera. Kiran *et al*. (2007) recorded five group of zooplankton consisted of Protozoans, Rotifers, Copepods, Cladocerans and Ostracods from a fish pond of Bhadra fish farm, Karnataka, India. Ali *et al*. (1989) recorded six zooplankton groups namely Protozoa, Rotifera, Copepoda, Cladocera, Ostracoda and Nauplii from pond ecosystem. During entire sampling period seasonally in Gulshan lake highest zooplankton abundance observed in pre monsoon (9295±815) ind/L [Table A-36] and the lowest in monsoon (5031±340) ind/L [Table A-34] and in Dhanmondi lake highest in pre monsoon (1343±164) ind/L [Table A-39] and the lowest in monsoon (838±75) ind/L. Das and Bhuiyan (1974) found the maximum production in summer months and minimum in August and January to February in some inland water of Dhaka city. Watson and Carpenter (1974) showed peaks of zooplankton in spring or summer months from the lake Hurun, Erie and Ontario, Canada. Kiran *et al.* (2007) found the highest peak of zooplankton during summer season and lower during rainy season.

During entire sampling period fifteen species of Protozoans were recorded from Gulshan lake and Dhanmondi lake respectively. Sampaio and Lopez (1985) observed five protozoan species from Massacara. Chowdhury *et al*. (1998) also recorded sixteen species of Protozoans. Lamai and Kolo (2003) recorded twenty six species of Protozoans from Dan-Zaria Dam. Ali *et al* (1989) also recorded similar result from a perennial pond of Dhaka city. Rahman *et al.* (2006) recorded protozoa as the 4th dominant group among zooplankton from Hamil beel, Bangladesh. Ali *et al. (*2005) reported Protozoa was present in all the months among zooplankton. Seasonally, the highest Protozoan abundance was found in monsoon months from both the lakes. Hossain and Hossain (2001) observed the highest value of protozoa in monsoon and the lowest in winter. Kiran *et al.* (2007) also found the highest peak of Protozoans during monsoon and the lowest in winter. But Chowdhury *et al*. (1989) recorded the dominancy of protozoa in winter months from a pond at Dhaka. Protozoa groups among Gulshan and Dhanmondi lakes in all three years separately shows statistically highly significant differences. [Table 12-14].

During entire sampling period seven and nine species of Copepods were recorded from Gulshan lake and Dhanmondi lake respectively. Pliuraitae (2003) recorded 11 genera of Copepods from Curonian Lagoon. Islam (2007) recorded 4 genera of Copepods from a pond of Rajshahi University campus, Bangladesh. Islam and Bhuiyan (2007) also identified 4 genera of Copepods in a pond of Rajshahi city, Bangladesh. Copepoda was the second dominant group among zooplankton abundance from Gulshan lake and Dhanmondi lake respectivel. Chowdhury and Raknuzzaman (2005) recorded the highest copepods abundance in May and the lowest in February from the river Buriganga, Bangladesh. Islam (2007) also found peak abundance of Copepoda in April and the minimum in September from a pond of Rajshahi University, Bangladesh. Fatema et al. (2005) showed the highest peak in January and the lowest in July. Kiran et al. (2007) observed the highest peak of copepods during rainy season and the lowest in summer season in fish pond of Bhadra fish farm, Karnataka, India. Chowdhury and Raknuzzaman (2005) also recorded seasonal variations of copepods, of which the highest abundance was found in summer and lowest in winter. Ahmed et al. (2003) registered the higher percent of copepods in summer months from the Meghna river, Bangladesh. Patra and Azadi (1987) also reported the highest copepod abundance in summer and lowest in winter from Halda river, Bangladesh. Ehsan et al. (1997) also observed summer peak of copepod abundance from Chanda beel, Bangladesh. Copepoda groups among Gulshan and Dhanmondi lakes in all three years separately shows statistically highly significant differences. [Table 12-14].

From the present study six and seven species of Cladocerans were identified from Gulshan lake and Dhanmondi lake respectively. Chowdhury and Raknuzzaman (2005) recorded six genera from Buriganga river. But Khan *et al*. (1978) recorded 12 genera of Cladocerans from Sadarghat area of Buriganga river whereas Ali *et al*.(1989) recorded three genera of Cladocerans from a pond of Dhaka city. Cladocera was the fourth dominant group among zooplankton which constituted of the total zooplankton abundance in Gulshan lake and Dhanmondi lake, respectively. Begum and Alam (1987) found Cladocerans as third and fourth in position according to their percentage composition in pond I and pond II respectively in Maijdee court, Noakhali. This findings of the present study was also supported by Mollah and Haque (1978) and Ameen *et al.* (1986) from fish pond, Bangladesh. Cladocera groups between Gulshan lake and Dhanmondi lake in three years data separately shows statistically highly significant differences. [Table 12-14].

During three years sampling total of thirty four and twenty seven species Rotifers were recorded from the Gulshan lake and Dhanmondi lake respectively. Among Zooplankton the most dominant group was rotifer which comprised in Gulshan lake and Dhanmondi lake respectively. Rahman *et al.* (2006) obtained almost similar observations from Hamil beel Bangladesh. Ehsan *et al*.(1997) and Patra and Azadi (1987) also found similar observations. Hossain *et al*. (1998) also found Rotifer to be the dominant group followed by Copepoda, Naupleus and Cladocera. Ahmed *et al.* (1992) also recorded Rotifer to be the dominant followed by Copepoda and Cladocera in Kaptai lake. Whereas Kaliyamurthy (1974) stated that in Pulicate lake, Copepoda was the most important group among the zooplankton populations. Fatema *et al*. (2005) observed that Rotifera was the top position among zooplankton. Begum *et al. (*1992) observed the highest Rotifer abundance in April from a fish pond. Chowdhury and Raknuzzaman (2005) also observed the highest abundance in May and the lowest in September from the river Buriganga. Seasonally the highest abundance of Rotifers was found from summer months from both lakes during the present study. Chowdhury and Raknuzzaman (2005) also found similar observations from Buriganga river Dhaka. Ahmed *et al*. (2003) found Rotifers was much abundant during winter months than summer. Kiran *et. al*. (2007) found density of Rotifers was maximum during summer season and minimum in rainy season. Rotifers groups among Gulshan and Dhanmondi lakes in all three years separately show statistically highly significant differences. [Table 12-14].

The abundance of the zooplankton was affected with the interaction of physico-chemical variables of the lake water. In the Gulshan lake during entire sampling period total zooplankton was inversely correlated with free carbon dioxide of water ($r=-0.550$, $p<0.01$) and water pH ($r=-0.366$, $p<0.01$) and ammonia-nitrogen ($r=-0.267$, $p<0.05$). [Table 18]. In the Dhanmondi lake also showed inverse correlation with free carbon dioxide of water ($r=-0.436$, $p<0.05$) and water pH ($r=-0.048$, $p<0.01$). Positive correlation shoed with Chemical oxygen Demand (COD) ($r=0.308$, $p<0.05$) [Table 19].

Kabir and Naser (2009) showed same results in two baors of Meherpur districts, Bangladesh. Islam (2007) found that zooplankton showed inverse relations with water temperature and pH and positive correlation with dissolved oxygen of water and alkalinity in a fish pond of Rajshahi city. Alam and Kabir (2003) found inverse relationship between zooplankton and alkalinity and positive correlation with pH in Sundarban ecosystem. Chowdhury and Mamun (2006) found that total zooplankton showed positive correlation with transparency and dissolved oxygen of water (DO) and significant negative correlation with total alkalinity of water in two fish ponds of Khulna.

Zooplankton abundance of Gulshan lake showed positive correlation with phytoplankton ($r=0.925$, $p<0.01$) and benthos ($r=0.805$, $p<0.01$). [Table 18]. In Dhanmondi lake zooplankton abundance also showed positive correlation with phytoplankton ($r=0.281$, $p<0.01$) and Benthos ($r=0.473$, $p<0.01$). [Table 19]. Total zooplankton species abundance among the Gulshan and Dhanmondi lakes during three years shows statistically highly significant differences. [Table 12-14].

Benthos:

A total of eighteen species of benthic organisms from Gulshan lake and twelve taxa from Dhanmondi lake were identified which belonged to Chironomids, Oligochaetes and Molluscs during the study period from April 2010 to March 2013. Kabir and Naser (2009) reported a total of 20 species (10 families) and 15 species (nine families) of benthic organisms was recorded from non-dredged oxbow lake Chandbill baor and dredged oxbow lake Harda baor respectively of Meherpur district Bangladesh. Khan *et al*. (2007b) identified 20 species of benthos under 16 families which belonged to Oligochaetes, Polychaetes, Insets, Bivalves and Gastropods from Mouri river, Khulna, Bangladesh. Chironomid larvae, Oligochaetes and Molluscs were the chief benthos in Gulshan lake and Dhanmondi lake respectively of which five species belonged to Chironomids, ten species to Oligochaetes and three species of Molluscs. The dominance of these groups of macro-benthos has been reported earlier by Das and Islam (1983), Karim and Ahmed (2006) from tropical freshwater ponds, Kumar and Mitra (1986) from oxbow lake and Rahman and Das (2001) from Rajdhala and Padmai beel of Netrokona district, Bangladesh. The probable cause of the occurrence of this dominant group of bottom fauna may be due to the favorable condition for their growth. Bottom type and amount of bottom deposit exert a significant influence upon the occurrence of bottom organisms. Monthly fluctuations of benthic abundance were found during the present study from both lakes. Similar observations were made from freshwater lake in Mymenshingh by Dewan (1973).

Seasonally the highest average Benthos abundance (1824±444) ind/m^2 was observed in pre monsoon [Table A-44] and the average lowest (1069±78) ind/m^2 in monsoon from Gulshan lake whereas in Dhanmondi lake the highest average abundance (1542±425) ind/m^2 was found in pre monsoon [Table A-48] and the lowest (915±84) ind/m^2 in post monsoon. Rahman and Das (2001) also found the highest number of benthos in winter from Rajdhalla beel, Netrokona district, Bangladesh. Habib *et al*. (1984a) found the highest density of benthos in summer and the lowest in winter from pond ecosystem. Mandal and Moitra (1975) also found the highest density in summer in fish pond at Burdwan, West Bengal, India. Joshi *et al*. (2007) also found the maximum density of benthic fauna during winter months and the decline in the density of benthic fauna during monsoon from fresh water stream, India. The maximum density during winter may be related to the availability of phytoplankton population in the form of food supply as also observed by Joshi *et al*. (1996) on Ganga river, India. The low density during monsoon may be due to increased water depth. Perhaps the greater number of benthic fauna in winter might be due to the less predation by bottom dwelling fish at low temperature or might be due to the complex community interaction. The frequency of availability of macro benthos varied in different points, months and seasons. These differences may have been due to the differences of bottom habitat and various physico-chemical as well as other environmental conditions. The differences may be also due to the difference of the volume of mud collected by the dredge. The abundance of total benthos of the Gulshan lake was found higher than the Dhanmondi lake.

In Bangladesh no attempts have been made to classify the water body on the basis of the availability of bBenthic organisms (Rahman and Das 2001). Khan *et al.* (1996) made a study on Kaptai lake and indicated the tropic status of Kaptai lake. They recorded the density 1965 (±1621) nos/m^2 from Rangamati area and 1758 (±1203) nos/m^2 from Kaptai town sampling area. In total 54 taxa of macro benthic invertebrate from Kaptai lake was reported at the same time. This indicating the lake status as oligotrophic to mesotrophic condition. In the present study an average of 1335±336 ind/m^2 and 1188±312 ind/m^2 benthos were recorded from the Gulshan lake and Dhanmondi lake respectively. This indicated that Gulshan lake status was high productive than the Dhanmondi lake.

Highest value of Chironomids group was observed in pre monsoon and the lowest in post monsoon from Gulshan lake [Table A42-44] whereas in Dhanmondi lake the highest value was found in monsoon and the lowest in pre monsoon [Table A46-48]. Ali *et al*. (1978a) also found the highest peak in summer and the lowest in winter. Aziz *et al*. (1982) also recorded the highest peak abundance of Chironomids in summer from derelict pond of Mymensingh. The high density of Chironomids in summer was also reported by Mandal and Moitra (1975) and Dewan (1973). Cowell and Vodopich (1981) observed in a sub tropical Florida lake that the population of *Chironomus* larvae declined in the summer and this was apparently related to low dissolved oxygen (DO). The abundance of Chironomids were 10 (ten) times more abundant in Gulshan lake than Dhanmondi lake. Chironomid larvae dominated the macro benthic fauna in Gulshan lake while in Dhanmondi lake Molluscs are dominant group among the total benthic fauna. Ismail *et al*. (1984) found the highest Chironomids abundance in July and the lowest in January from a pond of Jurain, Dhaka. Ali *et al*. (1978a) found the highest abundance in August and September and the lowest peak in December and January from a fish pond of Dhaka city. Rahman and Das (2001) also observed the highest number in December and the lowest in July from Rajdhalla beel of Netrokona district, Bangladesh. Mandal and Moitra (1975) found the peak in February and May in pond ecosystem. Chironomids abundance between Gulshan and Dhanmondi lakes during three years shows statistically highly significant differences. [Table 15-17].

Oligochaetes was the first dominant group in the Gulshan lake and second dominant group in the Dhanmondi lake. Mean value in the Gulshan lake was of (674±390 ind/m^2) [Table a-41] while in the Dhanmondi lake it varied (344±175 ind/m^2) [Table A-45]. Seasonally the highest value was observed in pre monsoon and the lowest in monsoon from the Gulshan lake whereas in the Dhanmondi lake also highest abundance was found in pre monsoon and the lowest in monsoon. Ismail *et al*. (1984) observed the peak abundance of Oligochaetes in April and the lowest in January from pond of Jurain, Dhaka. Ahmed *et al*. (1999b) also observed the peak in April and minimum in July from fresh water pond. Das *et al*. (1981) also found the highest peak in July and the lowest in

December. During the entire sampling period oligocheates abundance among the Gulshan lake and Dhanmondi lake show highly significant differences [Table 15-17].

Molluscs comprised of three species in the Gulshan lake and four species in the Dhanmondi lake and it was the third dominant groups in the Gulshan lake and highest group in the Dhanmondi lake. Very few species were found from the Gulshan lake. Rahman and Das (2001) also recorded the Molluscs as third dominant group in Rajdhala and Padmai beel But Karim and Ahmed (2006) observed the second dominant group as Molluscs in three ponds at BCDM, Rajendrapur, Gazipur, Bangladesh. In the Gulshan lake it ranged from 1 to 7 ind/m^2 and in the Dhanmondi lake it ranged from 30 to 1295 ind/m^2. Karim and Ahmed (2006) also found similar observation from carp culture ponds. Das and Islam (1983) observed the peak of Molluscs in July and October from artificial pond of Bangladesh Agricultural University Campus, Mymenshingh. Seasonally, the highest value was observed in pre monsoon and the lowest in post monsoon from the Gulshan lake [Table A42-44] whereas in the Dhanmondi lake the highest value was also found in pre monsoon and the lowest in post monsoon [Table A46-48]. Rahman and Das (2001) found that the maximum number of Molluscs in July from beel waters. Ali *et al.* (1978a) recorded the abundance of Molluscs in the month of August and October. Molluscs abundance between the Gulshan and Dhanmondi lakes in all three years shows statistically highly significant differences. [Table 15-17].

The correlation co-efficient between physico-chemical variables and total benthos are shown in Table 18 and 19. During the entire sampling period in the Gulshan lake total benthos exhibited positive correlations with dissolved oxygen ($r=0.403$, $p<0.01$), free carbon dioxide ($r=0.228$, $p<0.01$) and alkalinity ($r=0.513$, $p<0.05$). [Table 18]. Negative correlation shows with hardness ($r=-0.670$, $p<0.05$). In the Dhanmondi lake benthos showed inverse relations with air temperate ($r=-0.458$, $p<0.01$), water temperature ($r=-0.442$, $p<0.01$) and positive correlations with pH ($r=0.354$, $p<0.01$) and COD ($r = 0.308$, $p<0.05$) of water [Table 22]. In the Gulshan lake benthos showed positive correlation with phytoplankton ($r=0.925$, $p<0.01$) and zooplankton ($r=0.792$, $p<0.05$).

[Table 18]. In the Dhanmondi lake benthos showed positive correlation with phytoplankton ($r=0.281$, $p<0.01$) and zooplankton ($r=0.895$, $p<0.01$). [Table 19]. Total benthos species abundance among the Gulshan and Dhanmondi lakes during three years shows statistically highly significant differences. [Table 15-17]. Kabir and Naser (2009) showed same results in the two baors of Meherpur districts Bangladesh. Karim and Ahmed (2006) also found the positive relations between total benthos and dissolved oxygen of water. Joshi *et al*. (2007) found inverse correlation with air and water temperature in fresh water stream, India.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

Water pollution is a universal problem, determination of pollution and water quality of the Gulshan and Dhanmondi lake facilitate to indicate the current status of water pollution and restoration attempts that has been taking place on lake water. Due to various anthropogenic activities and poor sanitation lakes are highly susceptible for contamination as a result the community depend on unsafe, poor water consumption and the water ecology is severely affected.

Water quality in the Gulshan lake such as Ammonia-nitrogen, Alkalinity, Hardness, Conductivity and Total dissolved solids (TDS), Biological oxygen demand (BOD) and Chemical oxygen demand (COD) were in higher concentrations than the Dhanmondi lake. Dissolved Oxygen (DO) showed lower values in the Gulshan lake than the Dhanmondi lake. Heavy metals in water (Zinc, Chromium, Cadmium, Lead, Copper, Nickel and Manganese) were in higher concentrations in the Gulshan lake than the Dhanmondi lake. Sediments of the Gulshan lake contains higher heavy metals (Zinc, Chromium, Cadmium, Lead, Copper, Nickel, Manganese and Iron) than the Dhanmondi lake in all seasons. Plankton population was higher in the Gulshan lake than the Dhanmondi lake. This indicates that excess nutrient is coming in the lake and the plankton produced inside the lake water was not consumed ecologically. Sewage led water adding more nutrients to the lake, producing more plankton and thus causing pollution and eutrophication.

The absence of filter feeder fishes in the lake resulted in excess plankton population in the Gulshan lakes. The situation is opposite in the Dhanmondi lake. Average benthic organisms were higher in the Gulshan lake. Snails, bivalves etc were higher in the Dhanmondi lake. Preliminary trial in the Gulshan lake by introducing filter feeding benthic organism showed improvement of the water quality.

