CHAPTER I

INTRODUCTION

Wetland of Nepal

Wetlands are complex ecosystem containing hundreds of species of microbes, plants, invertebrates, fish, amphibians, reptiles, birds and mammals. Wetlands are the transitional in position between open water and terrestrial system, providing major ecological benefit to the environment in terms of biodiversity, habitat for aquatic flora and fauna, hydrological regime through storage of large quantities of water to recharge ground water during dry season, sustaining local communities and economic activities providing wood, energy, food resources etc (Gurung and Pradhan 1992). Wetlands also serve as erosion/flood control, water purification, and shoreline stabilization. Wetlands are highly fertile and productive ecosystem in the world and bear high significance in terms of their ecological, economic, cultural and recreational values (Husain, 1993). The total areas of wetland have been estimated to be 900 million hectares in the world (Jan, 1992), out of which 150 million hectares lies in Asia. In Asia also, 80 percent or120 million hectares of wetlands exist in seven different countries like Indonesia, China, India, Papua New Guinea, Bangladesh, Burma and Vietnam. The remaining 20 percent is shared by other 17 countries of Asia. More than 500000 ha of wetlands are disappearing each year from Asia alone (Jan, 1992).

Water Resources of Nepal

Nepal is also rich in fresh water resources in forms of rivers, lakes, reservoirs, village ponds, marginal swamps, irrigated fields etc (Table 1).

Table 1. Estimated Water surface area in Nepal

Water resource	Estimated area (ha.)	Coverage (%)
Natural water		
Rivers	395,000	48.35
Lakes	5,000	0.61
Reservoirs	1,500	0.18
Village ponds	5,954	0.72
Marginal swamps, gholes	11,500	1.4
Irrigated paddy field	398,000	48.71
Total	816,914	100.0

Source: Directorate of Fisheries Development, 2001/2002

Rivers

There are about more than 6,000 rivers, rivulets and streams covering about 395,000 hectare or 48.35% of total water resource. Major rivers are - Karnali River System, Gandaki River System, Koshi River System and Mahakali River System. All the rivers of Nepal form the part of the headwaters of the Ganges River Basin (one of the 20 largest rivers in the world). Discharge from Nepal contributes about 40 percent annual flow of Ganges System and 70 percent flow in dry season.

Lakes

The estimated area of the world's total lakes exceeds 176000 km3. Some 40 percent of the total volume of fresh water is contained in Great lake basin. Most lakes and reservoirs are much smaller and relatively shallow usually less than 20m depth. Lakes are natural water reservoirs of various size scattered all over the Nepal covering an area of 5,000 hectare (i.e. 0.61 percent) of the total water area. Lakes are also classified as major and minor lakes. Some of the major lakes are - Rara or Mahendra Lake, Phewa Lake, Begnas Lake and Rupa Lake or Rupakot Lake. Some of the minor lakes are - Khaptad Lake, Baragon Lake, Tilicho Lake, Phoksundo Lake, Dudhpokhari Lake, Jageswar Lake, Panch Pokhari, etc. Lakes occur from southern low altitutde plain of about 60m to more than five thousand meter altitude (Jonnes et.al. 1989, Lami and Giussani 1998, Gurung and Wagle 2000). The lakes above 3300m are not affected by human encroachment while that of foot hills are affected by human activities. Based on the origin, these lakes are classified into three types: glacial lakes, tectonic and ox-bow lakes. There are 44 glacial lakes in the northern Himalayan region which are located above 4000 m. Tectonic lakes occur in the hilly region and the most of lake of Nepal are tectonic origin which when drained out were replaced by flat basins like Kathmandu valley, Pokhara valley, Banepa, Panchkhal, Mariphant (Palpa), Dang, Surkhet. In mid hills, the famous lakes are Phewa (523 ha), Begnas (328 ha) and Rupa (115ha). The age and origin of these lakes are not known. Oxbow lakes are mainly confined to the southern part of the country particularly between the middle to southern Terai region which indicates rives shift. More than two dozen ox-bow lakes are present in Nepal and most of them are located in Chitwan National Park, Nawalparasi, Bardiya and Kailali (Sharma, 1977).

Reservoirs

Reservoirs are built to collect water to generate hydropower and irrigation. There are run off and reservoir type of hydropower projects in Nepal and both of them produce reservoirs of small and large areas respectively. As a result numerous small and large reservoirs are built at different parts of Nepal; the total area of reservoirs is about 1500 ha comprising 0.18% of the total water area; but the potential for expansion of reservoir area is very high in Nepal as mentioned in master plan for both irrigation and hydropower development.

Water quality parameters

The physicochemical and biological characteristic of water plays a big role in plankton productivity as well as the biology of the cultured organism and final yields. In shallow ponds, the littoral zone supports a much greater number of different kinds of animals than the sub- littoral and profoundal zones. This is due to the fact that the littoral zone comprises the basic materials which compose the shore itself, modified by the action of water, by drift material, by plant growths and by organic deposits of more recent origin. The number of benthic fauna usually diminishes with increasing depths beyond the littoral zone.
Water quality determines the species optimal for culture under different environment. The overall productivity of a water body can be easily deduced from its primary productivity, which forms the backbone of the aquatic food chains. The plankton community is comprised of the primary producers or phytoplankton and zooplankton, the secondary producers. The phytoplankton population represents the biological wealth of a water body, constituting a vital link in the food chain. The zooplankton forms the principal source of food for fish within the water body. Both the qualitative and quantitative abundance of plankton in a fish pond are of great importance in managing the successful aquaculture operation as they vary from location to location and pond to pond within the same location even within similar ecological conditions. The physicochemical attributes of a water body are principal determinant of growth rates and development. Climate has a major influence on water quality and consequently, the biodiversity within the water bodies.

The physicochemical factors and nutrient status of water quality play the most important role in governing the production of plankton biomass and bear great importance for fish culture. But little information is available in Nepal on the seasonal variation of plankton and their relationship with the physicochemical parameters of water. Faunal and floristic diversity of wetland is influenced by several physicochemical parameters such as water transparency, velocity, depth, hydrogen ion concentration and nutrient. Measurement of physicochemical parameters is the best way to assess the water quality whether suitable to aquatic life or not.

Temperature: It affects the chemical and biological reaction in water. A rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odor and elevates metabolic activities of organisms. Temperature influences the rate of diffusion and carrier mediated uptake of nutrient by a factor of about 2 for each 10 degree centigrade rise up to optimum temperature and thereafter the rate of uptake declines.

Transparency: It means light penetration capacity of water and is inversely proportional to the amount of the total suspended solids. Compensation level (photosynthesis=respiration) or eutrophic limit lies on 2.5 times the transparency value, below which respiration is in excess of productivity.

Conductivity: It means the ability of the water to pass electrical current and high conductivity indicates significant amount of dissolved substances in water.

P^H: It is the measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. P^H is drastically changed with time depending upon the exposure to air, biological activities and temperature changes. A pH range of 6.5 to 8.2 is considered optimal for the most organisms.

Free CO_2: The free carbon dioxide of most aquatic ecosystem is seldom present in excess quantities because of its reaction in the carbonate equilibrium and exchange with the atmosphere. Carbon dioxide stands at the threshold of all production.

Alkalinity: It is its capacity to neutralize a strong acid and is characterized by the presence of hydroxyl ions. A number of bases viz. carbonate, bicarbonates, and hydroxides are predominant. In highly productive water, the alkalinity ought to be over 100ppm (Saxsena, 1989).

Hardness: It is the measure o calcium and magnesium ions. Hard water lakes are usually more productive than soft water lakes. Soft water ranges from 0-75 ppm of hardness and hard water from 150-300 ppm (Department of Fisheries and Wildlife, 1994).

DO (Dissolved oxygen): It is affected by many factors, viz. temperature, photosynthesis, respiration and salinity. Cold water can hold more dissolved oxygen than warm water. Low content of dissolved oxygen is a sign of organic pollution. A tolerance limit of dissolved oxygen is not less than 6.0 ppm (Kudesia, 1985). Dissolved oxygen level of 5 to 6 ppm is usually required for normal growth and activity. DO levels below 3.0 ppm are stressful to most aquatic organism and below 1 or 2 ppm will not support fish.

Plankton

The word plankton was coined by Victor Henson in 1887 which meant tiny forms of life found in aquatic systems. The locomotory power of plankton is feeble and they wander with the help of winds, currents and tides. The planktons are the free floating and drifting microscopic organism having almost neutral buoyancy. They are important components of water system and serve as the indicators of water quality and contribute as feed for fishes. These are three different categories viz. seston including both plants and animals origin, tripton includes floating and non-living matters and neuston includes community of flora and fauna of surface film. The planktons are mainly of two types, viz., phytoplankton and zooplankton. Planktons are classified into three types on the basis of size:

1. **Macroplankton –** Plankton which are visible to naked eye.

2. Mesoplankton – These can be collected by net made of no. 25 bolting silk cloth (mesh size 0.03 to 0.04mm).

3. Nanoplankton – These are too smaller, cannot be secured by no. 25 bolting silk cloth.

Phytoplankton

These are plankton of plant origin and include the members from Chlorophyceae (green algae), Myxophyceae (blue green algae) and Bacillariophyceae. The phytoplanktons are microscopic organisms measuring about 0.02 mm. in length. The green phytoplankton's are responsible for primary productivity and form the primary trophic level in an aquatic ecosystem. They are known as producer. Some of the phytoplankton are non-photosynthetic plants e.g., bacteria and fungi.

Zooplankton

They are of animal origin and form the link between the primary trophic level and tertiary trophic level of the aquatic ecosystem. The zooplankton feed on phytoplankton and in turn is consumed by tertiary level of organisms.

Some phytoplankton releases toxic substances like hepatotoxins or neurotoxins into the water and regarded harmful to aquatic organisms. The eutrophication is a phenomenon in shallow lakes affecting the community structure of aquatic ecosystem through physical and chemical alterations of the environment. Such changes may promote alterations in the quality and quantity of phytoplankton and available food for the zooplankton population. In freshwater systems, zooplankton may increase with increasing eutrophication and abundance and diversity of zooplankton may vary with limnological features and trophic state.

JUSTIFICATION

A lot of limnological study had been done in different parts but very few limited works had been done on limnological aspects of lotic and lentic conditions in Nepal. In that also, there was no such work done on water quality and plankton in famous Barakune Daha of Dang so far. The present study is focused on the physicochemical parameters, abundance and distribution pattern of plankton diversity in Barakune Daha.