The results of present study concluded that the concentration of selected heavy metals, Zinc, Lead, Cadmium, Chromium, Nickel and Manganese were found in sediment of lakes clearly indicated that the heavy traffic and transportation is the major responsible source of these heavy metals along with other sources. There is need to develop and implement the proper legislation for the monitoring and maintaining of automobile vehicles and transportation of waste material.

Heavy metals are toxic and carcinogenic and have shown to cause serious health effects on humans and the flora and fauna. As a consequence various treatment methods have been developed for the treatment of metal contaminated waste streams and some processes can also recover the metals. Among the commonly used physico-chemical and biological technologies for heavy metal removal and recovery cost effectiveness, technical feasibility, plant simplicity and longevity of the process are the factors that govern the selection of an appropriate technology neglecting environmental issues in the past has resulted in the present situation in the Gulshan lake contain soils that have been contaminated by undesirable levels of metals and chemical compounds. When dredging in these soils contaminants may be released into the water column and thence into the food chain.

During study it was observed that wastewater outfalls connecting to the Gulshan lake were storm sewer pipes, open drains and private outfalls. Some drainage connections were made from domestic and commercial establishment into the lake. These drainages are mostly made of concrete. Many household drains and small industrial outfalls were open. Roadside drains are the most common open channel outfalls in those areas. Common examples of private outfalls are roof drains, parking lot drainage, direct discharge of domestic wastewater, outlet from small shops etc. Miscellaneous wastes were dumped very near the lake bank and ultimately washed into the lake. Some outlets from some nurseries were also observed which discharges water mix with agro-chemicals and dust into the lake. Some hanging toilets were also present on the bank of the lake and discharges human excreta directly into the lake. In the Dhanmondi lake all the outlets were sealed. No open drainage around the lake.

The water quality of Gulshan and Dhanmondi lakes were deteriorated as the growth of the town due to investment activities and other factors. The Dhaka City Corporation should set up appropriate monitoring and controlling mechanism by which the nearby waste discharging mechanism should be evaluated and regulated. The increasing values of parameters of certain contaminants in Gulshan lake indicates that the lake water not safe for aquaculture. The full scale risk assessment on the use of unsafe water supply and water quality monitoring has to be carried out including rural areas. The study was conducted with in period of four months. It may lack comprehensiveness.

Further research recommended to find the concentrations of the heavy metals in fish and different fish organs such as gills, skin and intestines. Also, research to find out the levels of heavy metals in sediments at different depths. Research on other heavy metals not covered in this study to find out their concentration levels in sediments, water, macro-benthos and different fish species of the two lakes. Finally it is recommended that a social study be carried to find out the level of public awareness on the dangers of aquatic pollution to the users of lakes especially water and fish. In order to undertake strong and continuous monitoring, the Dhaka North City Corporation should be employed with well-equipped. Laboratory facilities and personnel for around the year monitoring this surface water resource of the country.

Renovation of the Gulshan lake necessary to remove the soil from the lake beds and make little deeper. Construct the lake boundary can protect the garbage washed pollution into the lakes. Build proper drainage facilities to maintain appropriate water levels in different seasons for aquaculture. Point and non-point sources on the lake should be sealed or managed in such a way to reduce their adverse impact on water quality.

Sufficient walkways, pathways and drive ways along the lake sides should be constructed. Build sufficient green belts, park areas etc. along the lake sides. Make alternative arrangement by constructing waste disposal sites where all sewage and other environment polluting waste should be discharge. Public access should be regulated and appropriate uses of the lakes maintained.

Recreational use of lakes such as use of watercraft, swimming, and fishing should be introduced. A coordination committee, comprising of personnel from the ministry of Public Works, Rajdhani Unnon Kartipkha, WASA, Dhaka North City Corporation, Dhaka Metropolitan Police, Department of Environment, Department of Fisheries, Universities and Bangladesh Fisheries Research Institute, Dhanmondi and Gulshan Society, media personality and environment activists be act up to monitor the lake frequently. Further detailed research work should be carried out in the lakes.

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Table 18. Correlation coefficients between Physico-chemical parameters, Phytoplankton, Zooplankton and Benthos of Gulshan lake

Parameters	WD	AT	WT	Trns	DO	pH	Amn	CO_2	Alk	Hard	Cond	TDS	BOD	COD	Phyto	Zoo	Benthos
Water depth (m)	1.000																
Air temp. (^{0}C)	.123	1.000															
Water temp. (^{0}C)	.139	.971**	1.000														
Transparency (cm)	.483**	-.046	-.086	1.000													
DO (mg/L)	.008	.500**	.482**	.011	1.000												
pH	.152	.254**	.257**	-.116	.002	1.000											
Ammonia-Nitrogen (mg/L)	-.483**	-.260**	-.273**	-.129	-.089	-.113	1.000										
Free CO_2 (mg/L)	-.172*	.175*	.239**	-.375**	.176*	.229**	.132	1.000									
Alkalinity (mg/L)	-.411**	-.407**	-.411**	-.180*	-.174*	-.018	.549**	-.030	1.000								
Hardness (mg/L)	-.274**	.003	-.024	-.307**	-.344**	.162	.308**	.108	.355**	1.000							
Conductivity (µS/cm)	-.350**	-.099	-.095	-.363**	-.205*	.107	.526**	.107	.462**	.471**	1.000	.					
TDS (mg/L)	-.643**	-.280**	-.274**	-.449**	-.257**	-.098	.616**	.194*	.472**	.465**	.713**	1.000					
BOD (mg/L)	-.607**	-.239**	-.228**	-.460**	-.122	-.070	.586**	.205*	.360**	.371**	.613**	.800**	1.000				
COD (mg/L)	-.664**	-.215**	-.224**	-.419**	-.144	-.051	.643**	.212*	.439**	.402**	.634**	.859**	.766**	1.000			
Phyto (ind/L)	.149	.165	.110	.656	.635	-.221	-.257	-.108	.036	-,807**	-.576	-.505	-.552	-.521	1.000	,842**	,792*
Zoo (ind/L)	.051	.056	-.021	.554	.386	-.366**	-.267*	-.550**	.271	-.791	-.503	-.394	-.429	-.451	.925**	1.000	.805**
Benthos (ind/m^2)	-.442	.145	.052	.348	.403**	-.195	.167	.228**	.513*	-.670*	-.223	-.058	-.091	-.102	.692*	.803**	1.000

*** Correlation is significant at the 0.05 level and ** Correlation is significant at the 0.01 level**

Table 19. Correlation coefficients between Physico-chemical parameters, Phytoplankton, Zooplankton and Benthos of Dhanmondi lake

Parameters	WD	AT	WT	Trns	DO	pH	Amn	CO_2	Alk	Hard	Cond	TDS	BOD	COD	Phyto	Zoo	Benthos
Water depth (m)	1.000																
Air temp. (^{0}C)	.238**	1.000															
Water temp. (^{0}C)	.246**	.994**	1.000														
Transparency (cm)	.493**	.093	.104	1.000													
DO (mg/L)	.279**	.320**	.316**	.154	1.000												
pH	-.489**	-.342**	-.337**	-.303**	-.315**	1.000											
Ammonia-Nitrogen (mg/L)	-.309**	-.308**	-.340**	-.363**	-.243**	.372**	1.000										
Free CO_2 (mg/L)	-.069	.057	.026	-.087	.014	-.013	.077	1.000									
Alkalinity (mg/L)	-.298**	-.469**	-.460**	-.059	-.224**	.303**	.318**	.135	1.000								
Hardness (mg/L)	-.281**	-.061	-.063	-.055	-.174*	.351**	.272**	.018	.328**	1.000							
Conductivity (µS/cm)	-.314**	.126	.155	-.205*	-.217**	.261**	.280**	.054	.220**	.206*	1.000	.					
TDS (mg/L)	-.391**	.294**	.310**	-.170*	-.139	.182*	.036	-.045	.108	.157	682**	1.000					
BOD (mg/L)	-.209*	.008	-.005	-.165*	-.052	.108	.326**	.003	.185*	.210*	.143	.033	1.000				
COD (mg/L)	-.498**	-.269**	-.274**	-.492**	-.340**	.503**	.572**	.109	.231**	.166*	.410**	.237**	.232**	1.000			
Phyto (ind/L)	.124	-.457	-.444	.041	-.466	.200	-.026	-.194	-.002	-.137	-.417	-.141	-.311	.161	1.000	.281**	.895**
Zoo (ind/L)	.338	.010	.095	.221	-.157	-.048**	-.524	-.436*	-.177	-.078	-.155	-.124	.020	-.008	.281**	1.000	.473**
Benthos (ind/m^2)	.084	-.458**	-.442**	-.003	-.548	.354**	-.015	-.065	.103	-,025	-.401	-,204	-.152	.308*	.895**	.473	1.000

*** Correlation is significant at the 0.05 level and ** Correlation is significant at the 0.01 level**

Table 2. Year-wise variations of water quality parameters in Gulshan Lake

Parameters	2010-11	2011-12	2012-13	Average	P-value	Sig. level
Water depth (m)	3.4±0.5	3.7±0.3	3.8±0.3	3.6±0.2	0.207	NS
Air temp. (^{0}C)	29.1±1.3^a	27.6±3.8^b	27.3±3.6^b	28.0±1.0	0.007	**
Water temp. (^{0}C)	28.3±1.2^a	27.3±3.3^b	27.3±3.5^b	27.6±0.5	0.011	*
Transparency (cm)	35.4±1.7^a	33.2±3.5^b	33.7±2.8^b	34.1±1.2	0.005	**
Dissolved Oxygen (mg/L)	5.3±0.5	4.5±0.6	5.1±0.5	5.0±0.4	0.128	NS
pH	7.5±0.2	7.6±0.1	7.6±1.1	7.6±0.0	0.300	NS
Ammonia-nitrogen (mg/L)	10.9±2.2^b	11.1±2.3^b	12.1±1.9^a	11.4±0.6	0.004	**
Free CO_2 (mg/L)	20.5±3.7	20.1±1.8	17.2±0.7	19.3±1.8	0.056	NS
Alkalinity (mg/L)	158.4±18.6	168.5±23.1	193.7±6.9	173.5±18.2	0.052	NS
Hardness (mg/L)	98.2±4.3	104.7±3.4	107.4±3.8	103.5±4.7	0.054	NS
Conductivity (µS/cm)	450.5±64.4^b	498.5±79.6^a	509.1±84.6^a	486.1±31.2	0.018	*
TDS (mg/L)	232.0±35.8^c	237.3±38.4^b	244.8±41.6^a	238.0±6.5	0.000	***
BOD (mg/L)	7.5±0.9^c	7.8±1.0^a	7.6±1.1^b	7.6±0.2	0.000	***
COD (mg/L)	48.1±9.8^b	48.0±12.9^b	50.4±12.4^a	48.8±1.4	0.012	*

NS: Not significant; *Significant level: P<0.05; **Significant level: P<0.01 and ***Significant level: P<0.001

Table 3. Year-wise variations of water quality parameters in Dhanmondi Lake

Parameters	2010-11	2011-12	2012-13	Average	P-value	Sig. level
Water depth (m)	4.0±0.2	4.1±0.5	4.2±0.6	4.1±0.1	0.207	NS
Air temp. (^{0}C)	29.4±1.5	27.5±3.7	27.4±3.6	28.1±1.1	0.524	NS
Water temp. (^{0}C)	28.5±1.5	27.3±3.5	27.3±3.6	27.7±0.7	0.625	NS
Transparency (cm)	75.5±1.5^b	77.7±3.5^b	82.3±1.1^a	78.5±3.5	0.026	*
Dissolved Oxygen (mg/L)	6.7±0.6	6.5±0.4	6.4±0.1	6.5±0.2	0.126	NS
pH	7.6±0.1	7.5±0.1	7.6±0.1	7.6±0.0	0.549	NS
Ammonia-nitrogen (mg/L)	1.2±0.5^b	0.8±0.2^b	0.7±0.2^a	0.9±0.3	0.007	**
Free CO_2 (mg/L)	19.5±3.2	20.9±1.1	19.9±0.6	20.1±0.7	0.149	NS
Alkalinity (mg/L)	98.2±2.9^b	104.8±6.6^{ab}	106.6±2.8^a	103.2±4.4	0.050	*
Hardness (mg/L)	99.4±6.0	94.1±6.2	98.0±1.5	97.2±2.7	0.079	NS
Conductivity (μS/cm)	325.7±87.0	351.0±52.9	354.6±45.8	343.8±15.8	0.570	NS
TDS (mg/L)	164.7±25.3	165.1±23.5	179.4±14.0	169.8±8.3	0.874	NS
BOD (mg/L)	2.9±0.3	2.8±0.2	3.0±0.3	2.9±0.1	0.727	NS
COD (mg/L)	24.3±4.6	23.5±4.0	25.6±0.5	32.7±15.3	0.734	NS

NS: Not significant; *Significant level: P<0.05; **Significant level: P<0.01 and ***Significant level: P<0.001

Table 4. Season-wise variations of water quality parameters in Gulshan Lake

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average	P-value	Sig. level
Water depth (m)	3.39 ± 0.2^{b}	3.97 ± 0.07^{a}	3.67 ± 0.13^{ab}	3.66±0.11	0.042	*
Air temp. (^{0}C)	28.5 ± 0.24^{a}	30.6 ± 0.07^{a}	24.9 ± 1.6^{b}	28.0±1.0	0.011	*
Water temp. (^{0}C)	28.1 ± 1.2^{a}	30.0 ± 0.2^{a}	24.8 ± 1.3^{b}	27.6±0.8	0.007	**
Transparency (cm)	35.4 ± 1.7^{a}	33.2 ± 3.5^{b}	33.7 ± 2.8^{ab}	34.1±1.2	0.036	*
Dissolved Oxygen (mg/L)	4.87±0.1	5.53±0.3	4.6±0.4	5.0±0.2	0.120	NS
pH	7.6±0.0	7.6±0.1	7.5±0.1	7.6±0.04	0.512	NS
Ammonia-nitrogen (mg/L)	13.7 ± 0.33^{a}	8.5 ± 0.73^{b}	9.4 ± 0.45^{b}	10.52±0.84	0.001	**
Free CO_2 (mg/L)	20.5±1.3	20.3±1.8	17.0±0.5	19.3±0.9	0.180	NS
Alkalinity (mg/L)	187.3±7.5	153.5±17.3	187.7±28.3	173.1±8.0	0.218	NS
Hardness (mg/L)	109.8±3.7	99.5±2.6	104.0±3.6	104.5±2.2	0.179	NS
Conductivity (µS/cm)	563.2 ± 19.7^{a}	432.3 ± 13.7^{b}	471.4 ± 29.2^{ab}	489.0±22.3	0.014	*
TDS (mg/L)	273.9 ± 2.9^{a}	179.6 ± 0.9^{c}	231.8 ± 3.0^{b}	234.2±11.0	0.000	***
BOD (mg/L)	8.6 ± 0.2^{a}	6.7 ± 0.1^{c}	7.6 ± 0.1^{b}	7.6±0.3	0.000	***
COD (mg/L)	60.5 ± 0.1^{a}	36.6 ± 0.4^{c}	49.0 ± 1.7^{b}	48.7±3.5	0.000	***

NS: Not significant; *Significant level: P<0.05; **Significant level: P<0.01 and ***Significant level: P<0.001

Table 5. Season-wise variations of water quality parameters in Dhanmondi Lake

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average	P-value	Sig. level
Water depth (m)	3.7±0.1^{b}	4.5±0.2^{a}	4.1±0.1^{ab}	4.1±0.1	0.028	*
Air temp. (^{0}C)	3.7±0.1^{b}	4.5±0.2^{a}	4.1±0.1^{ab}	4.1±0.1	0.028	*
Water temp. (^{0}C)	28.8±0.3^{a}	30.7±0.1^{a}	24.9±1.5^{b}	28.1±1.0	0.010	*
Transparency (cm)	28.2±0.1 ^{a}	30.2±0.1 ^{a}	24.6±1.2 ^{b}	27.7±1.0	0.004	**
Dissolved Oxygen (mg/L)	76.4±2.4	80.1±2.0	79.1±1.1	78.5±1.2	0.482	NS
pH	6.2±0.1^{b}	6.9±0.3^{a}	6.5±0.1^{ab}	6.5±0.1	0.050	*
Ammonia-nitrogen (mg/L)	7.6±0.03^{a}	7.5±0.03^{b}	7.6±0.0^{a}	7.6±0.03	0.011	*
Free CO_2 (mg/L)	0.93±0.12	0.83±0.1	0.97±0.12	0.91±0.06	0.691	NS
Alkalinity (mg/L)	21.7±1.0	18.8±1.5	20.2±0.4	20.2±0.7	0.243	NS
Hardness (mg/L)	105.5±2.3	99.4±2.3	102.8±2.9	102.5±1.5	0.299	NS
Conductivity (µS/cm)	102.0±1.7^{a}	6.7±2.0^{ab}	92.9±2.3^{b}	97.2±2.7	0.050	*
TDS (mg/L)	396.5±8.3^{a}	337.5±16.8^{b}	285.7±17.4^{c}	340.0±17.6	0.005	**
BOD (mg/L)	189.5±2.4^{a}	171.8±3.0^{a}	148.0±9.2^{b}	169.7±6.7	0.006	**
COD (mg/L)	3.2±0.2^{a}	2.8±0.03^{b}	2.9±0.1^{b}	2.9±0.1	0.047	*

NS: Not significant; *Significant level: P<0.05; **Significant level: P<0.01 and ***Significant level: P<0.001

Table 6. Comparison of Physico-chemical parameters of Gulshan and Dhanmondi lake with significant result of t-test in first year (2010-11)