LIMITATION OF THE STUDY

A regular sampling of Physico- chemical parameters and Plankton were carried out fortnightly for a period of only six month (June to November, 2008) from the two sites.

Amount of nutrient status and trophic level of Daha could not be found out due to lack of equipment and other facilities.

CHAPTER II

OBJECTIVES

General: The general objectives are as follows:

- To identify the existing species of plankton and their composition.
- To determine the species diversity of plankton in the lake
- To find out the correlation between physicochemical parameters and planktons.

Specific: The specific objective of present work is to collect baseline information on physicochemical parameters i.e. depth, transparency, temperature, pH, dissolved oxygen, free carbon dioxide, hardness, chlorides, total alkalinity and plankton diversity in Barakune Daha.

CHAPTER III

LITERATURE REVIEW

The term limnology is derived from the Greek word 'lime' meaning pool, marsh or lake. Limnology is the branch of science which deals with the study of structural and functional attributes of the lentic freshwater environment and problems associated with them. In the beginning of the 19th century, the study of lake and ponds were started. The lake as science started as early as1887 when the Forbes described the lake as a 'microcosm'-a little world within itself. Limnology was defined by Forel (1892) who had been known as father of limnology. He worked on Swiss Lake and published his book ' Le lemon' in three volumes. The first text book on Limnology was also published by Forel (1901). He wrote an inspiring book 'the science of lake' which provides as impetus for investigation on fresh water and many workers entered into this new field thereafter.

There are a lot of works done on aquatic ecology in other countries. Philipose (1940) studied ecology of plankton of three fresh water ponds of Madras city and later in 1959 he studied on fresh water phytoplankton of inland fisheries.

Brehm (1953) studied some aquatic fauna from Kalipokhari, eastern Nepal. Miller (1961) studied the plankton of Ranipokhari. But, Loffler (1969) did a pioneer detail work on limnological research like limnochemistry and plankton distribution from 24 high altitude lakes of Khumbu Himal. Shey Phoksundo, Gosaikund, other adjoining lakes and Panch Pokhari lakes adjacent to Mt. Gauri Shanker and reported phytoplankton but absence of aquatic macrophytes in these water bodies.

Chakrabarty *et al.,* (1959) studied the plankton and the physicochemical conditions of river Jumna at Allahabad. The zooplankton community was represented by rotifera, protozoa, copepoda, cladoceran and ostracoda. The rotifers were found to be dominant group followed by protozoa and crustaceans. The collections were made during the early morning, midday and in the night and vertical migration was noticed by the presence or absence of certain forms during the morning, midday, and night collections of the same day. The study shows that water quality, turbidity and temperature have an influence on plankton populations.

George (1961) made ecological observation on the physicochemical nature of water, zooplankton and rotifers of certain shallow ponds of Delhi. George (1964) studied on the limnology of pond plankton, micro fauna and chemical constituent of water and their relation on fish production. Michael (1964) studied limnology of plankton of fresh water lakes of West Bengal. Saha et al (1971) studied the seasonal and diurnal variation in the physicochemical and biological condition of a perennial fresh water pond in the India. Olive (1971) stated that pollution status of water body was related to diversity index of benthic organism in village Mansor. Hoenel and Johnson (1972) investigated the characteristics of Great Bear Lake in relation to productivity and phytoplankton biomass correspondingly with physicochemical parameters. Chang (1972) studied the phytoplankton succession in a eutrophic lake with special reference to blue-green algal blooms in Astotin Lake, Canada and found that blue-green algae bloom was at high summer water temperature and high concentration of organic matter.

Hickle (1973) investigated the lakes of Pokhara valley during his research scheme of Nepal and reported low electrical conductivity in mid hill lakes like Phewa, Begnas, Rupa and Khaste of Pokhara valley. Lake Phewa was reported oligotrophic during 1970 (Hickel, 1973) and but later reported as eutrophic in the early 1980s (Hamilton, 1983). Many zooplankton samples were collected from Nepal and taxonomical studies were done (Deans and Dumont 1974, Dumont 1976, Dumont and Vane 1977).

Grime (1973) and Van der Valk and Davis (1976) found that species richness increase gradually with decrease in water depth. However, according to Van der Valk et al. (1983), the fluctuation in water level does not have same consequences for many wetland species. When mean water level was lowered, all species were able to shift down slope rapidly through a combination of clonal growth and seed germination. Study on moist bank community of Banghela tank, Udaipur, India showed that highest number of species occurred in September, while lowest number of species in March and April.

Kant and Kachroo (1975) recorded the diurnal change in the temperature and pH of water and diurnal movement of plankton in Dal Lake of Shrinagar. Holman et al (1975) studied the chemical and biological characteristics of water column in Lake Tohae. Rao (1977) investigated the ecology of certain phytoplankton of three fresh water lakes of Hyderabad. Kaul et al. (1978) observed that fresh water macrophytes had more dominant influence upon the physicochemical characteristics of water. The dense growth of aquatic macrophytes was mainly due to high nutrient level in water. Singh et al. studied the physicochemical characteristics of shallow water lakes during 1977-78 in Kumaon, India. The fluctuation of water level resulting from interaction between rainfall and evapo-transpiration had a noticeable effect on the water chemistry, essential pH. The pH of the water was alkaline in Nainital and in Naukuchital (above 8.0 for most part of the year) except for some parts during the winter in Nainital (6.9).The study showed Nainital eutrophic, Nauckuchital oligotrophic and Bhimtal mesotrophic.

More detailed works were carried out on different limnological/ biological aspects of the lakes of Pokhara Valley later (Ferro and Swar 1978, Ferrow 1978, Swar 1978 and Swar and Fernando 1978). Swar and Fernando (1979) recorded 39 species of cladocera showing a mixture of tropical and temperate species types.

Studies on the zooplankton diversity in the evaluation of the pollution status of water bodies were carried out by Khan and Rao (1981). The potential effects of thermal pollution, nutrient enrichment in eutrophication, interaction of ions, toxic substances like heavy metals, halogens, solids, reducing agents, and radioactive wastes on aquatic protozoan communities had been studied. Rotifers were found to be more sensitive to pollution than other groups of zooplankton. Among crustaceans, cyclopoids and cladoceran were found to be associated with increasing productivity. The ratio of calanoids to cyclopoids plus cladoceran was found to be good indication of trophic condition and valuable index of pollution.

Mahajan (1981) made preliminary studies of the identification of species among the zooplankton community, which could serve as indicators of different types of pollution. Species of zooplankton which could serve as indicators of thermal pollution and stress pollution, Eutrophication, Heavy metal pollution, Pesticidal pollution and miscellaneous pollution activities were studied. Toxicity tests conducted for the selected species indicate, different groups of zooplankton were found to be sensitive to different types of pollutants.

A preliminary study of Syarpu Daha (Rukum), a mid hill lake of Nepal was done by Pradhan (1982). Some limnological survey on Lake Rara, a deep Himalayan lake was conducted by the Integrated Fishery and Fish culture Development Project, Pokhara, Nepal (Ferrow 1976).

Handoo and Kaul (1982) found that the density of plankton decreased rapidly after September with the onset of cold weather in one site while it decreased from June to September in other three sites in four wetlands of Kashmir. The study also showed a gradual increase in species richness from 1.2 to 4.76 with decrease in water depth. Abundance, diversity and distribution of benthic animals were related to various physicochemical and biotic factors (Dutta and Malhotra, 1986).

The zooplankton diversity of four village ponds - Kadagrahara, Karpur, Side Hoskote and Chembenahalli in Bangalore district of Karnataka, was studied by Rao et al., (1982). Zooplanktons were found to be abundant when compared to phytoplankton. Protozoa were found to be richer in variety where as some of the rotifers were found to be high in numbers in all the ponds and poorer representation of the cladoceran in Kadagrahara, Chembenahalli and Karpur ponds because of the high concentrations of ammonia (10-20 mg/L).

Rao *et al.*,(1982) studied the physicochemical parameters and zooplankton diversity of perennial tank, Hutchammankere located near Anekal in Bangalore district for the period of two years. Zooplankton community constituted of Protozoa (43.09%), Rotifera (39.29%), Cladocera (2.22%), Copepoda (15.21%), Ostracoda (0.80%) and Nematodes (0.18%). Increase in temperature was found to be favourable for zooplankton multiplication. Turbidity was found to affect phytoplankton production but had less influence on zooplankton. Thus an inverse relationship was obtained between phytoplankton and zooplankton in relation to turbidity. An inverse relationship was observed between phytoplankton and zooplankton because of the grazing effects of zooplankton over phytoplankton.

A study on plankton and a few physicochemical features of Milghatta and Hutcharayangere tanks in the Malnad region of Karnataka was done by Sukumaran *et al.*, (1984). The zooplankton encountered includes Protozoa (3.54%), Rotifera (2.23%), Cladocera (3.15%), and Copepoda (15.41%) in Milghatta tank. The population in the

Hutcharayankere tank was very low compared to that of Milghatta tank. In Hutcharayankere tank, Copepods where the dominant groups (16.54% of the total plankton), whereas other groups were rare in occurrence. Since the tanks were low in nutrients these tanks were oligotrophic and hence less productive. The low nutrient content in these tanks to the red soil present in the region, which had low nutrient and organic matter, and also due to aquatic vegetation that takes up nutrients.

Barbato (1983) studied on the physicochemical characteristics of water and its plankton, benthic and fish production in Italy. Kohl (1986) did some limnological works on seasonal variation in plankton population of some fresh water lakes in Patna and Bihar. The abundance, diversity and distribution of benthic animals are closely related to various physicochemical and biological properties of aquatic environment (Dutta and Malhotra, 1986). Studies on some limnological aspects of selected closed water ecosystem of Udaipur, India were done by Karki (1988). Sheavely and Marshall (1989) studied the phytoplankton and water quality relationship within the eutrophic zones of lake. They observed the diatom and chlorophyceae more abundant during cooler part of spring than winter while cynophyceae were the characteristics of summer and early fall. Diatom abundance was also found high at lower water temperature, high nitrite, silica and oxygen levels.

Nakanishi (1986) categorized the lake Phewa as meso-eutrophic and lake Begnas and Rupa as eutrophic on the basis of total phosphorus and total nitrogen concentration. Baur and Baur (1988) have conducted several survey works in wetland of Nepal for biological diversity analysis. Pradhan (1998) carried out a study on aquatic weeds of Lake Rupa.
Swar and Gurung (1988), Swar and Pradhan (1993), Jones et al (1994), FRC (1994) in Pokhara, Nakanishi (1994) and IUCN (1996) did limnological studies on Lake Rupa including physico-chemical parameters and planktons and have reported 14 species of Zooplankton and 11 species of phytoplankton. Richness in Nitrogen (nitrite and ammonia) and orthophosphate favored the growth of phytoplankton in Taudaha Lake (Bhatta et al. 1999).

Venkataraman (1995) reported on the cladocera males of Indian region. The Cladoceran samples were collected in Tamilnadu, Rajasthan, Andaman and Nicobar Islands and West Bengal from various types of habitat such as rice fields, marshes, ponds, lakes, reservoir, streams, and rivers. A total of 16 species of freshwater Cladoceran male were reported in the study. In tropical and subtropical latitudes of India, males appear for a very short period and in small numbers. The adult males were not found to be similar to adult females, however, juveniles of males were found to have some similarity.

Zooplankton community structure and its relation to physicochemical parameters in lake Tasek, a tectonic lake in Garo hills, India was investigated by Das *et al.,* (1996)**.** Shannon diversity index (H'), Evenness index (J) and Species Richness index (S) were calculated. About 18 taxa of zooplankton were recorded of which 3 each belonged to Copepods and Cladoceran, 10 to Rotifers and 2 to protozoa. The correlation analysis among diversity, evenness and richness values revealed close relationship between H' and J, but neither was related to S. Evenness (J) was negatively correlated to zooplankton density, but

Species Richness was positively correlated. Zooplankton densities were found to exhibit significant positive relationships with phytoplankton densities, pH and alkalinity. Low values of conductivity, alkalinity, nitrates and phosphates found in Lake Tasek were suggestive of its oligotrophic nature. The abundance of copepods also indicated the stable environmental conditions. Since zooplankton densities exhibited the significant positive relationships with phytoplankton densities, pH and alkalinity, these variables were the important factors governing the abundance of zooplankton in Lake Tasek.

Chakrapani (1996) compared the zooplankton diversity and physicochemical analysis of both urban and non-urban lakes. 19 urban and 24 non-urban lakes were selected for the study. The zooplankton diversity of some of the urban and non-urban lakes was compared with the earlier study. The changes in the populations have indicated the influences of pollution on these lakes. Biological analysis indicated that lakes such Anekepalya, Bellandur, Chilkkahulimam, Harohalli, Kengeri, Kalkere, Nagavara, Nelamangala, Puttenahalli, Rachenahalli, Rampura, Tavarakere, Ulsoor, Varthur, Vengaiah, Yellahehalli, and Yellamallappuchetty were threatened ecologically and unsuitable for human usage.

Chakrapani (1996) studied the plankton diversity of Sixty one lakes of Bangalore and report zooplankton falling under five major groups - protozoa, rotifera, cladocera, copepoda and ostracoda. Fourteen forms of protozoa, twenty nine forms of rotifera, six forms of cladocera, four forms of copepoda and five forms of ostracoda were recorded. On the overall sixty two forms of zooplankton were observed including five unidentified forms. The appearance of intermediary stages of *Rabditis* species in five lakes indicates the presence of potential human parasites.

Alam and Khan (1998) reported the first record of cladoceran *Leydigia acanthocercoides* (Family: Chydoridae) from Aligarh, Uttar pradesh. 9 species belonging to 6 genera had been recorded. The female organism of Leydigia *acanthocercoides* had been described giving the characters of taxonomic importance. The species were found to inhabit the aquatic weeds in polluted ponds.

Seasonal distribution of the population structure of zooplankton was studied in connection with physicochemical parameters in an experimental perennial fish culture pond in Calcutta, West Bengal by Sarkar and Choudary (1999). 17 species under 13 genera of zooplankton was observed. Rotifers expressed superiority in the species richness followed by cladoceran and copepods. However, the cladocera was found to be the most abundant group followed by copepods and rotifers. Shannon index for zooplankton was found to vary in the pond. A significant multiple correlations involving the fluctuations of zooplankton number and concentration changes of dissolved oxygen, temperature, total alkalinity, total nitrogen, phosphate and pH were found. Thus, the study confirms the influence of these abiotic factors on zooplankton population.

Venkataraman (1999) studied the freshwater cladocera of southern Tamilnadu. Plankton net was dragged among the vegetation close to the bottom of the shallow waters in marshes to collect zooplankton. Oblique hauls were taken from the shores of manmade reservoirs and ponds. The study revealed the occurrence of 46 species of cladoceran belonging to 23 genera and 5 families. 5 species of *Daphnia* were observed, which were considered as limnetic cladocera found in temperate region. The study shows that temperature plays an important role in the species diversity and species size of cladocera.

Pandit (1999) studied the zooplankton diversity and analysed the general trophic structure of the plankton community in five different wetlands of Kashmir. Among the 141 species of zooplankton observed were 61 species of protozoa, 29 species of rotifers, 35 species of cladoceran, 13 species of copepoda and 3 species of ostracoda. The scheme depicting the generalized type of food web prevalent in the wetland with respect to zooplankton had been formulated. The study revealed the gradual decrease in the number of zooplankton species and increased primary productivity due to eutrophication. The eutrophication affected the species composition, biomass and structure of zooplankton community thus leading to rapid increase in the both density and biomass of phytoplankton community as compared to herbivores.

Rai (2000) carried detailed study on limnological characteristics and seasonal abundance of zooplanktons and phytoplankton from three major lakes viz. Phewa, Begnas and Rupa lakse in Pokhara valley and reported 26 species of phytoplankton and 18 species of zooplankton in Rupa.

Freshwater cladoceran of Andaman and Nicobar islands was studied by Venkataraman (2000) in a total of 106 freshwater habitats which include ponds, marshes, reservoirs, rice fields, dams, streams, rainwater pools. The zooplankton samples were collected by dragging the net close to the bottom among vegetation and clear water. 38 species belonging to 21 genera of 5 families were observed of which 24 were chydorids and 14 nonchydorids. The selected 7 stations were compared by the Sorensen index of similarity and Koch index of biotic diversity. The indices from Andaman group of islands were found to be high which inturn indicated the small number of species involved and their wide distribution. However, the indices for the Nicobar group of islands were found to be comparatively lower because of the influence of erratic occurrence of eurytropic species such *Moina micruta, Ceriodaphnia cornuta* and *Macrothrix spinosa.* The cladoceran proliferation was found to be affected during rainy season.

Venkataraman et al., (2001) studied the faunal diversity of the wetlands in the Indian Botanical Garden, Haora, West Bengal. About 55 species of zooplankton belonging to 6 different groups - Hydrozoa (1 species), Copepoda (4 species), Ostracoda (5 species), Cladocera (38 species) Conchosraca (1 species) and Rotifers (3 species) had been observed. Larger Cladoceran, *Daphnia* species were not recorded in the study because of high predation pressure by fish and macroinvertebrates. Due to increasing utilization of wetlands of Indian Botanical Gardens for pisciculture and due to other anthropogenic interferences, the bioaquatic environments of these lakes had been rapidly altered. The faunal diversity was dependent on the plants as well as the size of the wetland concerned and inversely related to anthropogenic activities.

Plankton abundance in relation to physicochemical features of Mancharibele reservoir in Bangalore district was studied by Sukumaran and Das (2002). Zooplankton population was found to comprise of four major groups, which include protozoa, rotifera, cladoceran and copepoda. Protozoa were represented by *Arcella, Centrophyxis* and *Difflugia* species. However, the numbers were found to be less. Rotifers were found to be the second dominant group and were represented by a large number of species and genera. Cladoceran density was less when compared to rotifers and six species were observed. Copepods were found to be represented mainly by *Diaptomus* and *Cyclops* nauplii. They were found to be the dominant group among the zooplankton. The optimal temperature requirement varied for different groups of zooplankton suggesting their abundance in different seasons. The high chloride content and temperature were also found to favour zooplankton abundance.

Das (2002) studied the dynamics of net primary production and zooplankton diversity in brackish water shrimp culture pond in northern part of Ganjam district, Orissa. Significant negative correlation was noticed between net primary production and zooplankton population. Copepods and rotifers were found to be the dominant groups among zooplankton. The zooplankton population varied with different seasons of the year with rainy and summer seasons showing the minimal density in zooplankton population.

Sinha (2002) reported the first record of cladoceran *Bosmina tripurae* from wetlands of Botanical gardens, Guwahati, Assam. The species was found to occur in association with other cladoceran namely *Daphnia species, Ceriodaphnia species, Moina species,* and *Simocephalus species.* The female organism of *Bosmina tripurae* had been described giving the characters of taxonomic importance. The study reveals the species extension in Assam, which had earlier been reported from Tamilnadu.

Banik (2002) reported 2 species of genus Collotheca (Collotheca *tetralobata* and *Collotheca hexalobata)* from the littoral regions of shallow water wetlands of Agartala, Tripura. *Collotheca tetralobata* was reported to differ from closely resembling *Collotheca ornata* by the presence of 2 longer lobes and 2 shorter lobes, paired lateral antennae, very long holdfast and interlobal cilia and the absence of pentagonal arrangement of 5 short lobes and much reduced holdfast. *Collotheca hexalobata* is characterized by the presence of 6 lobes, longer holdfast and its broad and oval base and by the absence of pentagonal arrangement of tubular lobes, interlobal cilia, greatly reduced holdfast with small and round base and a transparent lorica. The species, its ecological characteristics like physicochemical conditions of water, plant substrata preference and seasonal occurrence had been recorded. The species mostly occurred during summer and only one individual was recorded during winter.

Hydrobiological studies of Lake Mirik in Darjeeling, Himalayas was done by Jha and Barat (2003). Qualitative analysis of zooplankton was carried out and cladoceran and copepods were the groups, which were found to represent the zooplankton community. Among the copepods *Cyclops* was found to be the most abundant zooplankton followed by *Phyllodiaptomus* and among the cladoceran *Moina, Daphnia, Bosmina* were recorded. The pH of the lake was found to be acidic in nature and other physicochemical parameters and plankton analysis confirmed that the lake was polluted due to contaminants let into the lake, though the values were diluted due to heavy monsoons. Thus the study indicates that the lake cannot be used as a scarcity alternative for drinking water supply

Raut and Pejaver (2003) studied the rotifer diversity of three macrophytes infested lakes from Thane city, Maharashtra that include Lake Ambegosale, Lake Rewale, Lake Makhmali. Rotifera with 19 species belonging to 9 genera were obtained. This was compared with uninfested lakes in which only 10 species belonging to 6 genera were obtained. The study shows that the macrophytes help to increase the diversity of rotifers and rotifer population varied between mesotrophic and oligotrophic lakes.