Parameters	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Water depth (m)	Gulshan	2.4-4.6	3.4±0.5	-6.91	142	0.020*
	Dhanmondi	3.10-4.90	4.0±0.2			
Air temperature (0^0c)	Gulshan	22.00-32.8	29.1±1.3	-.57	142	0.330
	Dhanmondi	22.00-33.60	29.4±1.5			
Water temperature (0^0c)	Gulshan	22.40-39.8	28.3±1.2	-.19	142	0.560
	Dhanmondi	22.40-32.60	28.5±1.5			
Transparency (cm)	Gulshan	20.00-48.0	35.4±1.7	34.71	142	0.980
	Dhanmondi	63.00-94.00	75.5±1.5			
Dissolved Oxygen (mg/L)	Gulshan	2.60-7.1	5.3±0.5	-7.35	142	0.000**
	Dhanmondi	4.30-8.80	6.7±0.6			
PH	Gulshan	7.00-8.1	7.5±0.2	-1.51	142	0.950
	Dhanmondi	7.20-8.00	7.6±0.1			
Ammonia-nitrogen (mg/L)	Gulshan	5.20-20.0	10.9±2.2	23.56	142	0.000**
	Dhanmondi	0.40-3.00	1.2±0.5			
Free CO_2 (mg/L)	Gulshan	12.10-41.2	20.5±3.7	1.22	142	0.780
	Dhanmondi	8.58-40.40	19.5±3.2			
Alkalinity (mg/L)	Gulshan	140.00-232.0	158.4±18.6	34.16	142	0.005**
	Dhanmondi	68.00-128.00	98.2±2.9			
Hardness (mg/L)	Gulshan	126.0-159.5	98.2±4.3	1.18	142	0.480
	Dhanmondi	11.24-128.00	99.4±6.0			
Conductivity (µS/cm)	Gulshan	74.00-702.0	450.5±64.4	9.86	142	0.001**
	Dhanmondi	156.0-468.0	325.7±87.0			
TDS (mg/L)	Gulshan	162.50-312.4	232.0±35.8	11.87	142	0.001**
	Dhanmondi	21.40-221.80	164.7±25.3			
BOD (mg/L)	Gulshan	5.60-9.8	7.5±0.9	34.17	142	0.000**
	Dhanmondi	1.80-4.60	2.9±0.3			
COD (mg/L)	Gulshan	30.56-68.2	48.1±9.8	17.79	142	0.000**
	Dhanmondi	16.24-36.46	24.3±4.6			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 7. Comparison of Physico-chemical parameters of Gulshan and Dhanmondi lake with significant result of t-test in second year (2011-12)

Parameters	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Water depth (m)	Gulshan	2.50-4.40	3.7±0.3	-5.00	142	0.140
	Dhanmondi	3.40-5.10	4.1±0.5			
Air temperature (0^0c)	Gulshan	17.60-31.60	27.6±3.8	.036	142	0.830
	Dhanmondi	17.80-31.20	27.5±3.7			
Water temperature (0^0c)	Gulshan	18.00-31.00	27.3±3.3	.079	142	0.940
	Dhanmondi	18.20-31.00	27.3±3.5			
Transparency (cm)	Gulshan	20.00-46.00	33.2±3.5	-48.96	142	0.000**
	Dhanmondi	70.00-86.00	77.7±3.5			
Dissolved Oxygen (mg/L)	Gulshan	2.50-7.10	4.5±0.6	-11.57	142	0.150
	Dhanmondi	4.90-8.60	6.5±0.4			
PH	Gulshan	7.02-7.92	7.6±0.1	.45	142	0.330
	Dhanmondi	7.14-7.88.	7.5±0.1			
Ammonia-nitrogen (mg/L)	Gulshan	2.70-20.00	11.1±2.3	20.76	142	0.000**
	Dhanmondi	20-3.00	0.8±0.2			
Free CO_2 (mg/L)	Gulshan	12.50-26.80	20.1±1.8	-2.49	142	0.250
	Dhanmondi	16.40-30.40	20.9±1.1			
Alkalinity (mg/L)	Gulshan	101.7-245.0	168.5±23.1	16.45	142	0.000**
	Dhanmondi	88.4-132.0	104.8±6.6			
Hardness (mg/L)	Gulshan	86.8-136.0	104.7±3.4	6.98	142	0.640
	Dhanmondi	10.0-121.6	94.1±6.2			
Conductivity (μS/cm)	Gulshan	326.0-738.0	498.5±79.6	11.62	142	0.000**
	Dhanmondi	270.0-492.0	351.0±52.9			
TDS (mg/L)	Gulshan	160.4-341.0	237.3±38.4	11.99	142	0.000**
	Dhanmondi	126.8-213.0	165.1±23.5			
BOD (mg/L)	Gulshan	5.40-10.00	7.8±1.0	30.39	142	0.000**
	Dhanmondi	1.60-5.60	2.8±0.2			
COD (mg/L)	Gulshan	30.12-68.24	48.0±12.9	16.50	142	0.000**
	Dhanmondi	14.56-33.12	23.5±4.0			

***Significant at the 5% level.   ** Significant at the 1% level.**

Table 8. Comparison of Physico-chemical parameters of Gulshan and Dhanmondi lake with significant result of t-test in third year (2012-13)

Parameters	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Water depth (m)	Gulshan	3.00-4.60	3.8±0.3	-4.41	142	0.030*
	Dhanmondi	3.00-5.30	4.2±0.6			
Air temperature (0^0c)	Gulshan	18.60-31.00	27.3±3.6	-.99	142	0.320
	Dhanmondi	17.6-306.0	27.4±3.6			
Water temperature (0^0c)	Gulshan	18.2-304.0	27.3±3.5	.99	142	0.310
	Dhanmondi	17.80-30.80	27.3±3.6			
Transparency (cm)	Gulshan	22.00-46.00	33.7±2.8	-59.05	142	0.003*
	Dhanmondi	72.00-90.00	82.3±1.1[a]			
Dissolved Oxygen (mg/L)	Gulshan	3.40-7.40	5.1±0.5	-9.70	142	0.000**
	Dhanmondi	5.20-7.60	6.4±0.1			
PH	Gulshan	7.42-7.68	7.6±1.1	-.20	142	0.870
	Dhanmondi	7.44-7.82	7.6±0.1			
Ammonia-nitrogen (mg/L)	Gulshan	5.40-21.60	12.1±1.9	25.48	142	0.000**
	Dhanmondi	0.20-2.40	0.7±0.2			
Free CO_2 (mg/L)	Gulshan	12.20-21.60	17.2±0.7	-9.19	142	0.976
	Dhanmondi	16.40-23.40	19.9±0.6			
Alkalinity (mg/L)	Gulshan	108.0-216.0	193.7±6.9	14.32	142	0.000**
	Dhanmondi	96.8-120.4	106.6±2.8[a]			
Hardness (mg/L)	Gulshan	92.0-124.0	107.4±3.8	8.86	142	0.000**
	Dhanmondi	88.8-108.4	98.0±1.5			
Conductivity (µS/cm)	Gulshan	338.0-658.0	509.1±84.6	12.43	142	0.000**
	Dhanmondi	293.0-454.0	354.6±45.8			
TDS (mg/L)	Gulshan	152.0-320.0	244.8±41.6	10.25	142	0.000**
	Dhanmondi	156.4-216.0	179.4±14.0			
BOD (mg/L)	Gulshan	4.80-9.60	7.6±1.1	26.50	142	0.000**
	Dhanmondi	2.00-5.20	3.0±0.3			
COD (mg/L)	Gulshan	28.12-68.12	50.4±12.4	15.43	142	0.000**
	Dhanmondi	16.56-38.12	25.6±0.5			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 9. Comparison of Phytoplankton of Gulshan and Dhanmondi lake with significant result of t-test in first year (2010-11)

Phytoplankton (ind/L)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Cyanophyceae	Gulshan	11270-31000	18181±5418	15.82	23	0.000*
	Dhanmondi	374-750	506±111			
Chlorophyceae	Gulshan	1040-8200	3202±2050	22.17	23	0.000*
	Dhanmondi	332-520	413±61			
Bacillariophyceae	Gulshan	234-1900	718±447	5.67	23	0.000*
	Dhanmondi	230-700	393±155			
Total Phytoplankton	Gulshan	14532-33299	22100±5526	25.48	23	0.000*
	Dhanmondi	1112-1656	1312±178			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 10. Comparison of Phytoplankton of Gulshan and Dhanmondi lake with significant result of t-test in second year (2011-12)

Phytoplankton (ind/L)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Cyanophyceae	Gulshan	15820-41400	25709±7782	4.64	23	0.000*
	Dhanmondi	332-1050	625±295			
Chlorophyceae	Gulshan	1100-9600	4237±2778	4.12	23	0.000*
	Dhanmondi	272-686	391±123			
Bacillariophyceae	Gulshan	90-1950	608±486	6.20	23	0.012*
	Dhanmondi	108-700	365±199			
Total Phytoplankton	Gulshan	17340-43415	30554±9411	4.80	23	0.000*
	Dhanmondi	822-2386	1381±473			

***Significant at the 5% level. ** Significant at the 1% level**

Table 11. Comparison of Phytoplankton of Gulshan and Dhanmondi lake with significant result of t-test in third year (2012-13)

Phytoplankton (ind/L)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Cyanophyceae	Gulshan	15350-34000	25471±7247	8.53	23	0.000*
	Dhanmondi	297-900	458±186			
Chlorophyceae	Gulshan	1970-8176	3919±1996	14.73	23	0.000*
	Dhanmondi	341-751	520±122			
Bacillariophyceae	Gulshan	424-1400	878±237	5.31	23	0.020*
	Dhanmondi	154-1150	400±261			
Total Phytoplankton	Gulshan	18600-42200	30268±8759	12.22	23	0.000*
	Dhanmondi	821-2100	1379±391			

***Significant at the 5% level. ** Significant at the 1% level**

Table 12. Comparison of Zooplankton of Gulshan and Dhanmondi lake with significant result of t-test in first year (2010-11)

Zooplankton (ind/L)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Protozoa	Gulshan	640-1970	1275±390	5.06	23	0.000*
	Dhanmondi	31-156	93±40			
Copepoda	Gulshan	120-620	360±146	8.92	23	0.000*
	Dhanmondi	82-492	201±120			
Cladocera	Gulshan	60-900	381±242	4.56	23	0.000*
	Dhanmondi	22-104	58±29			
Rotifera	Gulshan	2740-5274	3789±801	6.41	23	0.000*
	Dhanmondi	410-804	629±107			
Total Zooplankton	Gulshan	4720-6584	5804±660	6.68	23	0.000*
	Dhanmondi	758-1204	980±141			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 13. Comparison of Zooplankton of Gulshan and Dhanmondi lake with significant result of t-test in second year (2011-12)

Zooplankton (ind/L)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Protozoa	Gulshan	1079-3375	2206±715	4.68	23	0.000*
	Dhanmondi	46-131	76±33			
Copepoda	Gulshan	99-408	238±85	7.08	23	0.000*
	Dhanmondi	65-659	208±205			
Cladocera	Gulshan	100-488	257±115	5.42	23	0.000*
	Dhanmondi	10-98	44±26			
Rotifera	Gulshan	2072-7138	4321±1431	5.10	23	0.000*
	Dhanmondi	492-1245	804±246			
Total Zooplankton	Gulshan	4826-9827	7021±1735	6.16	23	0.000*
	Dhanmondi	710-1580	1132±272			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 14: Comparison of Zooplankton of Gulshan and Dhanmondi lake with significant result of t-test in third year (2012-13)

Zooplankton (ind/L)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Protozoa	Gulshan	1661-3171	2348±445	4.89	23	0.000*
	Dhanmondi	49-400	157±144			
Copepoda	Gulshan	100-470	239±101	7.08	23	0.000*
	Dhanmondi	152-484	299±131			
Cladocera	Gulshan	102-340	229±75	5.42	23	0.000*
	Dhanmondi	24-317	103±99			
Rotifera	Gulshan	3290-7132	5248±1277	5.10	23	0.000*
	Dhanmondi	537-1138	877±205			
Total Zooplankton	Gulshan	6027-10685	8064±1455	6.16	23	0.000*
	Dhanmondi	795-2274	1435±499			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 15. Comparison of Benthos of Gulshan and Dhanmondi lake with significant result of t-test in first year (2010-11)

Benthos (ind/m^2)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Chironomids	Gulshan	216-1269	708±338	3.35	23	0.006*
	Dhanmondi	22-432	134±138			
Oligochaetes	Gulshan	222-1526	661±401	5.38	23	0.000*
	Dhanmondi	66-602	290±187			
Molluscs	Gulshan	3-6	5±1	9.47	23	0.000*
	Dhanmondi	384-1295	702±257			
Total Benthos	Gulshan	950-1971	1374±340	15.77	23	0.000*
	Dhanmondi	866-1539	1126±247			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 16. Comparison of Benthos of Gulshan and Dhanmondi lake with significant result of t-test in second year (2011-12)

Benthos (ind/m^2)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Chironomids	Gulshan	120-1450	730±432	2.80	23	0.017*
	Dhanmondi	24-646	152±188			
Oligochaetes	Gulshan	70-1811	626±498	5.37	23	0.000*
	Dhanmondi	78-661	301±194			
Molluscs	Gulshan	1-6	4±1	8.35	23	0.000*
	Dhanmondi	384-1509	754±319			
Total Benthos	Gulshan	862-1869	1360±450	9.93	23	0.000*
	Dhanmondi	610-1869	1208±345			

***Significant at the 5% level. ** Significant at the 1% level.**

Table 17. Comparison of Benthos of Gulshan and Dhanmondi lake with significant result of t-test in third year (2012-13)

Benthos (ind/m^2)	Lake	Annual range	Mean (±SE)	t	df	Sig. level
Chironomids	Gulshan	346-798	530±159	6.69	23	0.000*
	Dhanmondi	24-312	150±90			
Oligochaetes	Gulshan	262-1150	736±272	9.39	23	0.000*
	Dhanmondi	261-720	441±143			
Molluscs	Gulshan	1-7	4±2	4.33	23	0.000*
	Dhanmondi	412-1198	639±237			
Total Benthos	Gulshan	1020-1640	1448±116	17.15	23	0.000*
	Dhanmondi	927-1930	1230±345			

***Significant at the 5% level. ** Significant at the 1% level.**

Table A-1. Water quality of Gulshan lake during April 2010 to March 2011

Parameters	Pre Monsoon	Monsoon	Post Monsoon
Water depth (m)	3.0±0.2	3.9.0±0.2	3.4±0.2
Air temp. (^{0}C)	28.8±4.3	30.5±0.5	27.9±3.9
Water temp. (^{0}C)	28.0±4.1	29.6±0.6	27.3±3.3
Transparency (cm)	33.6±4.6	35.7±2.5	37.0±1.0
DO (mg/L)	4.9±0.5	5.9±0.3	5.2±0.6
pH	7.6±0.3	7.7±0.1	7.3±0.1
Ammonia (mg/L)	0.44±0.1	0.32±0.07	0.13±0.09
Free CO_2 (mg/L)	22.4±4.4	22.9±7.6	16.3±2.9
Alkalinity (mg/L)	175.6±1.0	138.6±18.6	160.9±12.7
Hardness (mg/L)	103.0±2.3	94.5±10.6	97.2±6.0
Conductivity (µS/cm)	524.9±53.7	413.3±3.7	413.3±26.6
TDS (mg/L)	267.7±8.9	196.1±27.3	232.2±27.7
BOD (mg/L)	8.4±0.2	6.7±0.6	7.5±0.6
COD (mg/L)	58.3±1.5	38.8±4.4	47.1±5.0

Table A-2. Water quality of Gulshan lake during April 2011 to March 2012

Parameters	Pre Monsoon	Monsoon	Post Monsoon
Water depth (m)	3.4±0.1	3.9±0.1	3.7±0.2
Air temp. (^{0}C)	28.6±3.3	30.7±0.5	23.4±6.2
Water temp. (^{0}C)	28.1±3.5	30.2±0.3	23.7±5.7
Transparency (cm)	29.7±1.8	36.7±1.5	33.1±1.8
DO (mg/L)	4.7±0.3	5.0±0.6	3.9±0.7
pH	7.6±0.1	7.5±0.1	7.6±0.1
Ammonia (mg/L)	0.45±0.1	0.23±0.05	0.24±0.08
Free CO_2 (mg/L)	21.2±1.3	21.1±1.7	18.0±2.8
Alkalinity (mg/L)	185.4±36.8	142.2±16.6	177.8±6.7
Hardness (mg/L)	106.0±6.2	100.9±4.7	107.3±3.2
Conductivity (µS/cm)	574.9±7.6	416.1±55.6	504.6±9.2
TDS (mg/L)	275.9.9±8.1	199.1±25.0	236.8±26.5
BOD (mg/L)	8.9±0.3	6.9±0.4	7.7±0.7
COD (mg/L)	61.5±2.3	36.9±5.5	45.5±5.5

Table A-3. Water quality of Gulshan lake during April 2012 to March 2013

Parameters	Pre Monsoon	Monsoon	Post Monsoon
Water depth (m)	3.6±0.1	4.1±0.0	3.8±0.1
Air temp. (^{0}C)	28.0±3.6	30.5±0.2	23.4±5.6
Water temp. (^{0}C)	28.2±3.5	30.3±0.2	23.4±5.4
Transparency (cm)	31.0±2.4	36.5±2.4	33.7±3.0
DO (mg/L)	5.0±0.4	5.7±0.4	4.7±0.5
pH	7.6±0.1	7.6±0.0	7.6±0.0
Ammonia (mg/L)	0.47±0.1	0.42±0.05	0.27±0.06
Free CO_2 (mg/L)	18.0±1.0	16.9±1.1	16.6±1.7
Alkalinity (mg/L)	201.1±6.0	187.4±6.1	192.5±22.9
Hardness (mg/L)	110.4±9.0	103.2±4.4	108.7±4.9
Conductivity (µS/cm)	589.9±22.7	421.2±68.7	516.3±42.6
TDS (mg/L)	285.6±10.2	202.4±38.3	246.5±23.2
BOD (mg/L)	8.6±0.3	6.5±1.1	7.6±0.8
COD (mg/L)	61.8±1.9	37.2±4.7	52.1±0.8