Zooplanktonic diversity of 6 ponds of Durg-Bhillai city, Chhatisgarh state was studied by Anil kumar *et al.,* (2004). Rotifers and copepods were found to be predominant group. The rotifers were represented by 5 species of *Brachionus* and 1 species of *Tesdinella*, indicating eutrophicated status. Copepods were mainly dominated by *Mesocyclops* species and cladoceran, the least abundant group comprises *Moina* species and *Ceriodaphnia* species. Ostracods were also observed in their collection with *Cypris* species being the dominant organism. Ostracods were also found to show diurinal variation between day (206 organisms/m^3) and night samples (555 organisms/m^3). The predominance of rotifers and copepods indicate the nutrient availability in these ponds.

A study on the physicochemical limnology and productivity of Jaisamand Lake, Udaipur was conducted by Sharma and Sarang (2004). The zooplankton density for Rotifers, Cladoceran and Copepoda varied from 13 to 233 organisms per liter. Comparison with earlier work shows of 49 species of zooplankton in 1980-82. Present record of 21 species indicates the decline in the diversity of zooplankton in the Jaisamand Lake. A positive correlation of water clarity with pH, total alkalinity, Electrical Conductivity, net primary productivity and gross primary productivity was observed whereas; a negative relationship was found for free carbondioxide and nitrate. The decline in zooplankton population in the lake was due to the predatory effect of fish species tilapia.

Awasthi and Tiwari (2004) studied the seasonal trends in abiotic factors in Lake Govindgarh, Rewa, Madhya Pradesh. An inverse relationship was observed between dissolved oxygen and temperature. The lake was perennial and alkaline in nature. The parameters found to show marked seasonal variations include temperature, transparency, pH, dissolved oxygen, free carbondioxide, alkalinity, calcium, chloride, nitrite and phosphate. The study revealed that Govindgarh Lake was polluted.

Pandey *et al.,* (2004) studied the seasonal fluctuation of zooplankton community in relation to physicochemical parameters in river Ramjan of Kishanganj, Bihar. The collections were dominated by rotifera, followed by cladocera and copepoda. Rotifera showed a negative correlation with pH, dissolved oxygen and transparency and copepods showed negative correlation with water temperature, nitrate and phosphate. The cladoceran also revealed negative correlation with pH, transparency and phosphate. This indicated several abiotic factors exert a considerable influence on the zooplankton abundance.

Sunkad and Patil (2004) assessed the water quality of Fort lake Belgaum, Karnataka. Zooplanktons were represented by four groups, which include Rotifers, Cladoceran, Copepods and Ostracods. Rotifers were found to contribute to the zooplankton richness of the Fort Lake accounting 52.38% followed by copepoda 26.5%, Cladoceran 16.45% and Ostracods 4.67%. The dominance of rotifers in the lake was due to the continuous supply of food material which inturn indicates the eutrophic nature of the lake. The level of phosphates in the lake was high (7.2 to 13.6 mg/L) due to the entry of sewage into the lake and hence supported the cause of eutrophication. Hence the lake was highly unsuitable for drinking water purposes.

Patil and Shrigur (2004) studied the morphology and identification characteristics of four copepods species namely *Thermocyclops crassus, Mesocyclops leukarti, Apocyclops royi* (order cyclopidae) and *Eudiaptomus gracilis* (order Calanoida and family Diaptomidae). The study was conducted in government fish farm, Goregaon, Mumbai. *Eudiaptomus gracilis* and *Apocyclops royi* were the first record for Mumbai.

Whitman *et al.,* (2004) characterized the Lake Michigan coastal lakes using zooplankton assemblages. Zooplankton assemblages and water quality were examined in 11 northeastern Lake Michigan coastal lakes of similar origin but varied trophic structure and limnological condition. Zooplankton samples were collected by vertical tows from 1 m from the lake bottom to the surface using a Wisconsin net. A total of 85 taxa were identified from 11 study lakes. The Shannon diversity index ($\log_e$) based on the lakes averages ranged from 2.07 to 2.29. Strong correlations were observed between differences in lake trophic status and zooplankton community. The rotifers were found to

Zooplankton diversity in five major coalfields areas in Jharkhand was studied by Saha (2004). Seventy species of zooplankton were recorded in this study. Cladoceran and rotifer were abundant groups (9 species each) followed by seven species of copepoda, and one species of ostracoda. The species were resistant to coal dust and indices for richness, diversity and evenness of the zooplankton did not present a trend in the dynamics of the plankton community. The evenness (J) showed insignificant relationship with species diversity index (H'), species richness (S) showed negative relationship with species diversity index values. The overall diversity of plankton was low due to high alkalinity of water due to fly ash deposition.

CHAPTER IV

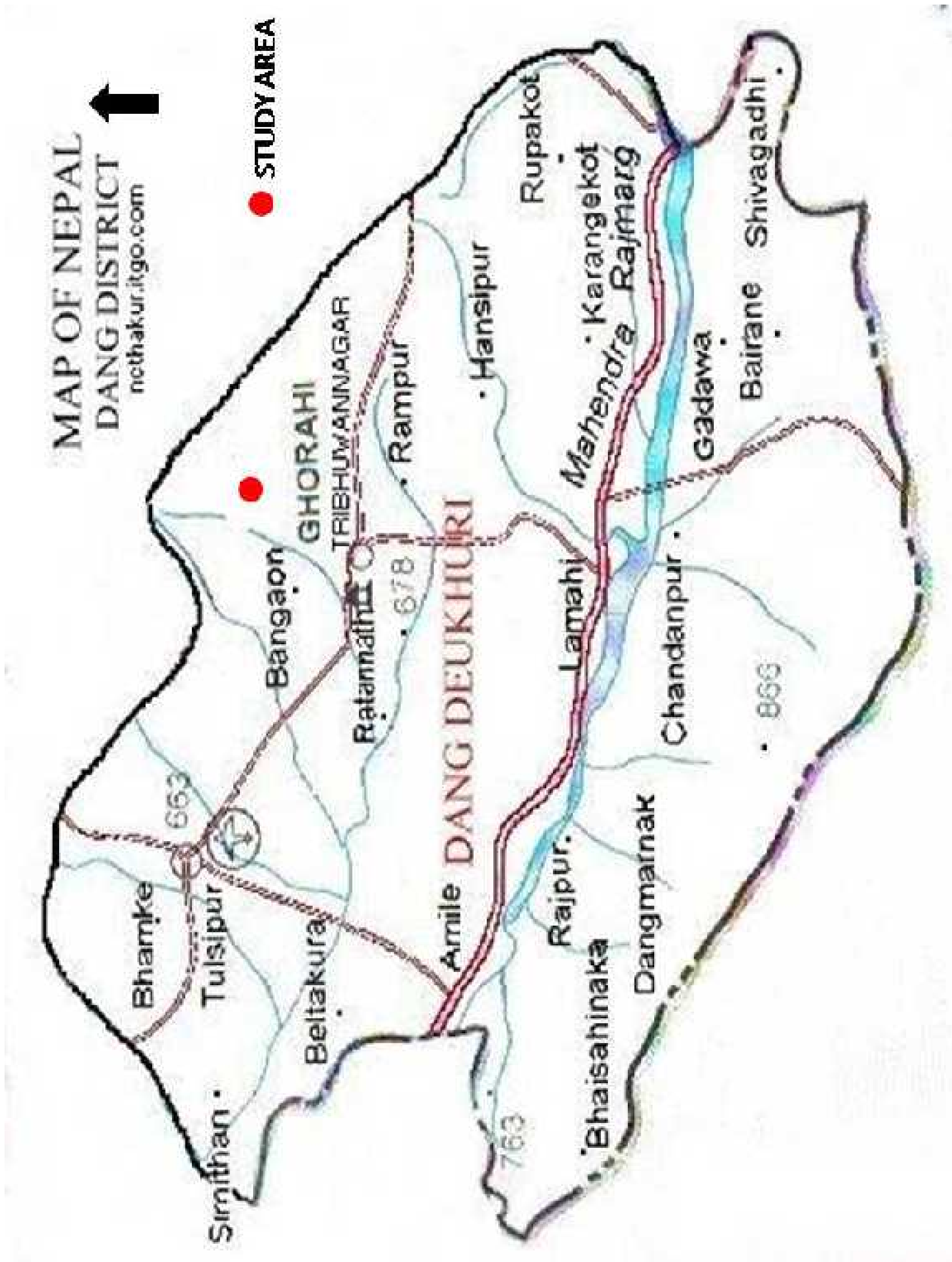
MATERIALS AND METHODS

Reconnaissance survey

Barakune Daha was visited during 5-8 May, 2008 and categorized the lake area into two stations before carrying the detailed study in the stations. Site A was selected towards east side of the Daha, on the basis of human disturbance i.e. washing clothes and bathing and this site was little shallower than site B. From the site A, the wall of Daha was eroded to some extent during rainy season and thereby helps to fill in the deeper parts of the basin. Site B was selected towards the west side of the Daha near the outlet of the pond .Human interference at this site was less and slightly deeper than site A. Research was carried out from June 2008 to November 2008 over a period of 6 months. Each station of the study area was visited fortnightly to carry out detailed study.

Description of the study Area

Barakune Daha is famous water body for its cultural, historical, religious and tourist point of view. It is situated in Gorahi municipality about 3 km north- west side of Gorahi Bazaar, the headquarter of Dang district. It is located at the latitude 28^o 4'15N and longitude 82^o 29'50^{o}E. The area around it is protected by "Baraha Khetra Ban Upobhokta Samitee". The Daha is a permanent water body and has underground and rain water as water source. The pond is rectangular in shape and has a total area about 1.0 ha and average depth of 1.2m.The experimental pond was surrounded by trees and sunlight was obstructed in day time also. In the 1990/92, Daha occupied an area of about 5ha.