Table A-4. Water quality of Dhanmondi lake during April 2010 to March 2011

Parameters	Pre Monsoon	Monsoon	Post Monsoon
Water depth (m)	3.8±0.1	4.0±0.1	4.2±0.3
Air temp. (^{0}C)	29.4±4.9	30.9±0.4	27.9±3.9
Water temp. (^{0}C)	28.4±4.5	30.1±0.5	27.1±3.2
Transparency (cm)	73.8±2.8	76.3±3.7	76.5±2.2
DO (mg/L)	6.2±0.9	7.4±0.3	6.4±0.6
pH	7.7±0.0	7.5±0.0	7.6±0.1
Ammonia (mg/L)	0.04±0.01	0.03±0.0	0.04±0.02
Free CO_2 (mg/L)	22.0±8.9	15.9±3.3	20.6±2.6
Alkalinity (mg/L)	101.5±9.2	96.1±8.7	97.0±9.5
Hardness (mg/L)	105.3±7.3	99.5±7.5	93.3±10.9
Conductivity (µS/cm)	421.5±22.7	304.0±50.5	251.6±78.5
TDS (mg/L)	188.4±20.3	167.7±18.9	138.1±6.8
BOD (mg/L)	3.2±0.5	2.7±0.1	2.8±0.1
COD (mg/L)	28.4±2.7	19.4±1.6	25.1±3.5

Table A-5. Water quality of Dhanmondi lake during April 2011 to March 2012

Parameters	Pre Monsoon	Monsoon	Post Monsoon
Water depth (m)	3.6±0.0	4.6±0.3	4.0±0.4
Air temp. (^{0}C)	28.5±3.1	30.7±0.3	23.4±6.0
Water temp. (^{0}C)	28.1±3.4	30.3±0.3	23.5±5.6
Transparency (cm)	74.3±1.1	81.2±0.8	77.7±1.7
DO (mg/L)	6.0±0.5	6.8±0.3	6.6±0.6
pH	7.6±0.0	7.4±0.1	7.6±0.1
Ammonia (mg/L)	0.03±0.01	0.01±0.01	0.02±0.01
Free CO_2 (mg/L)	22.2±2.5	20.0±1.5	20.6±0.4
Alkalinity (mg/L)	111.3±13.2	98.2±3.3	104.8±9.5
Hardness (mg/L)	100.9±8.9	92.8±5.7	88.7±4.3
Conductivity (µS/cm)	402.8±41.2	353.0±33.2	297.1±19.1
TDS (mg/L)	185.9±22.9	169.9±16.9	139.6±12.6
BOD (mg/L)	2.9±0.6	2.8±0.3	2.6±0.2
COD (mg/L)	26.8±1.1	19.1±0.8	24.6±3.9

Table A-6. Water quality of Dhanmondi lake during April 2012 to March 2013

Parameters	Pre Monsoon	Monsoon	Post Monsoon
Water depth (m)	3.7±0.2	4.8±0.3	4.1±0.4
Air temp. (^{0}C)	28.4±3.1	30.5±0.2	23.4±6.3
Water temp. (^{0}C)	28.2±3.1	30.3±0.2	23.3±6.1
Transparency (cm)	81.1±1.2	82.9±5.4	83.0±1.6
DO (mg/L)	6.3±0.1	6.5±0.1	6.5±0.1
pH	7.6±0.0	7.5±0.0	7.6±0.0
Ammonia (mg/L)	0.03±0.02	0.02±0.01	0.02±0.01
Free CO_2 (mg/L)	19.8±1.4	20.6±0.3	19.4±0.7
Alkalinity (mg/L)	109.4±4.6	103.8±2.4	106.5±3.0
Hardness (mg/L)	99.6±4.2	97.9±1.5	96.6±0.6
Conductivity (µS/cm)	400.0±50.3	355.5±36.6	308.4±11.5
TDS (mg/L)	194.1±13.0	177.7±15.0	166.3±7.0
BOD (mg/L)	3.4±0.7	2.8±0.2	2.9±0.1
COD (mg/L)	61.8±1.9	37.2±4.7	52.1±0.8

Table A-7. Heavy metal of Gulshan lake water during April 2010 to March 2011

Heavy Metals	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/L)	0.04±0.00	0.06±0.02	0.02±0.00
Chromium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Cadmium (mg/L)	0.04±0.01	0.05±0.01	0.00±0.00
Lead (mg/L)	0.06±0.03	0.20±0.13	0.08±0.02
Copper (mg/L)	0.05±0.01	0.14±0.02	0.12±0.03
Nickel (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Manganese (mg/L)	0.40±0.03	0.50±0.03	0.40±0.04

Table A-8. Heavy metal of Gulshan lake water during April 2011 to March 2012

Heavy Metals	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/L)	0.05±0.01	0.06±0.02	0.06±0.01
Chromium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Cadmium (mg/L)	0.05±0.01	0.05±0.01	0.04±0.02
Lead (mg/L)	0.11±0.05	0.17±0.07	0.28±0.05
Copper (mg/L)	0.14±0.05	0.14±0.03	0.15±0.03
Nickel (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Manganese (mg/L)	0.44±0.06	0.5±0.06	0.54±0.07

Table A-9. Heavy metal of Gulshan lake water during April 2012 to March 2013

Heavy Metals	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/L)	0.06±0.02	0.06±0.1	0.08±0.02
Chromium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Cadmium (mg/L)	0.06±0.01	0.05±0.01	0.07±0.01
Lead (mg/L)	0.14±0.02	0.11±0.01	0.32±0.04
Copper (mg/L)	0.06±0.02	0.14±0.02	0.18±0.02
Nickel (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Manganese (mg/L)	0.48±0.03	0.42±0.04	0.58±0.05

Table A-10. Heavy metal of Dhanmondi lake water during April 2010 to March 2011

Heavy Metals	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/L)	0.00±0.00	0.03±0.01	0.03±0.00
Chromium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Cadmium (mg/L)	0.00±0.00	0.05±0.01	0.00±0.00
Lead (mg/L)	0.08±0.02	0.20±0.04	0.11±0.01
Copper (mg/L)	0.06±0.01	0.12±0.01	0.06±0.02
Nickel (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Manganese (mg/L)	0.30±0.04	0.34±0.02	0.40±0.05

Table A-11. Heavy metal of Dhanmondi lake water during April 2011 to March 2012

Heavy Metals	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/L)	0.05±0.01	0.06±0.02	0.06±0.01
Chromium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Cadmium (mg/L)	0.05±0.01	0.05±0.01	0.04±0.02
Lead (mg/L)	0.11±0.05	0.17±0.07	0.28±0.05
Copper (mg/L)	0.14±0.05	0.14±0.03	0.15±0.03
Nickel (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Manganese (mg/L)	0.44±0.06	0.5±0.06	0.54±0.07

Table A-12. Heavy metal of Dhanmondi lake water during April 2012 to March 2013

Heavy Metals	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/L)	0.06±0.02	0.06±0.1	0.08±0.02
Chromium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Cadmium (mg/L)	0.06±0.01	0.05±0.01	0.07±0.01
Lead (mg/L)	0.14±0.02	0.11±0.01	0.32±0.04
Copper (mg/L)	0.06±0.02	0.14±0.02	0.18±0.02
Nickel (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00
Manganese (mg/L)	0.48±0.03	0.42±0.04	0.58±0.05

Table A-13. Sediment quality of Gulshan lake during April 2010 to March 2011

Sediment Parameters	Pre Monsoon	Monsoon	Post Monsoon
pH	6.3±0.09	6.6±0.09	6.7±0.32
Organic Matter (%)	4.47±1.49	4.34±1.34	5.1±1.03
Acidity (mqu/100g)	1.38±0.52	1.93±1.27	2.2±0.54
Total Nitrogen (%)	0.22±0.09	0.19±0.10	0.21±0.03
Ca (mequ/100g)	6.4±1.71	9.3±2.72	9.9±1.47
Mg (mequ/100g)	0.62±0.51	0.54±0.20	0.64±0.25
K (mequ/100g)	0.54±0.21	0.5±0.12	0.57±0.55
P (mequ/100g)	1.64±0.86	1.2±0.13	1.6±0.50

Table A-14. Sediment quality of Gulshan lake during April 2011 to March 2012

Sediment Parameters	Pre Monsoon	Monsoon	Post Monsoon
pH	6.4±0.79	6.7±0.18	6.8±0.18
Organic Matter (%)	5.7±1.31	5.21±2.07	5.8±0.72
Acidity (mqu/100g)	0.85±0.25	1.0±0.41	1.3±0.48
Total Nitrogen (%)	0.23±0.06	0.21±0.03	0.22±0.07
Ca (mequ/100g)	8.36±1.49	10.3±3.32	12.4±2.20
Mg (mequ/100g)	0.68±0.13	0.62±0.17	0.71±0.16
K (mequ/100g)	0.37±0.16	0.4±0.16	0.52±0.20
P (mequ/100g)	1.4±0.30	1.3±0.14	1.2±0.34

Table A-15. Sediment quality of Gulshan lake during April 2012 to March 2013

Sediment Parameters	Pre Monsoon	Monsoon	Post Monsoon
pH	6.5±0.75	6.8±0.14	6.9±0.09
Organic Matter (%)	6.6±1.04	6.1±2.57	6.9±0.90
Acidity (mqu/100g)	1.24±0.27	1.1±0.39	1.42±0.44
Total Nitrogen (%)	0.26±0.06	0.22±0.03	0.24±0.09
Ca (mequ/100g)	9.26±1.55	12.2±3.05	14.2±3.03
Mg (mequ/100g)	0.72±0.12	0.64±0.11	0.68±0.10
K (mequ/100g)	0.62±0.21	0.54±0.19	0.68±0.18
P (mequ/100g)	1.6±0.27	1.5±0.17	1.6±0.20

Table A-16. Sediment quality of Dhanmondi lake during April 2010 to March 2011

Sediment Parameters	Pre Monsoon	Monsoon	Post Monsoon
pH	6.1±0.08	6.2±0.16	6.8±0.26
Organic Matter (%)	3.05±0.80	1.63±0.40	3.7±0.80
Acidity (mqu/100g)	0.63±0.26	0.4±0.09	0.53±0.18
Total Nitrogen (%)	0.19±0.03	0.09±0.02	0.020.19±0.05
Ca (mequ/100g)	12.86±1.52	5.98±4.09	20.56±2.56
Mg (mequ/100g)	1.49±0.56	0.58±0.12	1.54±0.93
K (mequ/100g)	0.31±0.14	0.23±0.04	0.55±0.51
P (mequ/100g)	11.24±0.73	16.54±8.34	15.64±6.58

Table A-17. Sediment quality of Dhanmondi lake during April 2011 to March 2012

Sediment Parameters	Pre Monsoon	Monsoon	Post Monsoon
pH	6.4±0.23	6.5±0.25	6.7±0.42
Organic Matter (%)	3.62±1.09	2.56±0.57	3.31±0.57
Acidity (mqu/100g)	0.62±0.19	0.44±0.10	0.56±0.20
Total Nitrogen (%)	0.14±0.05	0.15±0.05	0.24±0.05
Ca (mequ/100g)	14.38±1.84	10.61±3.74	19.45±2.84
Mg (mequ/100g)	1.6±0.50	1.04±0.33	1.57±0.50
K (mequ/100g)	0.42±0.11	0.45±0.04	0.62±0.39
P (mequ/100g)	9.47±5.12	16.92±3.50	15.86±5.58

Table A-18. Sediment quality of Dhanmondi lake during April 2012 to March 2013

Sediment Parameters	Pre Monsoon	Monsoon	Post Monsoon
pH	6.5±0.11	6.4±0.21	6.9±0.28
Organic Matter (%)	3.64±0.91	2.68±0.27	3.42±0.20
Acidity (mqu/100g)	0.68±0.28	0.54±0.10	0.6±0.13
Total Nitrogen (%)	0.18±0.04	0.16±0.05	0.24±0.05
Ca (mequ/100g)	13.8±1.87	11.24±2.68	18.6±2.23
Mg (mequ/100g)	1.72±0.40	1.42±0.18	1.68±0.46
K (mequ/100g)	0.5±0.12	0.5±0.10	0.68±0.38
P (mequ/100g)	10.6±4.75	17.64±3.62	16.54±1.38

Table A-19. Heavy metals of Gulshan lake Sediment during April 2010 to March 2011

Heavy Metals in sediment	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/kg)	12.04±2.26	8.25±3.69	14.5±3.81
Chromium (mg/kg)	30.8±4.72	32.01±7.25	38.3±10.88
Cadmium (mg/kg)	0.12±0.03	0.15±0.08	0.11±0.04
Lead (mg/kg)	39.28±11.36	45.93±19.29	51.1±13.51
Copper (mg/kg)	5.38±1.03	4.08±1.11	2.28±0.31
Nickel (mg/kg)	38.83±8.64	35.12±10.77	34.08±6.77
Manganese (mg/kg)	90.02±18.29	44.78±21.62	31.22±19.02
Iron (mg/kg)	76.8±13.91	102.5±11.11	108.4±24.52

Table A-20. Heavy metal of Gulshan lake Sediment during April 2011 to March 2012

Heavy Metals in sediment	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/kg)	12.11±1.50	8.26±4.83	17.01±3.83
Chromium (mg/kg)	45.61±22.19	35.0±17.77	56.6±9.17
Cadmium (mg/kg)	0.22±0.07	0.11±0.02	0.14±0.03
Lead (mg/kg)	89.47±18.47	87.11±21.75	77.31±11.92
Copper (mg/kg)	6.69±1.17	8.02±1.37	3.78±0.47
Nickel (mg/kg)	58.61±11.56	37.12±8.85	36.92±15.11
Manganese (mg/kg)	91.87±14.94	44.82±1.99	37.86±15.94
Iron (mg/kg)	85.65±17.59	105.55±19.71	117.06±20.18

Table A-21. Heavy metal of Gulshan lake Sediment during April 2012 to March 2013

Heavy Metals in sediment	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/kg)	13.24±1.69	8.54±1.15	18.36±3.62
Chromium (mg/kg)	46.24±2.43	38.24±13.77	66.24±9.50
Cadmium (mg/kg)	0.28±0.06	0.16±0.05	0.14±0.03
Lead (mg/kg)	92.46±14.38	88.14±14.29	82.14±7.79
Copper (mg/kg)	7.12±1.21	8.15±1.24	4.26±1.04
Nickel (mg/kg)	62.54±5.65	38.84±6.65	37.24±9.18
Manganese (mg/kg)	92.54±13.96	45.26±10.22	40.12±12.08
Iron (mg/kg)	86.92±14.80	108.8±17.69	124.12±16.04

Table A-22. Heavy metal of Dhanmondi lake Sediment during April 2010 to March 2011

Heavy Metals in sediment	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/kg)	11.55±1.32	6.48±1.87	14.4±3.63
Chromium (mg/kg)	16.8±1.75	15.2±2.21	16.4±5.80
Cadmium (mg/kg)	0.1±0.05	0.08±0.03	0.11±0.02
Lead (mg/kg)	27.13±5.37	16.87±4.09	62.15±20.36
Copper (mg/kg)	2.07±0.31	2.57±1.33	2.9±0.70
Nickel (mg/kg)	18.32±4.55	14.21±1.80	17.7±14.76
Manganese (mg/kg)	7.7±3.40	8.34±1.65	13.9±1.45
Iron (mg/kg)	105.4±18.75	53.6±10.54	101.6±63.53

Table A-23. Heavy metal of Dhanmondi lake Sediment during April 2011 to March 2012

Heavy Metals in sediment	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/kg)	12.69±3.40	6.86±1.16	16.1±4.36
Chromium (mg/kg)	19.09±3.93	16.71±2.05	17.8±7.96
Cadmium (mg/kg)	0.09±0.04	0.09±0.01	0.12±0.01
Lead (mg/kg)	75.1±11.43	70.1±11.33	65.6±19.67
Copper (mg/kg)	2.98±0.87	2.82±0.58	3.09±0.42
Nickel (mg/kg)	20.8±8.93	15.6±2.32	18.9±9.98
Manganese (mg/kg)	14.38±4.48	10.68±4.92	18.9±12.58
Iron (mg/kg)	71.2±43.12	66.24±13.91	104.8±44.18

Table A-24. Heavy metal of Dhanmondi lake Sediment during April 2012 to March 2013

Heavy Metals in sediment	Pre Monsoon	Monsoon	Post Monsoon
Zinc (mg/kg)	12.11±2.71	7.26±1.33	16.4±3.63
Chromium (mg/kg)	20.4±3.54	17.4±2.15	18.8±6.96
Cadmium (mg/kg)	0.12±0.03	0.06±0.04	0.14±0.04
Lead (mg/kg)	76.8±14.73	68.4±8.04	72.4±12.35
Copper (mg/kg)	3.12±0.66	2.88±0.39	3.16±0.46
Nickel (mg/kg)	21.2±3.45	16.2±4.96	17.8±4.29
Manganese (mg/kg)	18.32±3.15	12.42±2.62	19.2±4.71
Iron (mg/kg)	114.32±14.69	84.26±16.99	108.8±18.10

Table A-25. Year-wise variations of Phytoplankton in Gulshan Lake

Phytoplankton (ind/L)	Year			Average
	2010-11	2011-12	2012-13	
Cyanophyceae	18181±5418	25709±7782	25471±7247	23120±6816
Chlorophyceae	3202±2050	4237±2778	3919±1996	3786±2275
Bacillariophyceae	718±447	608±486	878±237	735±390
Total Phytoplankton	22100±5526	30554±9411	30268±8759	27641±7899

Table A-26. Year-wise variations of Phytoplankton in Dhanmondi Lake

Phytoplankton (ind/L)	Year			Average
	2010-11	2011-12	2012-13	
Cyanophyceae	506±111	625±295	458±186	530±197
Chlorophyceae	413±61	391±123	520±122	441±102
Bacillariophyceae	393±155	365±199	400±261	386±205
Total Phytoplankton	1312±178	1381±473	1379±391	1357±347

Table A-27. Season wise Phytoplankton of Gulshan lake in April 2010 to March 2011

Phytoplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Cyanophyceae	21438±7643	15143±4348	17963±1954
Chlorophyceae	4791±2640	1761±818	3053±1269
Bacillariophyceae	749±777	643±269	763±217
Total Phytoplankton	26977±5188	17547±4278	21778±2694

Table A-28. Season wise Phytoplankton of Gulshan lake in April 2011 to March 2012

Phytoplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Cyanophyceae	33763±5272	18711±3677	24655±5242
Chlorophyceae	6689±3389	2376±1098	3648±1586
Bacillariophyceae	778±449	472±95	574±268
Total Phytoplankton	41229±1548	21558±4706	28876±6051

Table A-29. Season wise Phytoplankton of Gulshan lake in April 2012 to March 2013

Phytoplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Cyanophyceae	32625±1325	19175±5141	24613±6504
Chlorophyceae	5944±2308	2747±644	3065±772
Bacillariophyceae	897±166	903±399	835±123
Total Phytoplankton	39466±2258	22825±6008	28513±7026

Table A-30. Season wise Phytoplankton of Dhanmondi lake in April 2010 to March 2011

Phytoplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Cyanophyceae	596±105	525±76	397±36
Chlorophyceae	403±74	428±30	409±82
Bacillariophyceae	500±183	272±69	407±122
Total Phytoplankton	1499±181	1224±79	1213±88

Table A-31. Season wise Phytoplankton of Dhanmondi lake in April 2011 to March 2012

Phytoplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Cyanophyceae	699±333	836±183	342±82
Chlorophyceae	435±188	378±102	360±74
Bacillariophyceae	580±118	274±183	241±71
Total Phytoplankton	1714±618	1488±107	943±87

Table A-32. Season wise Phytoplankton of Dhanmondi lake in April 2012 to March 2013

Phytoplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Cyanophyceae	506±180	519±263	349±42
Chlorophyceae	527±153	591±109	443±68
Bacillariophyceae	623±358	354±74	224±79
Total Phytoplankton	1656±474	1464±160	1016±145

Table A-33. Year-wise variations of Zooplankton in Gulshan Lake

Zooplankton (ind/L)	Year			Average
	2010-11	2011-12	2012-13	
Protozoa	1275±390	2206±715	2348±445	1943±516
Copepoda	360±146	238±85	239±101	279±111
Cladocera	381±242	257±115	229±75	289±144
Rotifera	3789±801	4321±1431	5248±1277	4452±1170
Total Zooplankton	5804±660	7021±1735	8064±1455	6963±1283

Table A-34. Season wise Zooplankton of Gulshan lake in April 2010 to March 2011

Zooplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Protozoa	1306±469	1065±472	1453±114
Copepods	308±156	265±44	508±86
Cladocera	233±132	258±85	654±202
Rotifers	4406±989	3443±505	3517±597
Total Zooplankton	6253±332	5031±340	6132±399

Table A-35. Season wise Zooplankton of Gulshan lake in April 2011 to March 2012

Zooplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Protozoa	2738±690	2043±861	2206±715
Copepods	264±45	180±58	238±85
Cladocera	219±57	206±93	257±115
Rotifers	5923±873	3471±1122	4320±1431
Total Zooplankton	9144±669	5900±835	6021±938

Table A-36. Season wise Zooplankton of Gulshan lake in April 2012 to March 2013

Zooplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Protozoa	2418±434	2328±410	1969±410
Copepods	251±83	211±76	256±151
Cladocera	199±84	203±55	286±62
Rotifers	6327±561	4194±1099	3847±245
Total Zooplankton	9195±815	6936±954	6358±523

Table A-37. Year-wise variations of Zooplankton in Dhanmondi Lake

Zooplankton (ind/L)	Year			Average
	2010-11	2011-12	2012-13	
Protozoa	93±40	76±33	157±144	109±72
Copepoda	201±120	208±205	299±131	236±152
Cladocera	58±29	44±26	103±99	68±51
Rotifera	629±107	804±246	877±205	770±186
Total Zooplankton	980±141	1132±272	1435±499	1183±304

Table A-38. Season wise Zooplankton of Dhanmondi lake in April 2010 to March 2011

Zooplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Protozoa	97±68	84±29	98±15
Copepods	332±124	157±23	114±34
Cladocera	59±37	42±28	73±19
Rotifers	630±84	564±106	768±134
Total Zooplankton	1118±79	847±79	1053±150

Table A-39. Season wise Zooplankton of Dhanmondi lake in April 2011 to March 2012

Zooplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Protozoa	74±33	73±40	80±35
Copepods	401±272	103±34	122±74
Cladocera	38±21	32±15	62±34
Rotifers	830±339	702±163	882±242
Total Zooplankton	1343±164	910±144	1047±170

Table A-40. Season wise Zooplankton of Dhanmondi lake in April 2012 to March 2013

Zooplankton (ind/L)	Pre Monsoon	Monsoon	Post Monsoon
Protozoa	64±11	58±9	65±8
Copepods	263±102	190±56	181±52
Cladocera	40±15	45±7	46±152
Rotifers	963±145	653±97	795±183
Total Zooplankton	1330±100	946±102	1087±205

Table 41. Yearly variation of benthos in Gulshan lake

Benthos (ind/m^2)	Year			Average
	2010-11	2011-12	2012-13	
Chironomids	708±338	730±432	530±159	656±310
Ologochaets	661±401	626±498	736±272	674±390
Molluscs	5±1	4±1	4±2	4±2
Total Benthos	1374±340	1360±450	1270±219	1335±336

Table A-42. Season wise Benthos of Gulshan lake in April 2010 to March 2011

Benthos (ind/m^2)	Pre Monsoon	Monsoon	Post Monsoon
Chironomids	768±297	812±195	545±487
Oligochaetes	962±467	340±194	682±274
Molluscs	5±1	5±2	4±1
Total Benthos	1735±265	1157±90	1231±285

Table A-43. Season wise Benthos of Gulshan lake in April 2011 to March 2012

Benthos (ind/m^2)	Pre Monsoon	Monsoon	Post Monsoon
Chironomids	826±448	810±203	554±614
Oligochaetes	993±583	255±218	634±394
Molluscs	3±2	4±3	3±2
Total Benthos	1822±491	1069±78	1191±244

Table A-44. Season wise Benthos of Gulshan lake in April 2012 to March 2013

Benthos (ind/m^2)	Pre Monsoon	Monsoon	Post Monsoon
Chironomids	707±222	637±193	476±128
Oligochaetes	1112±299	587±389	811±193
Molluscs	5±2	5±3	4±3
Total Benthos	1824±444	1229±216	1291±251

Table 45. Yearly variation of benthos in Dhanmondi lake

Benthos (ind/m^2)	Season			Average
	2010-11	2011-12	2012-13	
Chironomids	134±138	152±188	150±90	145±139
Ologochaets	290±187	301±194	441±143	344±175
Molluscs	702±257	754±319	639±237	699±271
Total Benthos	1126±247	1208±345	1230±345	1188±312

Table A-46. Season wise Benthos of Dhanmondi lake in April 2010 to March 2011

Benthos (ind/m^2)	Pre Monsoon	Monsoon	Post Monsoon
Chironomids	71±56	121±168	211±159
Oligochaetes	386±226	244±144	241±195
Molluscs	861±302	744±222	502±109
Total Benthos	1318±269	1109±229	954±104

Table A-47. Season wise Benthos of Dhanmondi lake in April 2011 to March 2012

Benthos (ind/m^2)	Pre Monsoon	Monsoon	Post Monsoon
Chironomids	78±55	212±296	136±102
Oligochaetes	428±233	214±129	261±183
Molluscs	991±395	857±263	518±90
Total Benthos	1497±440	1283±495	915±84

Table A-48. Season wise Benthos of Dhanmondi lake in April 2012 to March 2013

Benthos (ind/m^2)	Pre Monsoon	Monsoon	Post Monsoon
Chironomids	147±70	149±147	155±60
Oligochaetes	568±145	380±114	374±93
Molluscs	827±293	567±204	524±85
Total Benthos	1542±425	1096±215	1053±112

Table B-1. Monthly abundance of Phytoplankton (ind/L) during first year in Gulshan lake

Species	First year (April 2010 to March 2011) in Gulshan lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Cyanophyceae													
Microcystis sp	750	3500	750	750	1500	1500	3500	3100	2500	3500	2000	1250	2050±1125
Polycistis sp	250	550	200	550	500	500	250	550	550	200	200	200	375±167
Anabaena sp	150	50	50	150	150	550	100	1200	0	250	550	150	305±345
Nostoc sp	50	0	0	50	120	0	0	550	450	550	1200	0	424±410
Oscillatoras sp	10500	12800	6250	5500	2500	5500	6200	8500	6500	8500	5500	7500	7146±2677
Total Cyanophyceae	**24200**	**31000**	**21350**	**13500**	**11270**	**14450**	**16450**	**16400**	**18500**	**20500**	**14950**	**15600**	**18181±5418**
Chlorophyceae													
Spirogyra sp	250	150	200	150	250	500	250	200	550	250	250	550	296±148
Pediastrum sp	500	550	100	250	0	0	100	550	600	200	550	850	425±249
Actinastrum sp	1500	500	1500	500	2000	250	550	2500	2500	1600	2750	2500	1554±917
Scenedesmus sp	500	500	200	0	250	0	0	550	0	550	550	550	456±145
Microspora sp	400	200	50	20	64	150	150	30	0	150	250	500	179±154
Synedra sp	200	70	0	50	0	50	100	24	0	0	150	500	143±156
Ulothrix sp	150	15	20	0	150	150	20	124	12	250	100	1200	199±341
Oedogonium sp	50	80	50	20	0	20	50	0	100	150	550	550	162±208
Closterium sp	0	0	50	50	0	0	0	50	0	50	200	1000	233±380
Total Chlorophyceae	**3550**	**2065**	**2170**	**1040**	**2714**	**1120**	**1220**	**4028**	**3762**	**3200**	**5350**	**8200**	**3202±2050**
Bacillariophyceae													
Tabellaria sp	12	6	12	100	48	150	150	100	20	50	20	100	64±54
Gomphonema sp	0	50	12	50	50	250	100	0	50	0	150	300	112±101
Navicula sp	50	0	20	200	250	0	0	150	0	150	0	550	196±175
Ditoma sp	28	28	30	250	0	150	50	50	100	0	50	0	82±75
Nitzchia sp	100	100	200	100	150	50	250	0	50	200	50	150	127±68

Anomoeoneis sp	0	0	0	0	0	100	150	50	550	0	100	250	200±184
Cystodinium sp	150	50	50	50	50	250	100	100	80	550	150	550	178±447
Total Bacllariophyceae	**340**	**234**	**324**	**750**	**548**	**950**	**800**	**450**	**850**	**950**	**520**	**1900**	**718±445**
Total Phytoplankton	**28090**	**33299**	**23844**	**15290**	**14532**	**16520**	**18470**	**20878**	**23112**	**24650**	**20820**	**25700**	**22100±5526**

Table B-2. Monthly abundance of Phytoplankton (ind/L) during second year in Gulshan lake

Species	Second year (April 2011 to March 2012) in Gulshan lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Cyanophyceae													
Microcystis sp	1000	5000	1000	200	2000	1250	4500	3500	2000	4000	4000	500	2413±1693
Polycistis sp	150	0	150	20	50	400	50	250	150	100	500	400	202±164
Spirulina sp	17500	17200	12800	9500	9800	8600	7400	4500	14100	13200	15500	13500	11967±4026
Anabaena sp	0	0	0	0	10	50	200	200	0	100	500	300	194±168
Nostoc sp	0	0	0	0	12	100	500	1000	0	1000	600	600	545±388
Oscillatoras sp	14200	19200	10100	6100	6200	6500	8200	10250	11200	12220	10200	14200	10714±3878
Total Cyanophycea	**32850**	**41400**	**24050**	**15820**	**18072**	**16900**	**20850**	**19700**	**27450**	**30620**	**31300**	**29500**	**25709±7782**
Chlorophyceae													
Spirogyra sp	400	100	500	200	0	400	0	500	400	200	500	400	360±143
Pediastrum sp	400	250	500	200	150	250	500	800	500	400	1050	750	479±271
Actinastrum sp	5375	1500	2100	0	2000	200	250	2000	3100	2100	3750	3750	2375±1541

Scenedesmus sp	500	50	400	580	296	1000	550	1200	200	200	1000	1000	581±382
Microspora sp	0	0	0	0	0	0	10	15	0	0	100	200	81±89
Synedra sp	40	0	50	0	64	46	0	0	50	200	400	1000	231±335
Ulothrix sp	15	25	15	100	100	50	10	80	15	300	300	500	126±157
Oedogonium sp	0	0	10	0	0	2	0	100	100	400	1000	1000	373±448
Closterium sp	0	0	150	20	20	100	0	100	110	200	400	1000	233±209
Total Chlorophyceae	**6730**	**1925**	**3725**	**1100**	**2630**	**2048**	**1320**	**4795**	**4475**	**4000**	**8500**	**9600**	**4237±2778**
Bacillariophyceae													
Tabellaria sp	6	3	6	12	24	100	50	50	10	20	40	80	33±31
Gomphonema sp	0	0	0	0	0	0	0	0	0	0	0	300	300±0
Navicula sp	20	10	50	100	200	100	100	50	50	100	150	300	103±82
Ditoma sp	14	7	14	28	56	112	0	0	50	100	120	260	76±77
Nitzchia sp	0	0	0	0	0	0	225	100	0	120	100	210	151±61
Anomoeoneis sp	100	50	300	200	100	200	100	0	300	200	200	400	195±106
Cystodinium sp	80	20	80	80	25	100	200	50	80	340	240	400	141±125
Total Bacllariophyceae	**220**	**90**	**450**	**420**	**405**	**612**	**675**	**250**	**490**	**880**	**850**	**1950**	**608±486**
Total Phytoplankton	**39800**	**43415**	**28225**	**17340**	**21107**	**19560**	**22845**	**24745**	**32415**	**35500**	**40650**	**41050**	**30554±9411**

Table B-3. Monthly abundance of Phytoplankton (ind/L) during third year in Gulshan lake

Species	Third year (April 2012 to March 2013) in Gulshan lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Cyanophyceae													
Microcystis sp	1200	1000	1300	1000	1500	850	4300	2000	500	2800	3600	800	1738±1208
Polycistis sp	200	800	200	400	150	200	100	400	50	300	200	100	258±203
Spirulina sp	14000	14200	11200	8700	8700	7800	6400	8600	10800	12400	14500	12200	10792±2733
Anabaena sp	500	1000	1200	200	300	500	100	0	200	600	200	600	491±351
Nostoc sp	400	0	500	300	500	800	0	700	400	800	1000	1200	660±291
Oscillatoras sp	15000	16500	12300	7500	4200	6400	7600	10300	12300	16800	14500	16800	11683±4424
Total Cyanophyceae	**31300**	**33500**	**26700**	**18100**	**15350**	**16550**	**18500**	**22000**	**24250**	**33700**	**34000**	**31700**	**25471±7247**
Chlorophyceae													
Spirogyra sp	500	500	500	200	0	0	100	100	100	500	300	200	300±183
Pediastrum sp	300	200	250	400	500	300	0	400	200	300	500	150	318±119
Actinastrum sp	4500	1200	1200	500	1200	1500	50	1200	1500	1200	2200	2800	1588±1154
Scenedesmus sp	1000	500	400	0	120	200	400	250	300	200	800	600	434±274
Microspora sp	250	150	0	400	200	300	200	300	140	300	600	400	295±134
Synedra sp	50	0	300	120	0	100	20	200	100	0	800	500	243±256
Ulothrix sp	26	200	150	230	200	0	500	200	0	500	500	300	281±166
Oedogonium sp	1500	0	500	110	12	400	400	600	500	300	800	600	520±394
Closterium sp	50	100	300	200	120	76	300	500	300	100	600	100	229±177
Total Chlorophyceae	**8176**	**2850**	**3600**	**2160**	**2352**	**2876**	**1970**	**3750**	**3140**	**3400**	**7100**	**5650**	**3919±1996**
Bacillariophyceae													
Tabellaria sp	12	100	150	150	200	0	50	150	150	120	150	200	130±58
Gomphonema sp	0	200	200	100	100	100	0	100	160	0	300	100	151±71
Navicula sp	100	200	0	200	300	24	100	0	100	200	0	50	142±89
Ditoma sp	250	0	500	0	120	0	0	50	50	220	100	150	180±148

Nitzchia sp	12	115	200	250	100	100	230	200	0	120	50	150	139±75
Anomoeoneis sp	400	100	150	40	78	50	100	250	100	200	300	200	164±110
Cystodinium sp	50	0	200	150	0	150	200	50	400	40	200	100	154±108
Total Bacllariophyceae	**824**	**715**	**1400**	**890**	**898**	**424**	**680**	**800**	**960**	**900**	**1100**	**950**	**878±237**
Total Phytoplankton	**40300**	**37065**	**31700**	**21150**	**18600**	**19850**	**21150**	**26550**	**28350**	**38000**	**42200**	**38300**	**30268±8759**

Table B-4. Monthly abundance of Phytoplankton (ind/L) during first year in Dhanmondi lake

Species	**First year (April 2010 to March 2011) in Dhanmondi lake**												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Cyanophyceae													
Microcystis sp	100	150	20	20	300	150	200	150	100	50	12	100	113±185
Polycistis sp	150	50	50	100		150	100	50	150	150	100	150	109±44
Spirulina sp			150	250	200	120	50	100	50		150	50	124±71
Anabaena sp	50	250		100	50	50	20			100	200		103±81
Nostoc sp		150		50		20		100	50	50	50	100	71±42
Oscillatoras sp	250	150	200		20	100	20	50	24	24	50	120	92±80
Total Cyanophycea	**550**	**750**	**420**	**520**	**570**	**590**	**390**	**450**	**374**	**374**	**562**	**520**	**506±111**
Chlorophyceae													
Spirogyra sp	250	100	150	50	50	100	50	100	150	100	50	20	98±63
Pediastrum sp	50	50	100		100	50	200	150	100	12	40	50	82±55
Scenedesmus sp	150	100	20	100	50		12	120	50		20	150	77 53
Microspora sp		100		50		100		50		50			70±27

Synedra sp	20		50	100	150	50	20		100	100	100	20	71±45
Ulothrix sp	12	24	50		50	100		100	20	50			51±34
Oedogonium sp	24	20	50	100		50	50			40	100	50	54±29
Closterium sp		12			20	20				12	50	50	27±18
Total	**506**	**406**	**420**	**400**	**420**	**470**	**332**	**520**	**420**	**364**	**360**	**340**	**413±61**
Chlorophyceae													
Bacillariophyceae													
Tabellaria sp	50	50	100	100	50	12	20	150	100	20	100	50	67±42
Gomphonema sp	150	50	20		100		50	50	120	50	50	150	79±47
Navicula sp	50	50	50	20	50	50	100	2	100	120	200	50	70±53
Ditoma sp	150		150	50	12	50	20	12	150	200			88±73
Nitzchia sp	50	100	50	20	20	150	150	32	12	50	250	50	78±72
Anomoeoneis sp	150	50		20	12		50		50	20	100	100	61±46
Total	**600**	**300**	**370**	**210**	**244**	**262**	**390**	**246**	**532**	**460**	**700**	**400**	**393±155**
Total Phytoplankton	**1656**	**1456**	**1210**	**1130**	**1234**	**1322**	**1112**	**1216**	**1326**	**1198**	**1622**	**1260**	**1312±178**