MAP OF NEPAL
DANG DISTRICT
ncthakur.itgo.com
STUDY AREA
GHORAHI
TRIBHUWANNAGAR
Bangaon
Rampur
Hansipur
Rupakot
Karangekot
Mahendra Rajmarg
Gadawa
Bairane
Shivagadhi
DANG DEUKHURI
Lamahi
Chandanpur
866
678
663
Tulsipur
Bhamke
Beltakura
Amile
Rajpur
Bhaisahinaka
763

Sampling of Physicochemical parameters

For the chemical analysis of water, water samples were collected from the surface layer.

Colour

A small amount of pond water was taken in a petri dish for the judgment of color of the pond water. The Petri dish with water was kept on a white paper and then the color of the water was examined.

Depth

The depth of the pond was measured by using a long nylon rope which was tied with appropriate weight at its one end. The nylon rope along with the weight was lowered in the water body till it touched the bottom. The length of the rope which was just inside the water was measured with the help of the measuring tape (m). The depths of three different stations were recorded and the mean depth was found out.

Temperature

The temperature was measured by using a standard mercury thermometer graduated up to 50^0C with a precision of 0.10^oC. The temperature of the surface water was measured by simply by dipping the bulb of the thermometer into the water body of the pond. While taking the reading precaution was taken that the sunlight does not fall on the thermometer. The air temperature was recorded by keeping the thermometer for two minutes under a shady place.

Transparency

The transparency of the water of the pond was measured with the help of secchi disc. This disc was discovered by an Italian scientist secchi (1865) for studying the transparency of the aquatic bodies. The secchi disc is a metallic plate of 20 cm diameter and on its upper surface is painted with four alternate black and white quadrants. At the centre of this disc there is a hook to tie a graduated rope. The arithmetical mean of the distance at which the disc disappeared from view of descent and that at which it reappeared in ascent was noted as secchi disc transparency. The actual reading was taken by means of just appearance and reappearance of the disc. The underwater was measured with the help of a measuring tape and expressed in cm and noted as visibility depth.

Turbidity

Turbidity is inversely proportional to the transparency and is directly proportional to the amount of suspended organic and inorganic matters. Hence, the turbidity of the pond water was calculated by using transparency value into the following equation (Mistui, 1957).

Turbidity(X) =1000/1.568Y-1.275

Where,

X = Turbidity.

Y = Transparency value.

Dissolved oxygen (DO)

The dissolved oxygen was measured by using Winkler's method. 300ml of water was taken in BOD bottle from each station while filling it precaution was taken that no air bubbles entered with water sample in the oxygen bottle. Then 2 ml each of manganous sulphate and alkaline KI solution was poured in the bottle well below the surface from the walls and a brown precipitate was appeared. After that 2 ml that 2ml of conc. H_2SO_4 was added to dissolve the brown precipitate by shaking the BOD bottle.100ml of solution was taken in a conical flask and was titrated against standard sodium thiosulphate solution using starch as an indicator. At the end point, initial dark blue colour changes to colorless. The final calculations were made by following formula.

$$\text{Dissolved oxygen, mg/l} = \frac{\text{(ml x N) of titrant x 8 x 1000}}{V2\,\frac{(V1 - V)}{V1}}$$

Where, N = Normality of the titrant.

V1 = Volume of the sample bottle after placing the stopper.

V2 = Volume of the part of the contents titrated.

V = Volume of mangnous sulphate and potassium iodide added.

The chemicals used for the determination of dissolved oxygen were prepared in the laboratory in the following way:

a) $MnSO_4$ solution: Weighted gently 120 gm of $MnSO_4$.H20. It was dissolved in double distilled water and the volume was made to 250 ml. by adding double distilled water. It was then filtered through ordinary filter paper and kept in polythene bottle.

b) Alkaline iodide solution: 100 gm of KOH and 50 gm of KI were weighed and dissolve in 200ml of boiled distilled water.

c) Sodium thiosulphate ($Na_2S_2O_3$) solution 0.025N: Weighed gently 6.205 gm. of $Na_2S_2O_3.5H_20$ and was dissolved in freshly boiled and cooled distilled water and the volume was made to 1litre.

d) Starch solution: 1gm. of starch powder was weighed and dissolved in 100ml of warm distilled water and a few drops of formaldehyde solution.

Free carbon dioxide

For the measurement of carbon dioxide, 50 ml. of water sample was taken in a beaker and titrated against 0.045 N (Na_2CO_3) sodium carbonate solutions from the burette using 2 drops of phenolphthalein as an indicator. After adding 2 drops of indicator, the water sample became colorless which indicated that the CO_2 was present in that water sample. Then it was titrated with Na_2CO_3) solution till a faint pink color end point was just seen. The final calculations were made by the given formula.

$$\text{Free } CO_2\text{, mg/l} = \frac{\text{Volume of Na0H used x NaoH normality x 1000}}{\text{Volume of sample taken}}$$

The chemicals used for the determination of dissolved oxygen were prepared in the laboratory in the following way:

a) Sodium hydroxide, 0.05N: Weighed gently 40 gm of NaOH and dissolved it in 1 litre of distilled water to make 1.0N NaOH. Then dilute 50 ml of 1.O N NaOH in 1 litre and standardize it with H_2SO_4, HCL or Oxalic acid.
b) Phenolphthalein Indicator: 0.5 gm. of phenolphthalein was weighed and dissolved it in 95% of ethanol and 50 ml. distilled water was added and to it 0.02N NaOH was added drop wise until a faint pink color appeared.

Total Alkalinity

50 ml. of sample water was taken in a conical flask and 2 drops of phenolphthalein indicator was added to it. If the sample remains colorless, it indicates the absence of total alkalinity. Then immediately 2 or 3 drops of methyl red bromocresol green indicator was added in the same flask and was titrated against sulfuric acid (0.02) until the color changed from yellow to orange. Total volume of the titrant used for both the titration is total alkalinity.

$$\text{PA as } CaCO_3\text{, mg/l} = \frac{\text{(A x Normality of HCl) x 1000x 50}}{\text{ml of sample}}$$

$$\text{TA as } CaCO_3\text{, mg/l} = \frac{\text{(B x Normality of HCl) x 1000 x50}}{\text{ml of sample}}$$

Where, A = ml of HCL used with only phenolphthalein
B = ml of total HCL used with phenolphthalein and methyl orange
PA = Phenolphthalein alkalinity
TA = Total alkalinity

Concentration of carbonates ($C0^{3--}$), bicarbonates ($HC0^{3-}$) and hydroxyl ions ($0H^{-}$) were determined as mentioned in the table 2 using data of PA and TA

Table 2. Values of Hydroxyl ions, Carbonates and Bicarbonates from the values of Phenolphthalein and Total Alkanities.

Result of titration	$0H^{-}$ alkalinity as CaC03 (ppm)	$C0^{—3}$ alkalinity as $CaC0^{3}$ (ppm)	$HC0^{3-}$ alkalinity as $CaC0^{3}$ (ppm)
PA = 0	0	0	TA
PA < 1/2 TA	0	2PA	TA-2PA
PA = 1/2 TA	0	2PA	0
PA > 1/2 TA	2PA-TA	2 TA-PA)	0
PA = TA	TA	0	0

Where, P = Phenolphthalein alkalinity
T = Total alkalinity

The chemicals used for the determination of Total alkalinity were prepared in the laboratory in the following way:

a) Sulphuric acid titrant (0.1N): Diluted 2.8ml of concentrated sulphuric acid to 1 litre using distilled water to get 0.1N sulphuric acid.

b) Methyl orange indicator, 0.05%: Dissolved 0.5 g of methyl orange in 100ml of distilled water.

c) Phenolphthalein Indicator: Dissolved 0.5 g of phenolphthalein in 50ml of 95% ethyl alcohol. Added 50ml of distilled water and 0.02 N sodium hydroxide drop wise till a faint pink colour appeared.

Hydrogen ion concentration (P^{H})

P^{H} is defined as the intensity of the acidic or basic character of a solution at a given temperature. P^{H} is the negative logarithm of hydrogen ion concentration. $P^{H} = - \log [H^{+}]$. P^{H} values from 0 to 7 are diminishingly acidic, whereas values of 7 to 14 are increasingly alkaline. The pH of natural water usually lies in the range of 4.4 to 8.5. For measuring the pH of water sample a digital P^{H} meter was calibrated with pH 7 buffer solutions (HI 777P) and the instrument was immersed in a well-mixed sample and readings were noted down.

Total Hardness

The total hardness was determined by versanate (EDTA) method using eriochrome Black T as an indicator. 50 ml. of water sample was taken in a conical flash and to it added 1 ml. of Ammonia-Buffer solution and 150 mg. of eriochrome Black T indicator. The solution turned wine red and the content was titrated against 0.01n EDTA solution from the burette. The titration was continued with constant shaking of the conical flask till the color changed from wine red to violet or bright blue. The calculations were made by using the following formula:

$$\text{Total hardness as } CaC0^3\text{, mg/l} = \frac{\text{ml of EDTA x 1000}}{\text{ml of sample}}$$

The chemicals used for the determination of total hardness were prepared in the laboratory in the following way:

a) Buffer solution: i) 16.9 gm. of Ammonium chloride (NH_4Cl) was dissolved in 143 ml. of Ammonium hydroxide (NH_4OH).

ii) 1.179 gm. of disodium salt of EDTA and 0.780 gm. of $MgSO_4.7H_2O$ were dissolved in 50 ml. of double distilled water.
Solution (i) and (ii) were mixed and diluted to 250 ml. by adding double distilled water.

b) Eriochrome Black T- indicator: 0.40 gm. of eriochrome Black-T was mixed with 100gm. of NaCl and then grinded in a mortar. It was then preserved in a neat and clean bottle.

c) EDTA solution, 0.01N: Weighed gently 3.723 gm. of disodium salt of EDTA and dissolved in double distilled water. The volume was made to 1 litre and stored in clean polythene bottle.

Chloride

About 50ml of water sample was taken in a conical flask and 2ml of potassium chromate indicator was added. The solution was titrated against standardized silver nitrate until a brick red colour precipitate of silver chromate started precipitating. The volume of silver nitrate consumed was noted down.

i) Silver nitrate, 0.02N:

3.400g of dried silver nitrate is dissolved in distilled water to make 1 litre of solution and keep in a dark bottle.

ii) Potassium chromate, 5%:

5gm of potassium chromate was dissolved in 100ml of distilled water.

Calculation:

$$\text{Chloride, mg/l} = \frac{(\text{ml} \times \text{N}) \text{ of AgNo3} \times 1000 \times 35.5}{\text{ml sample}}$$

Sampling of Water for the identification of Plankton

Plankton collection

For the estimation of planktons, 40 lit. of surface water was collected by using a plastic bucket. The surface water was filtered through plankton net having bolt silk no. 30 with mesh size 25mm and 60µ diameter. The final volume of water was 60 ml, remained at the cap of plankton net. The sample was transferred to another 100 ml plastic bottle and labeled mentioning the time, date and place of sampling site.

Preservation and Sedimentation

Preservation of the samples before analysis was done by addition of 5% formalin and 1ml of Lugol's solution added per 100ml of sample for sedimentation in small plastic bottles. The samples were brought to the laboratory of Central Department of Zoology, T.U. Kirtipur for identification.

Counting in S-R cell

For plankton counting, the Sedgwick-Rafter(S-R) cell was used which is 50mm long, 20mm wide and 1mm deep and the volume of the chamber is 1 ml. The counting chamber is equally divided into 1000 fields; each of the volume is 1u1. 1ml sample from each of the sampling station was transferred to the Sedgwick-Rafter counting cell and left to stand for 15 minutes to allow the plankton to settle then under compound microscope of 10 magnification planktons were counted within 10 fields of S-R randomly. The plankton were then identified up to the genus level and enumerated following APHA (1992), Bellinger (1992), Needham and Needham (1972), Ward and Wipple (1959).

Calculation

The numerical calculation of plankton of concentrated sample was done by using the following formula:

$N = (A \times 1000 \times C) / (V \times F \times L)$ Where,

N= No. of plankton cells or units per liter of original water
A= Total no. of plankton counted
C= Volume of final concentrate of the samples in ml.
V= Volume of a field in cubic mm.
F= No. of fields counted.
L= Volume of original water in liters.

Statistical analysis

The statistical tools like correlation coefficient and regression coefficient used with mean, standard deviation, probable error and t- test to determine the relation between the different physicochemical parameters and plankton using SPSS 11.5 Microsoft.

Species diversity

The species diversity of index was done by using Shannon's Wiener Index method.

$$H = 3.3219 \{N\log_{10}N - \sum_{i=1}^{k} n_i \log_{10} n_i\}/N$$

Where N= total sample size.

n_i= number of individuals of a species.
k= number of species.
J= H/Hmax
Hmax= Maximum species diversity.log2k or Hmax= 3.3219log10k

CHAPTER V

OBSERVATION AND RESULT

Physical analysis of Water

The physical parameters that were studied during the investigation period were- water color, transparency, depth, turbidity, air temperature and water temperature.

Colour

During the study period, the color of the lake water changed gradually. The colors fluctuated from brownish to pale green. The change of colour may be due to the suspended clay and silt particles and swarms of planktons. In this study period, it was seen that the transparency and the water colour were directly correlated i.e. when the colour of water was clear; the transparency was high and vice versa. The colour of lake water remained brownish from June to August while pale green colour recorded from August to November, 2008.

Temperature

Temperature had important role on the production of planktons in a lake. The variation of temperature of air as well as water temperature of the lake was recorded regularly during the study period. The air temperature ranged from 20^{o}C to 26.50 and maximum air temperature was recorded on 15th June, 14th August and 29th August while minimum air temperature was recorded on 26th November. The average air temperature was 23.25^{o}C.

Water temperature of sample site 'A' ranged from 19.50^{o}C to 26.00^{o}C. The water temperature was minimum on 26th November and maximum on 15th June, 30th June, 30th July, 14th August and 29th August (Table 3). Water temperature of sample site 'B' found ranging between 19.20^{o}C to 26.20^{o}C. Maximum water temperature was recorded on 15th June while minimum water temperature was recorded on 26th November (Table 4). The average water temperature was 22.70^{o}C.

Transparency

Transparency is due to the suspended matters like silt and clay or due to planktonic organism. During the study period, transparency was variable. The lowest transparency was 10.00cm on 30th July and the highest transparency value was recorded 28.00cm on 28th August at sampling site 'A'. The average transparency was 19.00cm. At sample site 'B', lower transparency was 10cm during 15th July while highest transparency was 32cm on 26th November .The average transparency was 21cm (Table 3 and 4). The variation of transparency might be due to rainfall, swarm of plankton, algae or suspended silt and clay particles, wind action and surface run off etc.

Table 3. Physicochemical parameters in Sampling site A (Fortnight data collection).

Parameters	June 15-08	June 30-08	July 5-08	July 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Min.	Max.	Average
Air Temp (^{0}C)	26.50	26.00	26.00	26.20	26.50	26.50	25.50	25.00	24.50	23.50	20.50	20.00	20.00	26.50	23.25
Water Temp (^{0}C)	26.00	26.00	25.50	26.00	26.00	26.00	25.00	24.50	24.00	23.00	20.00	19.50	19.50	26.00	22.75
Transparency (cm)	15.20	13.00	10.50	10.00	25.00	28.00	25.00	23.00	22.00	20.00	22.00	19.00	10.00	28.00	19.00
Turbidity (cm)	44.33	52.33	65.83	69.42	26.36	42.62	26.36	28.74	30.10	33.23	30.10	35.06	26.36	69.42	47.89
Depth (cm)	70.00	79.00	80.00	82.00	78.00	79.00	75.00	72.00	70.00	72.00	68.00	67.00	67.00	82.00	74.50
pH	8.00	8.50	8.00	8.20	6.50	6.80	6.70	7.30	7.50	7.40	7.50	7.20	6.50	8.50	7.50
DO (mg/l)	3.50	3.80	3.50	3.70	3.20	3.50	4.00	4.50	4.50	4.20	4.50	4.20	3.20	4.50	3.85
$C0_2$ (mg/l)	7.00	7.20	7.00	7.20	7.50	8.00	7.00	6.50	6.00	6.00	5.50	5.50	5.50	8.00	6.75
Hardness (mg/l)	40.00	39.50	55.00	40.50	55.50	55.00	57.00	57.50	60.00	58.00	61.00	65.00	39.50	65.00	52.25
Total Alkalinity (mg/l)	35.00	37.00	40.00	39.00	40.00	42.00	45.00	47.00	50.00	55.00	58.00	58.00	35.00	58.00	46.50
Chloride (mg/l)	9.00	11.50	10.00	10.50	12.00	15.00	13.00	15.00	13.00	13.50	14.00	15.00	9.00	15.00	12.00

Table 4. Physicochemical parameters in Sampling site B (Fortnight data collection).

Parameters	June 15-08	June 30-08	July 5-08	July 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Min.	Max.	Average
Air Temp (^{0}C)	26.50	26.00	26.00	26.20	26.50	26.50	25.50	25.00	24.50	23.50	20.50	20.00	20.00	26.50	23.25
Water Temp (^{0}C)	26.20	26.00	25.50	26.00	26.00	26.00	25.00	24.80	24.00	23.00	20.00	19.20	19.20	26.20	22.70
Transparency (cm)	12.50	12.00	10.00	13.00	18.00	20.00	21.00	25.00	28.00	31.00	30.00	32.00	10.00	32.00	21.00
Turbidity (cm)	54.57	57.00	69.42	52.33	37.10	33.23	31.59	26.36	23.45	21.12	21.85	20.44	20.44	69.42	44.93
Depth (cm)	80.00	87.00	90.00	92.00	85.00	79.00	75.00	75.00	72.00	70.00	70.00	68.00	68.00	92.00	80.00
pH	7.20	7.50	7.50	7.20	7.20	7.00	7.20	7.10	7.20	7.00	7.10	7.10	7.00	7.50	7.25
DO (mg/l)	4.00	4.50	4.30	4.50	4.00	4.30	4.00	5.00	5.20	5.10	5.00	4.80	4.00	5.20	4.60
$C0_2$ (mg/l)	7.00	7.50	7.50	7.20	7.50	7.80	7.30	7.00	6.80	6.10	6.50	6.50	6.10	7.80	6.95
Hardness (mg/l)	39.00	39.50	42.00	41.00	38.00	36.00	40.00	45.00	48.00	52.00	55.00	58.00	36.00	58.00	47.00
Total Alkalinity (mg/l)	33.00	35.00	38.00	37.00	35.00	32.00	35.00	37.00	40.00	42.00	45.00	42.00	32.00	45.00	38.50
Chloride (mg/l)	8.00	9.00	9.50	11.00	10.00	13.00	11.50	14.00	12.00	11.00	11.50	12.00	8.00	14.00	11.00

Table 5. Mean± SD values of Physicochemical parameters at site A													
Parameters	June 15-08	June 30-08	July 15-08	July 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Mean± SD
Air Temp (^{0}C)	26.5	26.0	26.0	26.2	26.5	26.5	25..5	25.0	24.5	23.5	20.5	20.0	24.7±2.28
Water Temp (^{0}C)	26.0	26.0	25.5	26.0	26.0	26.0	25.0	24.5	24.0	23.0	20.0	19.5	24.29±2.33
Transparency(cm)	15.2	13.0	10.5	10.0	25.0	28.0	25.0	23.0	22.0	20.0	22.0	19.0	19.39±5.95
Turbidity (cm)	44.33	52.33	65.83	69.42	26.36	42.62	26.36	28.74	30.1	33.23	30.1	35.06	40.37±15.0
Depth (cm)	70.0	79.0	80.0	82.0	78.0	79.0	75.0	72.0	70.0	72.0	68.0	67.0	74.33±5.14
pH	8.0	8.5	8.0	8.2	6.5	6.8	6.7	7.3	7.5	7.4	7.5	7.2	7.46±0.62
DO (mg/l)	3.5	3.8	3.5	3.7	3.2	3.5	4.0	4.5	4.5	4.2	4.5	4.5	3.92±0.45
$C0_2$ (mg/l)	7.0	7.2	7.0	7.2	7.5	8.0	7.0	6.5	6.0	6.0	5.5	5.5	6.70±0.79
Hardness (mg/l	40.0	39.5	55.0	40.5	55.5	55.0	57.0	57.5	60.0	58.0	61.0	65.0	53.66±8.71
Total Alkalinity	35.0	37.0	40.0	39.0	40.0	42.0	45.0	47.0	50.0	55.0	58.0	58.0	5.50±8.1
Chloride (mg/l)	9.0	11.5	10.0	10.5	12.0	15.0	13.0	15.0	13.0	13.5	14.0	15.0	12.62±2.04