Table B-5. Monthly abundance of Phytoplankton (ind/L) during second year in Dhanmondi lake

Species	Second year (April 2011 to March 2012) in Dhanmondi lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Cyanophyceae													
Microcystis sp	300	200	50	0	550	250	150	100	50	100	50	150	177±149
Polycistis sp	200	250	150	250	50	100	100	150	100	0	0	100	145±69
Spirulina sp	0	150	0	550	150	70	20	0	150	50	100	0	155±167
Anabaena sp	100	150	50	150	200	100	50	50	12	150	150	200	114±63
Nostoc sp	0	50	0	0	0	3	20	0	20	20	20	40	25±15
Oscillatoras sp	300	250	600	0	20	50	0	50	12	12	12	24	133±195
Total Cyanophyceae	**900**	**1050**	**850**	**950**	**970**	**573**	**340**	**350**	**344**	**332**	**332**	**514**	**625±295**
Chlorophyceae													
Spirogyra sp	300	50	100	50	20	50	100	50	100	50	100	50	85±73
Pediastrum sp	0	100	10	100	12	30	150	200	50	20	20	40	67±63
Actinastrum sp	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp	100	250	50	0	20	30	0	20	20	150	12	100	75±77
Microspora sp	20	150	0	150	50	20	50	20	20	0	0	50	59±53
Synedra sp	50	100	250	0	100	50	0	0	50	50	100	0	94±68
Ulothrix sp	0	0	50	50	50	100	50	100	50	20	50	12	53±28
Oedogonium sp	2	36	50	50	0	50	100	0	0	20	0	24	42±29
Closterium sp	0	0	0	0	20	0	0	0	0	0	12	12	15±5
Total Chlorophyceae	**472**	**686**	**510**	**400**	**272**	**330**	**450**	**390**	**290**	**310**	**294**	**288**	**391±123**
Bacillariophyceae													
Tabellaria sp	100	100	50	20	250	20	20	100	50	100	65	30	75±64
Gomphonema sp	300	50	48	50	50	50	40	20	12	20	0	100	67±81
Navicula sp	150	100	18	18	32	100	50	12	20	12	150	0	60±55
Ditoma sp	0	250	12	20	20	50	50	50	100	150	24	150	80±75

Nitzchia sp	100	0	0	0	22	250	50	16	6	20	150	100	79±81
Anomoeoneis sp	50	150	0	0	14	0	24	0	0	40	50	150	68±57
Total Baclariophyceae	**700**	**650**	**128**	**108**	**388**	**470**	**234**	**198**	**188**	**342**	**439**	**530**	**365±109**
Total Phytoplankton	**2072**	**2386**	**1488**	**1458**	**1630**	**1373**	**1024**	**938**	**822**	**984**	**1065**	**1332**	**1381±473**

Table B-6. Monthly abundance of Phytoplankton (ind/L) during third year in Dhanmondi lake

Species	Second year (April 2011 to March 2012) in Dhanmondi lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Cyanophyceae													
Microcystis sp	0	200	50	100	200	100	0	50	100	50	0	100	106±58
Polycistis sp	100	100	150	50	350	12	200	100	50	100	100	50	114±89
Spirulina sp	50	300	18	100	200	100	50	50	50	0	50	120	99±83
Anabaena sp	0	50	0	0	0	23	0	18	50	12	20	50	32±17
Nostoc sp	100	12	12	200	100	50	100	100	17	100	72	100	80±53
Oscillatoras sp	200	100	200	0	50	12	50	0	100	50	100	50	91±64
Total Cyanophycea	**450**	**762**	**430**	**450**	**900**	**297**	**400**	**318**	**367**	**312**	**342**	**470**	458±186
Chlorophyceae													1±0.41
Spirogyra sp	100	150	150	150	20	0	12	12	50	100	120	0	86±58
Pediastrum sp	50	0	12	0	0	100	100	100	50	50	50	112	69±34
Actinastrum sp	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp	100	150	100	50	100	150	100	50	100	0	0	50	95±37
Microspora sp	0	300	50	30	150	120	0	16	20	12	24	100	82±91
Synedra sp	150	36	300	50	50	0	50	100	50	100	100	12	91±80

Ulothrix sp	50	100	0	100	0	0	100	50	0	50	0	100	79±27
Oedogonium sp	0	15	0	300	20	112	13	13	100	100	100	50	82±87
Closterium sp	50	0	50	0	100	100	100	0	100	72	20	20	68±34
Total Chlorophyceae	**500**	**751**	**662**	**680**	**440**	**582**	**475**	**341**	**470**	**484**	**414**	**444**	**520±122**
Bacillariophyceae													
Tabellaria sp	200	200	0	100	100	0	100	0	16	0	0	15	104±75
Gomphonema sp	150	100	100	15	38	150	0	100	50	50	100	0	85±46
Navicula sp	300	18	18	0	100	0	50	50	0	100	50	200	98±94
Ditoma sp	200	50	50	200	50	200	100	0	20	50	120	100	104±68
Nitzchia sp	300	100	0	50	0	46	0	0	50	17	100	20	85±92
Anomoeoneis sp	0	50	100	0	50	50	12	12	18	100	100	18	51±37
Total Bacllariophyceae	**1150**	**518**	**268**	**365**	**338**	**446**	**262**	**162**	**154**	**317**	**470**	**353**	**400±262**
Total Phytoplankton	**2100**	**2031**	**1360**	**1495**	**1678**	**1325**	**1137**	**821**	**991**	**1113**	**1226**	**1267**	**1379±391**

Table B-7. Monthly abundance of Zooplankton (ind/L) during first year in Gulshan lake

Species	First year (April 2010 to March 2011) in Gulshan lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Ptotozoa													
Euglena acus	450	100	100	20	100	100	20	64	48	250	100	150	125±119
E. oxyuris	20	150	0	50	50	0	40	50	100	50	150	250	91±72
E.clavata	0	0	100	50	100	0	0	100	20	0	100	100	81±33
E.fusca	120	50	250	100	50	50	0	50	50	100	250	0	107±80
E. spathyrhyncha	200	50	0	50	50	50	100	150	50	100	50	100	86±50
E. sanguinea	22	0	50	0	0	0	0	0	0	20	20	50	32±16

E. mainxi	0	50	250	250	50	0	50	150	100	250	500	0	183±148
Euglena sp	30	0	0	50	50	100	0	100	250	0	250	50	110±90
Phacus longicaudata	20	50	50	100	100	0	0	0	0	250	0	100	96±75
P. pleuronectus	170	250	100	0	0	550	250	150	150	200	250	20	209±140
Phacus sp	40	100	50	150	50	200	400	250	250	0	0	0	166±121
Difflugia sp	40	20	0	20	0	550	500	0	150	100	150	100	181±201
Volvox sp	50	50	20	50	20	0	0	100	150	150	100	150	84±53
Epistylis sp	0	0	0	20	20	40	50	50	250	0	50	150	79±80
Arcella sp	0	0	0	0	0	100	0	100	0	50	0	0	83±29
Total Protozoa	1162	870	970	910	640	1740	1410	1314	1568	1520	1970	1220	1275±390
Copepoda													
Mesocyclops edax	10	0	24	20	20	60	50	150	200	50	20	50	59±60
M. varicans	20	50	40	20	50	0	150	100	250	100	0	0	87±75
Cyclops sp	30	0	50	20	20	50	0	200	100	150	50	50	72±60
Diaptomus gracilis	10	100	50	0	50	64	150	0	0	0	100	100	78±43
Diaptomus sp.	0	0	50	20	100	0	100	0	20	50	150	150	80±53
Naupleus	0	50	100	150	50	50	50	50	50	20	100	100	70±37
Bryocamptus sp.	50	40	0	0	0	0	0	0	0	40	0	0	43±6
Total Copepoda	120	240	314	230	290	224	500	500	620	410	420	450	360±146
Cladocera													
Diaphanosoma brachyurum	20	100	100	20	100	20	150	50	150	40	150	50	79±52
Moina brachiata	0	0	150	20	0	50	150	125	250	50	50	150	111±74
Skapheloberis kingi	0	0	20	50	100	150	100	250	250	100	20	50	109±85
Polyphemus sp	20	100	50	50	0	100	0	250	150	150	100	100	107±65
Cydoruss sp	20	0	0	0	50	0	150	50	100	100	0	0	78±47
Total Cladocera	60	200	320	140	250	320	550	725	900	440	320	350	381±242
Rotifera													
Brachionus angularis	1050	550	1050	550	20	200	0	200	50	120	150	0	394±391

B. diversicornis	0	0	0	0	50	100	100	0	150	150	0	50	100±45
B. caudatus	150	550	0	50	20	0	0	250	250	200	0	100	196±167
B. calicyflorus	550	400	150	50	100	100	0	40	0	0	0	0	199±197
B. falcatus	0	0	0	0	100	50	40	0	50	100	50	50	63±26
B. forficula	100	24	50	0	250	0	100	100	0	150	150	100	114±65
B. plicatilis	0	0	0	0	0	50	50	0	100	250	100	250	133±93
B. quadridentata	0	1250	100	50	200	100	250	0	100	0	50	150	250±381
B. rubens	200	0	0	50	0	150	0	50	100	150	150	0	121±57
B. budapestinensis	550	250	200	50	250	100	50	0	50	200	0	250	195±152
Keratella vulga	0	0	0	50	0	0	0	0	0	0	500	0	275±318
Keratella cochlearis	150	100	50	0	150	50	200	0	0	250	0	100	131±70
Filinia longiseta	0	150	150	50	100	250	150	0	0	150	100	250	150±66
F. terminalis	550	200	100	150	150	0	0	0	150	250	250	150	217±135
Rotaria neptunia	0	250	50	200	0	40	00	150	0	200	20	150	133±86
Asplanchna priodonta	250	0	0	350	250	0	100	100	0	0	250	50	193±110
Asplanchna herricki	0	200	250	20	50	100	250	0	50	150	100	200	137±85
Asplanchna sp	40	0	0	50	100	50	50	10	0	0	50	0	50±26
Anuraeopsis fissa	20	50	100	150	150	250	250	500	50	100	0	250	170±138
Monostylla bula	0	0	0	100	150	100	250	250	0	0	250	250	193±73
Trichocerca pocellus	20	250	200	150	250	0	150	100	100	500	0	0	191±138
T. cylindrica	100	0	250	50	0	100	0	100	250	250	250	500	206±138
T. braziliensis	20	0	50	0	100	0	150	0	150	0	50	250	110±80
Lindia sp.	10	250	0	50	0	0	0	500	200	100	100	0	173±166
Epiphenes sp	550	250	150	50	250	250	100	500	0	150	0	200	245±162
Cephalodella incilla	150	0	150	550	250	0	20	0	150	0	100	0	196±171
Synchaeta sp	0	150	50	200	0	0	0	50	100	200	50	0	114±69
Dicranophorus sp	0	0	100	250	50	100	0	40	150	100	50	50	99±67
Mytilina sp	200	150	0	50	250	50	100	100	0	50	0	50	111±74

Chromogaster sp	50	100	300	50	50	150	50	200	100	0	150	100	118±78
Lecane sp	20	0	100	20	150	50	0	150	300	0	0	250	130±104
Hexarthra sp	150	0	100	0	100	250	250	250	250	250	100	50	175±82
Ascomorpha sp	250	150	200	100	150	100	550	200	0	150	150	250	205±125
Total Rotiferta	5130	5274	3900	3440	3690	2740	3210	3840	2850	4170	3170	4050	3789±801
Total Zooplankton (ind/L)	6472	6584	5504	4720	4870	5024	5670	6379	5938	6540	5880	6070	5804±660

Table B-8. Monthly abundance of Zooplankton (ind/L) during second year in Gulshan lake

Species	Second year (April 2011 to March 2012) in Gulshan lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Ptotozoa													
Euglena acus	750	125	100	30	50	20	20	20	13	25	25	150	111±207
E. oxyuris	0	0	0	0	0	0	0	0	5	30	50	200	71±88
E.clavata	0	250	300	80	0	0	0	50	3	30	150	200	133±109
E.fusca	250	0	0	50	50	0	0	0	65	250	200	0	144±100
E. spathyrhyncha	550	0	500	250	50	50	200	50	18	250	200	100	202±181
E. sanguinea	0	0	32	250	100	0	0	0	3	0	0	50	87±98
E. mainxi	0	0	250	100	50	50	0	100	0	0	100	200	121±76
Euglena sp	0	250	125	0	200	250	0	150	250	500	50	200	219±125
Phacus longicaudata	125	0	0	200	200	125	400	50	250	250	500	500	260±157
P. pleuronectus	250	2375	500	500	250	2375	50	150		500	200	250	673±855
Phacus sp	125	250	100	500	100	250	500	500	500	250	500		325±176
Difflugia sp	0	0	0	0	13	2	250	500	500	250	250	500	283±206
Volvox sp	2	0	0	0	0	0	0	0	0	0	0	0	2±0
Epistylis sp	0	0	50	0	16	2	25	125	0	125	250	500	137±168

Arcella sp	0	125	0	0	0	50	0	0	144	0	0	200	130±62
Total Protozoa	**2052**	**3375**	**1957**	**1960**	**1079**	**3174**	**1445**	**1695**	**1751**	**2460**	**2475**	**3050**	**2206±715**
Copepoda													
Mesocyclops edax	15	0	10	10	20	3	10	50	250	12	10	50	40±71
M. varicans	20	0	20	0	50	0	20	50	125	13	20	50	41±35
Cyclops sp	100	0	50	100	40	60	100	200	13	125	100	200	99±60
Diaptomus gracilis	0	0	0	0	0	16	0	0	0	0	0	0	16±0
Naupleus	100	250	100	100	120	20	50	30	20	10	100	30	78±67
Bryocamptus sp.	10	0	0	0	0	0	0	0	0	3	0	0	7±5
Total Copepoda	**245**	**250**	**180**	**210**	**230**	**99**	**180**	**330**	**408**	**163**	**230**	**330**	**238±85**
Cladocera													
Diaphanosoma brachyurum	20	125	62	10	125	50	13	50	125	3	125	52	63±49
Moina brachiata	15	125	50	0	0	20	13	125	250	100	50	104	85±73
Skapheloberis kingi	10	0	20	100	70	20	2	125	100	100	100	48	63±45
Polyphemus sp	100	0	100	62	125	10	200	125	0	0	0	0	103±59
Cydoruss sp	0	0	0	0	0	0	13	25	13	0	0	0	17±7
Total Cladocera	**145**	**250**	**232**	**172**	**320**	**100**	**241**	**450**	**488**	**203**	**275**	**204**	**257±115**
Rotifera													
Brachionus angularis	2250	1250	1500	50	75	500	50	50	0	28	125	20	536±774
B. caudatus	0	250	0	0	15	0	0	0	0	0	250	8	131±138
B. calicyflorus	1500	1000	150	100	38	100	0	40	0	8		50	332±537
B. falcatus	0	0	0	0	0	0	50	0	25	0	0	0	38±18
B. forficula	0	0	0	0	0	2	0	0	13	0	0	0	8±8
B. plicatilis	0	0	0	2	0	0	0	0	0	0	0	0	2±0
B. quadridentata	1250	1250	625	20	250	0	0	0	0	0	0	0	679±564
B. rubens	0	0	0	0	125	10	100	20	0	0	0	0	64±57
B. budapestinensis	0	250	250	100	250		50	10	10	3	50	50	102±106
Keratella cochlearis	0	25	0	25	0	0	0	0	0	0	0	0	25±0

Filinia longiseta	250	125	125	0	13	0	0	0	0	0	200	0	143±90
F. terminalis	500	200	350	100	300	10	100	0	0	600	250	50	246±195
Rotaria neptunia	0	125	50	100	0	10	0	50	25	150	250	20	87±78
Asplanchna priodonta	500	300	50	200	500	15	500	30	0	150	125	250	238±190
Asplanchna herricki	5	25	100	100	40	0	200	0	0	0	0	0	78±71
Asplanchna sp	2	0	0	0	8	0	100	10	20	0	20	250	59±91
Anuraeopsis fissa		250	125	100	100	0	100	400	50	500	125	500	225±176
Monostylla bula	2	0	0	0	0	0	500	250	0	150	20	500	237±223
Trichocerca pocellus	2	2	100	0	0	20	0	200	0	125	25	0	68±76
T. cylindrica	2	25	100	250	250	0	0	0	50	125	500	500	200±191
T. braziliensis	0	0	24	25	0	0	120	0	0	0	0	50	55±45
Lindia sp.	0	0	0	2	2	150	250	250	600	500	500	120	264±222
Epiphenes sp	250	500	100	500	250	200	0	250	300	150	500	250	295±142
Cephalodella incilla	0	0	0	125	500	30	20	500	500	250	500	250	297±208
Synchaeta sp	0	0	0	125	20	0	0	125	250	250	500	500	253±187
Dicranophorus sp	0	0	0	2	50	0	150	150	100	100	250	250	132±88
Mytilina sp	125	125	124	250	100	250	20	110	250	20	125	150	137±79
Chromogaster sp	0	0	0	200	125	125	150	200	0	0	120	500	203±135
Lecane sp	0	0	0	200	200	200	50	250	500	500	0	150	256±161
Hexarthra sp	500	250	500	500	250	250	250	500	250	500	500	500	396±129
Ascomorpha sp	0	0	500	200	300	200	200	500	250	115	500	250	302±145
Total Rotiferta	**7138**	**5952**	**4773**	**3276**	**3761**	**2072**	**2960**	**3895**	**3193**	**4224**	**5435**	**5168**	**4321±1431**
Total Zooplankton (ind/L)	**9580**	**9827**	**7142**	**5618**	**5390**	**5445**	**4826**	**6370**	**5840**	**7050**	**8415**	**8752**	**7021±1735**

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Table B-9. Monthly abundance of Zooplankton (ind/L) during third year in Gulshan lake