Table 6 Mean± SD values of Physicochemical parameters at site B													
Parameters	June 15-08	June 30-08	July 15-08	July 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Mean± SD
Air Temp (^{0}C)	26.5	26.0	26.0	26.2	26.5	26.5	25..5	25.0	24.5	23.5	20.5	20.0	24.7±2.28
Water Temp (^{0}C)	26.2	26.00	25.5	26.00	26.00	26.00	25.0	24.8	24.0	23.0	20.0	19.2	24.30±2.40
Transparency (cm)	12.5	12.0	10.0	13.0	18.0	20.0	21.0	25.0	28.0	31.0	30.0	32.0	21.04±8.06
Turbidity (cm)	54.57	57.0	69.42	52.33	37.1	33.23	31.59	26.36	23.45	21.12	21.85	20.44	37.37±16.75
Depth (cm)	80.0	87.0	90.0	92.0	85.0	79.0	75.0	75.0	72.0	70.0	70.0	68.0	78.58±8.27
pH	7.2	7.5	7.5	7.2	7.2	7.0	7.2	7.1	7.2	7.0	7.1	7.1	7.19±0.16
DO (mg/l)	4.0	4.5	4.3	4.5	4.0	4.3	4.0	5.0	5.2	5.1	5.0	4.8	4.55±0.45
$C0_2$ (mg/l)	7.0	7.5	7.5	7.2	7.5	7.8	7.3	7.0	6.8	6.1	6.5	6.5	7.05±0.50
Hardness (mg/l)	39.0	39.5	42.0	41.0	38.0	36.0	40.0	45.0	48.0	52.0	55.0	58.0	44.45±7.19
Total Alkalinity	33.0	35.0	38.0	37.0	35.0	32.0	35.0	37.0	40.0	42.0	45.0	42.0	37.58±3.96
Chloride (mg/l)	8.0	9.0	9.5	11.0	10.0	13.0	11.0	14.0	12.0	11.0	11.5	12.0	10.87±1.74

Depth

Depth is most important physical factors that affect the distribution of the plankton as well as other chemical parameters according to the depth. Depth of two stations was recorded in each observation and calculated the mean depth to represent the fortnightly data. The minimum depth record was 67cm on 26th November while maximum depth was recorded 82cm on 30th July at site ‘A’. The average mean depth value was 74.50cm. The average mean depth value record was 80.00cm at station ‘B’. The highest depth value was 92 cm on 30th July and minimum record was 68cm on 26th November.

Turbidity

During the present investigation period, the highest turbidity value recorded was in the month of 15th July and the value was found to be 65.83cm and 69.42cm at both sample sites. The lowest value was recorded on 13th September and the value was 26.36cm at site ‘A’ and it was 20.44 on 26th November at site ‘B’. According to Jhingran (1975), the turbidity of natural water system may be due to the suspended inorganic substances such as silt and clay or due to planktonic organisms.

Chemical analysis of Water

The productivity of any lake depends on the presence of several chemical substances found in water body. Chemical natures of water alter the physical properties of the medium and also have a significant influence on the distribution and metabolic activities of the life forms. The important chemical parameters are dissolved oxygen, free carbon dioxide and hydrogen ion concentration (pH). The other influencing chemical parameters include total alkalinity, total hardness and chlorides.

Hydrogen ion concentration (pH)

The hydrogen ion concentration of natural water is an important environmental factor. The variations of pH are linked with the species composition and life process of animal and plant communities. The pH in present study ranged from 6.50 to 8.50 at sample site ‘A’. The maximum pH was recorded 8.5 on 30th June and minimum 6.5 on 14th August. The average pH was found to be 7.50. The water of the lake was found neutral to slightly alkaline. The pH of the at site ‘B’ ranged from 7.0 to 7.5 with maximum of 7.50 on 30th June and 15th July and minimum 7.0 on 29th August and 28th October. The average pH was found to be 7.25.

Dissolved oxygen

The presence of oxygen in the water is obtained from the atmosphere by absorption and from the photosynthesis of plants. The dissolved oxygen found in lake water is essential for animal community for respiration and other life process. The dissolved oxygen of the lake water ranged from 3.2 to 4.5 ppm and 4.0 to 5.2 ppm at site ‘A’ and ‘B’ respectively. The minimum value of dissolved oxygen was found 3.2 ppm on 14th August and maximum 4.5 ppm on 28th September, 13th October and 12th November at sample site 'A'. The average dissolved oxygen was 3.85ppm. The minimum dissolved oxygen at sample site 'B' was 4.0 on 15th June, 14th August and 13th September and maximum oxygen 5.2 ppm on 13th October. The average dissolved oxygen was 4.60ppm.

Free carbon dioxide

The free carbon dioxide ranged from 5.5 to 8.0 ppm and 6.1 and 7.8 ppm at site 'A' and 'B' respectively. The minimum free carbon dioxide was 5.5 ppm on 12th and 26th November and the maximum 8.0 ppm on 29th August at site 'A'. The average value thus calculated was 6.75 ppm. The minimum value of free carbon dioxide was 6.5 ppm on 12th and 26th November and the maximum value 7.80 ppm on 29th August at site 'B'. The average value was 6.95ppm.

Total alkalinity

The total alkalinity is due to presence of carbonate and bicarbonate in the water. In the present study works, the total alkalinity was high ranging from 35.0 to 58.0 ppm and 32.0 to 45.0 ppm at site 'A' and 'B' respectively. The minimum bicarbonate alkalinity was 35.00ppm on 15th June and maximum 58.00ppm on 26th November at site 'A'. The average value was 46.50ppm. At sample site 'B', minimum alkalinity was 32.00ppm on 29th August and the highest alkalinity was 45.00ppm on 12th November.

Total Hardness

Hardness is caused by the calcium and magnesium ions present in water. Magnesium is an essential constituent for all the primary producers. Usually, natural water resources of Nepal contain more than 100mg/l of the total hardness (Lind, 1974 cited in Karna, 1993). During the present study, the minimum value was recorded 39.5 ppm was on 30th June and the highest value of the total hardness recorded was 65.00ppm on 26th November at station A. The average value was 52.50ppm at sample site 'A'. The minimum was 36.0 ppm and maximum value was 58.0 ppm on 26th November at sample site 'B'. The average value of total hardness was 47.0 ppm at sample site 'B'.

Chloride

The value of Chloride at sample site 'A' varied from 9.0 ppm to 15.0 ppm. The minimum chloride value was 9ppm on 15th June and maximum chloride was 15.0ppm on 29th August, 28th September and 26th November. During study period at site 'B', the Chloride value was ranged between 8ppm to 14ppm. The minimum value was 8ppm on 15th June and maximum value was 14 on 28th September. The average value was 11ppm.

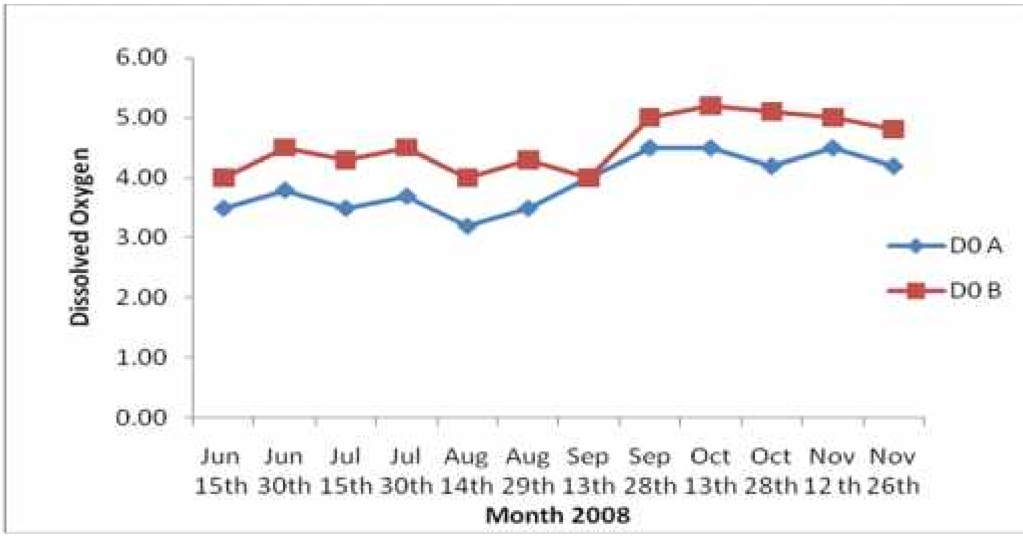


Fig.1. Fortnightly variation of dissolved oxygen (ppm) at sample site A & B.

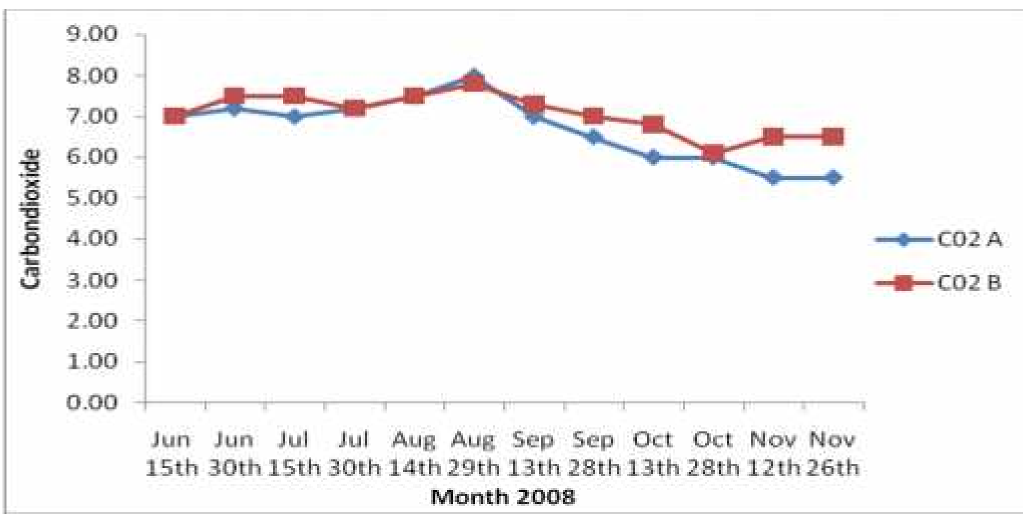


Fig.2. Fortnightly variation of Carbondioxide (ppm) at sample site A & B.