Species	Third year (April 2012 to March 2013) in Gulshan lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Ptotozoa													
Euglena acus	200	150	200	100	200	50	12	0	100	50	50	200	119±73
E. oxyuris	10	12	2	120	100	20	50	12	0	100	100	0	53±47
E.clavata	100	59	120	100	50	50	0	0	0	12	120	150	85±44
E.fusca	100	0	0	50	50	100	50	200	100	100	200	0	106±58
E. spathyrhyncha	400	300	500	500	0	0	100	0	30	200	300	200	281±166
E. sanguinea	50	100	32	250	50	0	50	100	12	0	100	0	83±70
E. mainxi	100	0	200	150	100	50	12	50	200	0	50	300	121±90
Euglena sp	200	250	125	300	0	250	50	100	400	300	150	200	211±102
Phacus longicaudata	0	200	50	0	400	300	100	500	50	400	300	400	270±162
P. pleuronectus	1000	1600	800	600	600	1400	500	400	250	600	200	600	713±429
Phacus sp	300	500	400	200	200	500	400	300	300	500	400	100	342±131
Difflugia sp	150	0	0	100	100	2	200	200	200	250	100	50	135±78
Volvox sp	20	0	0	0	20	50	100	50	100	0	0	0	57±36
Epistylis sp	20	0	0	100	150	20	25	100	0	50	50	100	68±46
Arcella sp	0	0	0	0	0	50	12	50	12	0	12	20	26±19
Total Protozoa	**2650**	**3171**	**2429**	**2570**	**2020**	**2842**	**1661**	**2062**	**1754**	**2562**	**2132**	**2320**	**2348±445**
Copepoda													
Mesocyclops edax	20	12	20	12	0	20	20	150	50	120	50	12	44±47
M. varicans	12	50	50	20	20	50	40	100	100	50	100	100	58±34
Cyclops sp	50	0	0	50	10	120	12	150	12	12	50	100	57±50
Diaptomus gracilis	12	50	12	12	0	50	20	40	0	50	30	20	30±17
Diaptomus sp.	10	0	20	20	0	12	12	10	0	0	20	0	15±5
Naupleus	50	100	120	100	20	10	20	12	20	12	60	20	45±40

Bryocamptus sp.	12	0	20	12	50	12	0	8	0	2	50	12	20±18
Total Copepoda	**166**	**212**	**242**	**226**	**100**	**274**	**124**	**470**	**182**	**246**	**360**	**264**	**239±101**
Cladocera													
Diaphanosoma brachyurum	12	100	40	20	60	120	0	100	150	120	150	50	84±50
Moina brachiata	16	0	50	100	20	10	10	50	100	100	100	100	60±41
Skapheloberis kingi	12	50	50	40	50	12	20	60	50	50	50	12	38±18
Polyphemus sp	50	20	60	12	150	2	150	100	30	12	0	60	59±53
Cydoruss sp	12	0	0	2	0	12	20	12	10	0	2	2	9±7
Total Cladocera	**102**	**170**	**200**	**174**	**280**	**156**	**200**	**322**	**340**	**282**	**302**	**224**	**229±75**
Rotifera													
Brachionus angularis	1800	1100	120	150	100	200	500	250	1200	200	1200	1400	685±610
B. diversicornis	0	2	0	0	3	0	0	4	0	0	0	0	3±1
B. caudatus	50	100	12	0	00	2	0	50	0	0	100	12	47±41
B. calicyflorus	1000	150	1500	200	300	200	50	60	0	8	0	100	357±493
B. falcatus	20	0	0	12	0	0	10	0	12	0	8	0	12±5
B. forficula	2	0	4	0	0	2	0	12	0	0	20	0	8±8
B. plicatilis	0	0	3	2	0	6	0	0	10	0	0	2	5±3
B. quadridentata	600	250	1200	120	300	0	120	0	400	0	500	400	432±330
B. rubens	0	100	10	100	20	0	0	0	0	0	0	0	58±49
B. budapestinensis	50	100	50	100	50	12	50	10	20	12	100	150	59±45
Keratella vulga	2	0	0	0	0	0	30	0	0	0	0	0	16±20
Keratella cochlearis	12	20	0	4	0	6	0	12	0	2	0	12	10±6
Filinia longiseta	150	100	50	12	0	10	100	0	50	200	0	200	97±74
F. terminalis	100	200	150	0	100	12	50	100	300	50	200	300	142±98
Rotaria neptunia	0	200	0	150	60	0	12	0	50	100	200	100	109±69
Asplanchna priodonta	300	500	500	400	100	12	200	120	150	120	100	300	234±164
Asplanchna herricki	12	0	120	50	120	200	100	200	0	50	0	120	108±65
Asplanchna sp	100	12	50	12	100	50	50	50	100	150	100	200	81±55

Anuraeopsis fissa	120	400	0	150	200	400	0	200	500	200	100	300	257±136
Monostylla bula	0	200	50	0	180	100	300	150	100	300	120	400	190±111
Trichocerca pocellus	14	50	100	120	12	100	200	0	50	120	50	24	76±58
T. cylindrica	200	200	120	200	150	50	0	100	120	100	100	0	134±52
T. braziliensis	30	26	0	20	100	50	120	60	50	0	20	50	53±34
Lindia sp.	200	500	100	100	32	0	300	400	200	400	200	300	248±146
Epiphenes sp	300	150	0	400	300	100	300	0	200	500	400	200	285±125
Cephalodella incilla	400	400	50	38	500	500	250	500	60	0	0	0	300±203
Synchaeta sp	0	100	0	200	120	0	100	60	300	56	500	400	204±161
Dicranophorus sp	200	120	100	150	150	100	100	300	100	0	0	0	147±67
Mytilina sp	200	100	50	250	100	250	0	200	50	20	126	150	136±81
Chromogaster sp	0	300	200	120	300	150	200	18	0	200	300	500	229±131
Lecane sp	200	500	200	200	250	16	200	500	100	0	200	150	229±148
Hexarthra sp	500	400	400	500	250	250	100	300	16	500	500	100	318±176
Ascomorpha sp	200	500	500	200	300	200	200	200	50	400	500	200	288±151
Colurella bicuspidata	20	12	0	0	0	0	0	0	0	12	0	20	16±5
Total Rotiferta	**6986**	**7132**	**6039**	**4308**	**4757**	**3290**	**4042**	**4500**	**4868**	**4264**	**6248**	**6538**	**5248±1277**
Total Zooplank(ind/L)	**9802**	**10515**	**8710**	**7104**	**6877**	**6406**	**5827**	**7032**	**6804**	**7072**	**8740**	**9122**	**7834±1480**

Table B-10. Monthly abundance of Zooplankton (ind/L) during first year in Dhanmondi lake

Species	First year (April 2010 to March 2011) in Dhanmondi lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Ptotozoa													
Euglena acus	12	0	12	2	15	2	2	2	30	12	10	20	11±8
Euglena sanguinea	2	0	2	4	2	2	2	0	12	0	0	12	5±4
E. oxyuris	2	2	4	2	5	12	12	2	2	6	2	12	5±4
E.clavata	0	0	0	0	0	0	0	0	0	0	0	10	10±0
E.fusca	2	2	0	0	2	12	0	0	12	12	12	20	9±6
E. mutabilis	0	0	0	12	0	0	0	0	0	12	20	12	14±3
E. entefosa	2	2	4	12	12	0	12	2	2	0	10	20	8±6
Euglena sp	3	12	12	0	3	12	20	12	2	12	20	0	11±6
Phacus longicaudatus	4	12	12	8	40	24	10	2	20	0	20	10	15±10
P. pleuronectus	2	0	12	12	24	0	0	12	12	0	0	0	12±6
Phacus sp	2	12	0	0	12	2	0	20	12	10	20	20	12±7
Volvox sp	0	2	4	12	12	0	20	20	12	12	20	10	12±6
Ceratium hirundinella	0	2	4	0	0	12	24	12	0	12	10	10	11±6
Difflugia sp	0	0	0	0	0	0	0	0	2	0	12	0	7±5
Total protozoa	**31**	**46**	**66**	**64**	**127**	**78**	**102**	**84**	**118**	**88**	**156**	**156**	**93±38**
Copepoda													
Mesocyclops edax	120	42	42	0	42	12	12	2	0	20	40	10	34±32
M. varicans	94	5	48	0	24	42	12	12	12	10	0	20	28±26
Cyclops sp	44	100	12	32	12	20	12	10	0	40	0	10	29±27
Diaptomus gracilis	150	50	0	42	12	40	2	40	10	40	20	40	41±38
Diaptomus sp.	40	12	12	12	24	2	12	0	40	24	12	20	19±12
Naupleus	12	122	10	24	40	24	2	20	10	0	112	112	44±45
Metanaupleus	32	35	40	12	0	12	2	10	20	12	12	12	18±12

Bryocamptus sp.	0	2	2	0	16	16	12	12	12	16	20	10	12±6
Mysis larva	0	0	2	0	0	0	16	0	0	0	16	0	11±7
Total Copepoda	**492**	**368**	**168**	**122**	**170**	**168**	**82**	**106**	**104**	**162**	**232**	**234**	**201±115**
Diaphanosoma brachyurum	0	12	12	12	12	0	12	20	12	12	0	0	13±3
Skapholebaris kingi	0	0	2	4	0	5	2	10	2	2	10	20	6±6
Moina brachiata	10	12	0	0	36	12	12	10	12	10	30	12	16±9
Daphnia lumholtzi	0	0	12	12	24	0	2	12	40	40	20	12	19±12
Cydorus sp	0	12	0	0	0	12	12	12	10	2	12	20	12±5
Bosmina sp	12		0	0	12	2	12	2	20	12	0	40	14±11
Total Cladocera	**22**	**36**	**26**	**28**	**84**	**31**	**52**	**66**	**96**	**78**	**72**	**104**	**58±28**
Rotifera													
Brachionus angularis	12	5	40	0	40	12	12	12	46	112	150	50	45±44
B. diversicornis	2	2	0	8	24	0	24	0	12	24	40	4	16±12
B. caudatus	2	2	40	12	48	16	16	20	40	124	12	50	32±32
B.calicyflorus	0	0	0	0	16	40	24	0	12	24	240	100	65±77
B. calyciflorus var. dorcas	12	0	40	12	2	12	12	120	84	40	20	0	35±36
B. falcatus	12	12	0	0	6	24	56	150	44	0	0	12	40±45
B. forficula	2	0	32	0	0	2	2	20	12	12	10	0	12±10
B. quadridentata	0	2	12	0	50	12	12	40	0	0	12	0	20±16
B. rubens	40	42	40	2	0	0	12	0	0	0	0	12	25±16
Keratella vulga	84	60	100	2	40	24	52	40	12	112	40	0	51±33
Keratella cochlearis	0	12	0	0	40	12	24	0	24	0	0	20	22±9
Filinia longiseta	2	0	24	12	0	12	0	0	12	0	20	10	13±7
F. terminalis	2	24	12	0	24	0	12	20	20	10	10	20	15±7
Rotaria neptunia	12	12	0	80	36	0	0	10	50	20	20	100	38±31
Asplanchna priodonta	0	0	2	12	0	12	20	20	100	100	0	0	38±40
Monostylla bula	80	50	2	40	24	40	24	10	50	20	12	20	31±21
Anuraeopsis fissa	100	100	12	0	0	12	24	0	0	0	12	10	39±39

Trichocerca pocellus	12	40	40	80	24	40	0	100	50	10	2	100	45±33
T. braziliensis	32	120	60	0	0	100	42	0	80	0	112	0	78±32
Euchlanis dilatata	0	0	0	0	0	0	0	40	0	0	2	20	21±16
Epiphenes sp	32	2	12	0	0	0	11	50	20	20	0	10	20±14
Lepadella sp	42	32	100	112	12	40	0	0	46	24	0	10	46±34
Horaeala brehmi	44	12	50	132	0	84	112	132	0	66	20	20	67±44
Polyarthra vulgaris	80	32	40	40	24	112	112	20	10	0	10	0	48±37
Total Rotifera	604	561	658	544	410	606	603	804	724	718	744	568	629±103
Total Zooplankton(ind/L)	**1149**	**1011**	**918**	**758**	**791**	**883**	**839**	**1060**	**1042**	**1046**	**1204**	**1062**	**980±135**

Table B-11. Monthly abundance of Zooplankton (ind/L) during second year in Dhanmondi lake

Species	**Second year (April 2011 to March 2012) in Dhanmondi lake**												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Protozoa													
Euglena acus	15	0	50	10	15	0	50	10	15	0	50	10	25±19
Euglena sanguinea	2	0	2	2	2	0	2	2	2	0	2	2	2±0
E. oxyuris	5	3	4	0	5	3	4	0	5	3	4	0	4±1
E.fusca	2	2	0	0	2	2	0	0	2	2	0	0	2±0
E. mutabilis	0	0	0	3	0	0	0	3	0	10	0	3	5±4
E. entefosa	6	2	0	20	6	2	0	0	6	2	0	0	6±6
Euglena sp	3	3	45	0	3	3	45	0	3	3	45	25	18±20
Phacus longicaudatus	10	15	20	5	10	15	20	0	10	15	10	30	15±7

P. pleuronectus	5	0	10	3	5	0	10	0	5	0	5	5	6±3
Phacus sp	2	15	0	0	2	15	0	10	2	30	0	10	11±10
Volvox sp	0	4	0	20	0	4	0	40	0	4	0	0	14±16
Ceratium hirundinella	0	2	0	0	0	2	0	0	0	2	0	0	2±0
Difflugia sp	0	0	0	0	0	0	0	0	2	0	0	0	2±0
Total protozoa	**50**	**46**	**131**	**63**	**50**	**46**	**131**	**65**	**52**	**71**	**116**	**85**	76±33
Copepoda													
Mesocyclops edax	150	120	10	0	15	15	10	10	15	10	10	0	37±52
M. varicans	100	5	25	0	15	5	25	0	15	5	25	0	24±30
Cyclops sp	50	200	10	20	5	10	13	20	5	20	13	20	32±54
Diaptomus gracilis	200	50	0	30	10	50	0	30	0	50	0	30	56±60
Diaptomus sp.	50	18	13	10	10	18	13	10	50	18	13	10	19±15
Naupleus	20	223	10	10	20	12	0	10	20	120	100	100	59±69
Metanaupleus	42	35	50	2	0	20	0	2	0	0	0	2	22±21
Bryocamptus sp.	0	8	0	0	0	8	0	0	0	8	0	0	8±0
Mysis larva	0	0	8	0	0	0	8	0	0	0	8	0	8±0
Total Copepoda	**612**	**659**	**126**	**72**	**75**	**138**	**69**	**82**	**105**	**231**	**169**	**162**	208±205
Cladocera													
Diaphanosoma brachyurum	5	5	20	40	5	5	1	40	25	15	10	40	18±15
Skapholebaris kingi	0	0	0	0	0	0	0	2	10	0	0	0	6±6
Moina brachiata	5	5	0	0	5	5	10	2	5	20	15	2	7±6
Daphnia lumholtzi	0	0	20	0	0	10	5	20	20	50	10	6	18±15
Bosmina sp	15	0	0	0	0	15	0	0	10	10	15	12	13±2
Cydorus sp	5	3	0	0	0	3	0	0	0	3	0	0	4±1
Total Cladocera	**30**	**13**	**40**	**40**	**10**	**38**	**16**	**64**	**70**	**98**	**50**	**60**	44±26
Rotifera	0	0	0	0	0	0	0	0	0	0	0	0	
Brachionus angularis	15	5	50	0	700	5	10	0	56	125	250	10	123±217
B. diversicornis	0	2	0	5	0	2	4	0	0	0	0	4	3±1

B. caudatus	0	8	50	10	0	8	16	10	50	375	0	200	81±126
B.calicyflorus	0	0	0	0	8	50	0	0	8	0	550	0	154±265
B. calyciflorus var. dorcas	20	0	50	10	2	0	0	25	100	50	0	0	37±33
B. falcatus	0	53	0	0	6	53	106	130	64	100	0	53	71±39
B. forficula	0	0	45	0	0	10	0	0	0	0	0	0	28±25
B. quadridentata	0	2	0	0	4	2	4	0	50	100	0	8	24±38
B. rubens	50	20	20	0	0	0	0	0	0	0	0	0	30±17
Keratella vulga	100	50	50	0	0	13	26	50	3	126	180	126	72±58
Keratella cochlearis	0	5	0	0	0	5	0	25	50	0	0	0	21±21
Filinia longiseta	5	0	0	0	0	10	0	0	0	0	0	0	8±4
F. terminalis	12	12	0	0	0	0	0	0	0	0	0	0	12±0
Rotaria neptunia	15	2	0	100	100	2	100	0	50	50	50	40	51±39
Asplanchna priodonta	0	0	10	10	0	10	10	22	150	150	25	200	65±78
Monostylla bula	100	100	10	50	50	50	20	0	100	0	0	0	60±36
Anuraeopsis fissa	80	80	0	0	0	8	0	0	0	0	0	0	56±42
Trichocerca pocellus	2	10	50	100	50	50	50	50	50	0	0	50	46±26
T. braziliensis	50	100	50	0	0	100	0	100	100	50	150	45	83±36
Euchlanis dilatata	0	0	0	0	0	0	0	0	10	0	2	10	7±5
Polyarthra vulgaris	100	0	100	50	0	130	50	130	20	0	0	50	79±42
Epiphenes sp	50	8	0	0	0	10	11	10	10	0	18	0	17±15
Conochillus sp	0	5	0	0	0	0	0	4	50	0	0	50	27±26
Lepadella sp	12	20	50	100	0	100	100	100	23	0	10	20	54±41
Horaeala brehmi	15	10	100	100	0	100	100	100	90	0	10	90	72±42
Lindia sp	0	0	0	0	0	0	0	0	3	0	0	0	3±0
Total Rotifera	**626**	**492**	**635**	**535**	**920**	**718**	**607**	**756**	**1037**	**1126**	**1245**	**956**	**804±246**
Total Zooplankton(ind/L)	**1318**	**1210**	**932**	**710**	**1055**	**940**	**823**	**967**	**1264**	**1526**	**1580**	**1263**	**1132±272**

Table B-12. Monthly abundance of Zooplankton (ind/L) during third year in Dhanmondi lake

Season	Third year (April 2012 to March 2013) in Dhanmondi lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Ptotozoa													
Euglena acus	10	12	20	2	20	2	12	2	20	2	12	12	11±7
Euglena sanguinea	5	4	2	0	12	12	2	0	2	12	12	2	7±5
E. oxyuris	0	0	0	6	0	3	4	6	0	0	6	2	5±2
E.clavata	2	6	4	2	2	2	2	2	6	12	0	0	4±3
E.fusca	0	0	2	2	0	0	0	0	2	0	2	14	4±5
E. mutabilis	2	2	4	4	12	4	4	0	0	2	0	3	4±3
E. spathyrhynchus	3	0	12	2	0	2	2	2	4	2	4	0	4±3
E. entefosa	2	0	3	0	2	0	0	12	2	0	12	0	6±5
Euglena sp	0	6	0	12	0	0	2	2	0	2	20	12	8±7
Phacus longicaudatus	12	10	12	0	2	6	12	6	12	10	2	6	8±4
P. pleuronectus	0	2	0	0	3	0	6	2	0	12	0	5	5±4
Phacus sp	12	12	2	6	2	12	2	4	2	2	0	10	6±5
Volvox sp	2	0	3	2	2	0	12	10	0	6	2	2	5±4
Ceratium hirundinella	3	0	2	12	6	2	12	2	0	2	0	6	5±4
Difflugia sp		2		2	2	4	2	6	12	2			4±4
Total protozoa	**53**	**56**	**66**	**52**	**65**	**49**	**74**	**56**	**62**	**66**	**72**	**74**	**62±9**
Copepoda													
Mesocyclops edax	15	50	20	20	50	12	50	20	20	50	12	12	28±17
M. varicans	5	50	12	30	0	50	20	12	50	20	20	10	25±17
Cyclops sp	100	120	50	10	12	20	12	0	0	2	20	0	38±43
Diaptomus gracilis	50	50	12	10	20	30	2	12	100	12	0	20	29±28
Diaptomus sp.	50	50	0	2	50	20	0	50	50	20	50	20	36±19
Naupleus	60	20	100	30	20	20	4	100	2	50	50	60	43±33

Metanaupleus	50	12	60	50	12	2	2	2	6	0	12	20	21±22
Bryocamptus sp.	8	10	12	0	2	12	6	2	4	12	20	12	9±5
Mysis larva	0	0	8	0	0	2	12	0	0	20	12	2	9±7
Total Copepoda	**338**	**362**	**274**	**152**	**166**	**168**	**108**	**198**	**232**	**186**	**196**	**156**	**211±77**
Cladocera													
Diaphanosoma brachyurum	2	12	10	50	12	2	2	20	12	10	20	20	14±13
Skapholebaris kingi	6	2	20	2	2	4	2	12	20	2	2	0	7±7
Moina brachiata	8	2	0	0	0	0	0	4	0	2	2	12	5±4
Daphnia lumholtzi	0	10	12	0	2	12	12	2	2	0	12	4	8±5
Bosmina sp	6	2	0	2	4	18	0	4	20	12	16	2	9±7
Cydorus sp	0	0	2	0	6	6	2	6	2	2	2	12	4±3
Macrothrix sp	2	2	0	0	10	2	12	0	10	12	0	2	7±5
Total Cladocera	**24**	**30**	**44**	**54**	**36**	**44**	**30**	**48**	**66**	**40**	**54**	**52**	**44±12**
Rotifera													
Brachionus angularis	150	60	60	12	200	12	50	12	50	150	100	12	72±64
B. diversicornis	12	20	0	20	50	20	20	40	12	50	60	12	29±18
B. caudatus	0	12	100	30	0	12	30	0	50	100	100	120	62±43
B.calicyflorus	20	0	12	0	12	20	12	0	40	0	12	0	18±10
B. calyciflorus var. dorcas	0	10	0	50	20	12	100	12	60	60	0	50	42±31
B. falcatus	12	50	0	0	0	50	50	100	50	50	100	120	65±34
B. forficula	0	0	50	15	12	10	12	0	0	0	50	20	24±18
B. quadridentata	2	50	20	12	2	20	40	30	20	50	50	60	30±20
B. rubens	20	20	50	20	0	0	0	12	50	20	50	50	32±17
Keratella vulga	50	100	20	50	50	100	50	20	0	100	100	100	67±33
Keratella cochlearis	50	5	0	0	0	20	12	0	0	0	0	20	21±17
Filinia longiseta	12	0	12	2	12	12	0	12	2	12	0	12	10±4
F. terminalis	20	12	3	12	0	0	2	0	30	0	20	20	15±9
Rotaria neptunia	50	50	10	40	50	50	50	0	15	35	30	0	38±15

Asplanchna priodonta	10	0	20	50	100	5	4	0	100	120	80	100	59±46
Monostylla bula	50	15	40	0	30	12	0	50	20	0	50	20	32±16
Anuraeopsis fissa	12	100	0	50	0	20	12	13	22	12	0	12	28±30
Trichocerca pocellus	50	50	30	12	100	12	0	20	0	40	50	60	42±26
T. braziliensis	12	80	0	50	0	100	0	0	50	100	50	40	60±31
Euchlanis dilatata	12	12	12	0	30	0	12	20	20	00	0	14	17±6
Polyarthra vulgaris	50	50	50	50	8	100	100	100	40	60	4	20	53±34
Epiphenes sp	20	0	0	0	2	0	0	10	0	20	20	0	14±8
Conochillus sp	50	12	0	0	20	12	12	50	12	30	50	20	27±17
Lepadella sp	120	50	60	12	20	50	60	60	50	20	50	50	50±28
Horaeala brehmi	150	20	50	50	20	60	50	50	100	12	100	50	59±40
Chromogaster sp	3	6	12	0	12	0	20	12	10	0	12	4	10±5
Lindia sp	2	3	2	0	2	0	2	0	12	2	0	2	3±4
Total Rotifera	**939**	**787**	**613**	**537**	**752**	**709**	**700**	**623**	**815**	**1043**	**1138**	**988**	**804±187**
Total Zooplankton(ind/L)	**1354**	**1235**	**997**	**795**	**1019**	**970**	**912**	**925**	**1175**	**1335**	**1460**	**1270**	**1121±211**

Table B-13. Monthly abundance of Benthos (ind/m^2) during first year (in Gulshan lake

Species	First year (April 2010 to March 2011) in Gulshan lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Chironomids													
Chironomus sp	245	845	964	812	302	542	100	144	124	1125	624	854	557±364
Pantala (Odonata)	0	0	0	0	0	0	0	96	24	0	96	0	72±42
Nepa elongata	0	0	0	50	0	0	44	0	20	0	24	0	33±15
Nepa (Hemiptera)	96	144	14	72	244	245	72	144	144	144	48	96	122±712
Total Chironomids	**341**	**989**	**978**	**934**	**546**	**787**	**216**	**384**	**312**	**1269**	**792**	**950**	**708±338**
Oligochaets													
Lumbriculus sp	48	48	0	144	48	48	44	44	244	44	112	132	87±65
Nais sp	48	144	24	44	0	144	48	62	44	22	44	48	61±42
Tubifex sp	325	144	112	48	212		316	48	44	44	324	44	151±122
Chaetogaster sp	96	22	48	22	96	22	44	96	127	44	22	96	61±38
Branchiodrillus semperi	425	212	38	20	144	16	132	144	96	22	44	44	111±117
B. hortensis	324	144	0	0	40	0	44	96	244	44	22	22	109±109
Aelosoma sp	244	48	0	0	44	0	132	24	22	96	0	112	90±75
Dero sp	96	96	0	0	22	0	42	48	44	39	68	48	56±26
Aulophorus sp	20	90	0	0	22	0	144	0	0	0	0	90	73±53
Total Oligochaets	**1626**	**948**	**222**	**278**	**628**	**230**	**946**	**562**	**865**	**355**	**636**	**636**	**661±401**
Molluscs													
Bellamya bengalensis	2	1	2	1	2	2	1	1	3	2	1	2	2±1
Brotia costula	1	3	2	1	1	3	1	2	1	1	1	2	2±1
Terabia	1	2	2	2	1	1	1	1	1	2	2	2	2±1
Total Molluscs	**4**	**6**	**6**	**4**	**4**	**6**	**3**	**4**	**5**	**5**	**4**	**6**	5±1
TOTAL BENTHOS	**1971**	**1943**	**1206**	**1216**	**1178**	**1023**	**1164**	**950**	**1182**	**1629**	**1432**	**1592**	**1374±344**

Table B-14. Monthly abundance of Benthos (ind/m^2) during second year in Gulshan lake

Species	Second year (April 2011 to March 2012) in Gulshan lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Chironomids													
Chironomus sp	301	1084	1033	760	244	612	72	244	96	1450	312	1198	564±475
Pantala (Odonata)	0	0	0	0	0	0	0	96	24	0	96	0	72±42
Nepa elongata	0	0	0	0	0	0	0	0	0	0	20	4	20±11
Total Chironomids	**421**	**1180**	**1047**	**785**	**556**	**852**	**120**	**452**	**192**	**1450**	**452**	**1250**	**682±435**
Oligochaets													
Lumbriculus sp	0	96	0	72	48	24	0	48	373	50	144	142	107±107
Nais sp	96	112	24	45	0	72	48	48	0	0	72	72	65±27
Tubifex sp	460	244	68	98	212	0	316	72	48	20	424	96	196±157
Chaetogaster sp	120	48	0	0	96	23	0	96	0	0	0	0	77±40
Branchiodrillus semperi	530	192	0	0	48	0	288	158	0	0	0	0	243±182
B. hortensis	430	120	0	0	96	0	0	172	324	0	0	0	228±143
Aelosoma sp	44	88	0	0	20	0	25	92	2	0	68	21	48±34
Branchiura sowerbyi	112	24	0	0	48	20	301	24	0	0	0	140	88±102
Dero sp	19	48	0	0	0	0	0	0	0	0	0	0	34±21
Aulophorus sp	0	5	0	0	0	0	24	0	0	0	0	0	15±13
Total Oligochaets	**1811**	**977**	**92**	**215**	**568**	**139**	**1002**	**710**	**747**	**70**	**708**	**471**	**640±498**
Molluscs													
Bellamya bengalensis	2	1	1	3	1	2	1	1	1	2	1	1	1±1
Brotia costula	1	1	2	2	1	1	1	2	1	1	1	1	1±1
Terabia	2	1	1	1	2	2	1	1	2	2	2	1	1±1
Total Molluscs	**5**	**3**	**4**	**6**	**4**	**5**	**3**	**4**	**4**	**5**	**4**	**1**	5±2
TOTAL BENTHOS	**2237**	**2160**	**1143**	**1006**	**1128**	**996**	**1125**	**1166**	**943**	**1525**	**1168**	**1720**	**1327±451**

Table B-15. Monthly abundance of Benthos (ind/m^2) during third year in Gulshan lake

Species	Third year (April 2012 to March 2013) in Gulshan lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Chironomids													
Chironomus sp	708	652	244	658	548	342	244	88	156	186	452	74	363±232
Pantala (Odonata)	64	58	0	52	124	54	24	224	84	98	12	154	86±62
Nepa elongata	54	0	12	22	0	0	54	234	0	122	24	88	76±74
Nepa (Hemiptera)	86	124	112	0	126	232	24	0	148	154	42	182	123±62
Belostoma (Hemiptera)	42	0	0	20	0	0	0	24	0	40	0	12	28±13
Total Chironomids	**954**	**834**	**368**	**752**	**798**	**628**	**346**	**570**	**388**	**600**	**530**	**510**	**607±195**
Oligochaets													
Lumbriculus sp	52	112	0	64	64	24	54	42	376	240	144	186	123±107
Nais sp	224	93	48	24	0	56	0	38	0	56	72	178	88±68
Tubifex sp	146	168	230	0	156	0	234	62	42	324	164	342	187±98
Chaetogaster sp	212	122	68	24	46	24	15	66	0	76	234	0	89±78
Branchiodrillus semperi	232	234	342	12	24	124	256	158	0	112	0	234	173±106
B. hortensis	142	136	246	0	54	0	0	134	128	32	0	112	123±64
Aelosoma sp	100	92	26	12	0	8	28	96	64	34	54	24	49±34
Dero sp	124	100	102	0	22	24	42	10	0	42	0	86	61±42
Aulophorus sp	10	43	0	0	12		21	0	0	0	0	16	20±13
Branchiura sowerbyi	20	98	88	126	53	244	258	42	42	120	0	140	112±79
Total Oligochaets	**1262**	**1198**	**1150**	**262**	**431**	**504**	**908**	**648**	**652**	**1036**	**668**	**1318**	**836±355**
Molluscs													
Bellamya bengalensis	3	1	3	2	0	2	0	3	2	1	1	2	2±1
Brotia costula	2	1	1	3	0	2	0	2	1	1	1	4	2±1
Terabia	1	1	3	1	1	1	0	2	1	2	1	1	1±1
Total Molluscs	**6**	**3**	**7**	**6**	**1**	**5**	**1**	**7**	**4**	**4**	**3**	**7**	**5±2**
TOTAL BENTHOS	**2222**	**2035**	**1525**	**1020**	**1230**	**1137**	**1256**	**1225**	**1044**	**1640**	**1201**	**1835**	**1447±402**

Table B-16. Monthly abundance of Benthos (ind/m^2) during first year in Dhanmondi lake

Species	First year (April 2010 to March 2011) in Dhanmondi lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Chironomids													
Chironomus sp	22	44	44	372	22	44	432	132	212	66	150	66	134±138
Total Chironomids	**22**	**44**	**44**	**372**	**22**	**44**	**432**	**132**	**212**	**66**	**150**	**66**	**134±138**
Oligochaets													
Lumbriculus sp	22	44	48	0	22	0	0	44	44	48	44	88	63±34
Nais sp	412	49	312	86	230	132	44	214	72	364	29	312	45±19
Tubifex sp	0	44	44	0	0	0	0	0	0	0	0	0	188±137
Chaetogaster sp	0	0	44	44	0	0	0	24	0	0	29	44	44±0
Branchiodrillus semperi	124	0	0	0	0	0	0	0	0	0	0	0	33±10
B. hortensis	44	0	0	0	0	0	0	24	0	0	0	0	72±74
Aelosoma sp	0	88	0	0	0	0	22	44	0	48	58	116	34±14
Total Oligochaets	**602**	**200**	**448**	**154**	**242**	**132**	**66**	**350**	**88**	**460**	**182**	**560**	**290±187**
Molluscs													
Lamellidens	275	545	312	66	25	450	132	192	88	96	262	140	215±160
Bellamya bengalensis	300	400	312	212	44	212	138	120	240	312	48	236	215±110
Brotia costula	200	350	264	120	312	72	121	48	185	146	44	336	183±110
Terabia	0	0	44	96	240	196	44	24	96	24	240	66	107±86
Total Molluscs	**775**	**1295**	**932**	**494**	**621**	**930**	**435**	**384**	**609**	**578**	**594**	**778**	702±257
TOTAL BENTHOS	**1399**	**1539**	**1424**	**1020**	**885**	**1106**	**933**	**866**	**909**	**1104**	**926**	**1404**	**1126±247**

Table B-17. Monthly abundance of Benthos (ind/m^2) during second year in Dhanmondi lake

Species	Second year (April 2011 to March 2012) in Dhanmondi lake												
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Mean**
Chironomids													
Chironomus sp	24	50	24	372	24	24	646	152	225	48	150	88	158±188
Total Chironomids	**24**	**50**	**24**	**372**	**24**	**24**	**646**	**152**	**225**	**48**	**150**	**88**	**158±188**
Oligochaets													
Lumbriculus sp	0	101	0	0	0	0	28	48	0	24	58	116	52±38
Nais sp	24	0	48	0	24	0	0	44	58	24	44	96	38±24
Tubifex sp	445	49	282	86	230	112	50	287	72	364	29	312	182±143
Chaetogaster sp	0	160	24	0	0	0	0	0	0	0	0	0	92±96
Branchiodrillus semperi	0	0	24	20	0	0	0	24	0	0	29	58	24±15
B. hortensis	144	0	0	4	0	0	0	0	0	0	0	0	74±99
Aelosoma sp	48	0	0	0	0	0	0	24	0	0	0	0	36±17
Total Oligochaets	**661**	**310**	**378**	**110**	**254**	**112**	**78**	**427**	**130**	**412**	**160**	**582**	**276±194**
Molluscs													
Bellamya bengalensis	325	650	312	48	25	450	150	192	96	96	240	140	235±183
Brotia costula	325	475	312	212	48	212	238	120	240	312	48	456	231±138
Terabia	250	384	264	120	312	72	121	48	120	146	24	336	169±121
Total Molluscs	0	0	96	96	240	196	48	24	96	24	240	72	118±83
TOTAL BENTHOS	**900**	**1509**	**984**	**476**	**625**	**930**	**557**	**384**	**552**	**578**	**552**	**1004**	732±319

Table B-18. Monthly abundance of Benthos (ind/m^2) during third year in Dhanmondi lake

Species	Third year (April 2012 to March 2013) in Dhanmondi lake												
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Chironomids													
Chironomus sp	112	142	28	24	234	312	168	78	224	148	86	246	150±90
Total Chironomids	**112**	**142**	**28**	**24**	**234**	**312**	**168**	**78**	**224**	**148**	**86**	**246**	**150±90**
Oligochaets													
Lumbriculus sp	50	42	56	12	55	42	53	27	112	34	34	68	49±25
Nais sp	120	68	14	54	56	120	112	86	58	88	24	126	77±38
Tubifex sp	238	268	168	86	150	0	12	234	0	124	230	126	164±80
Chaetogaster sp	120	100	128	86	12	52	134	68	76	56	46	56	78±37
Branchiodrillus semperi	12	20	24	26	0	22	68	0	15	15	0	183	43±55
B. hortensis	124	40	68	121	22	13	42	34	0	12	36	0	51±41
Aelosoma sp	56	52	81	0	0	52	0	24	0	12	0	34	44±23
Total Oligochaets	**720**	**590**	**539**	**385**	**295**	**301**	**421**	**473**	**261**	**341**	**370**	**593**	**441±143**
Molluscs													
Bellamya bengalensis	250	324	258	132	22	234	234	156	96	124	68	148	171±89
Brotia costula	324	360	312	150	14	112	154	56	56	246	156	342	190±122
Terabia	212	384	156	182	256	12	86	112	232	156	88	251	177±99
Total Molluscs	30	130	126	112	134	54	127	136	58	68	168	72	101±43
TOTAL BENTHOS	**816**	**1198**	**852**	**576**	**426**	**412**	**601**	**460**	**442**	**594**	**480**	**813**	**639±237**