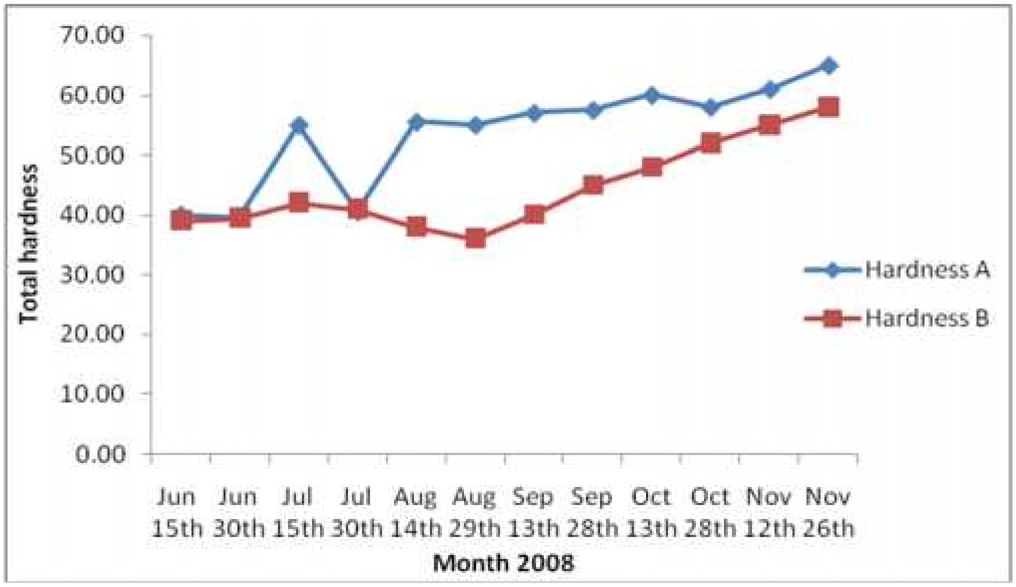


Fig.3. Fortnightly variation of Total hardness (ppm) at sample site A & B.

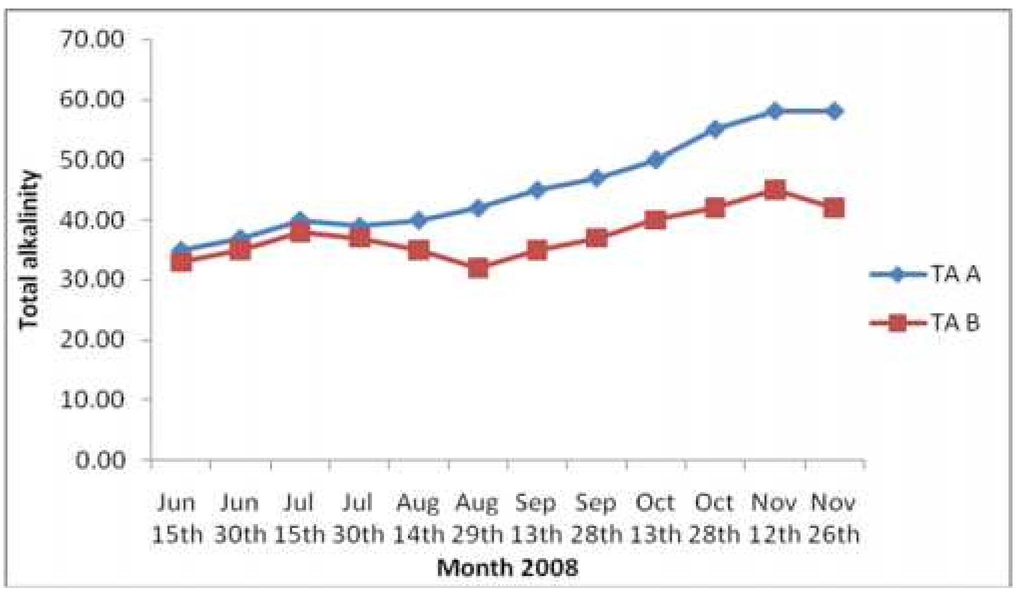


Fig.4. Fortnightly variation of Total alkalinity (ppm) at sample site A & B.

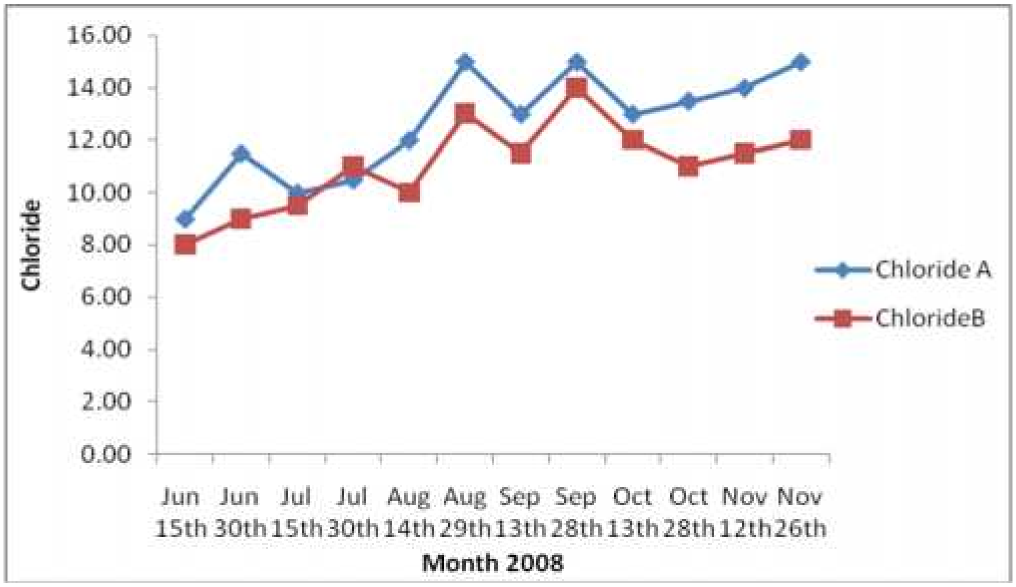


Fig.5. Fortnightly variation of Chloride (ppm) at sample site A & B.

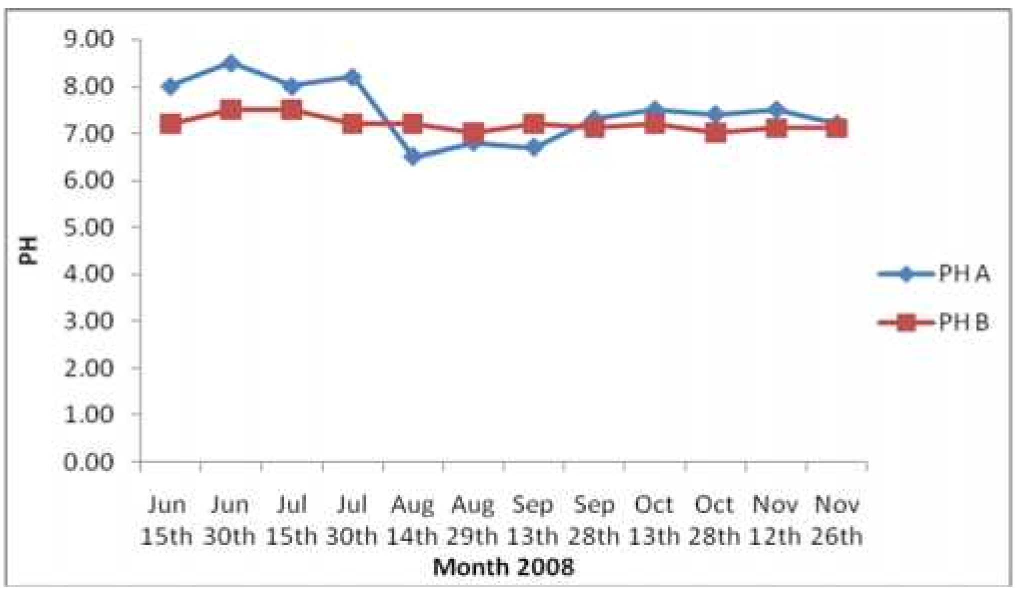


Fig.6. Fortnightly variation of P^H at sample site A & B.

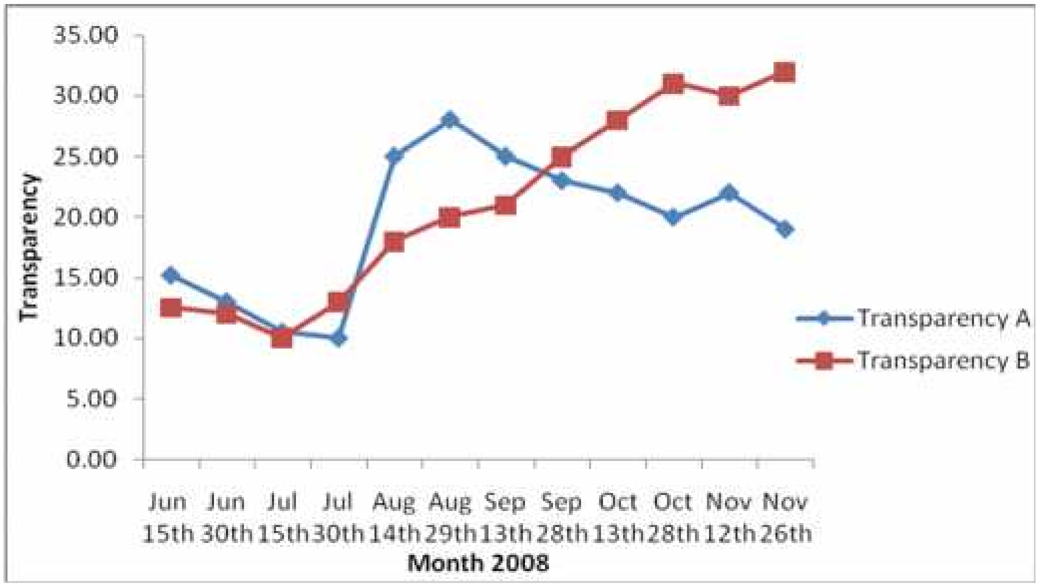


Fig.7. Fortnightly variation of Transparency (cm) at sample site A & B.

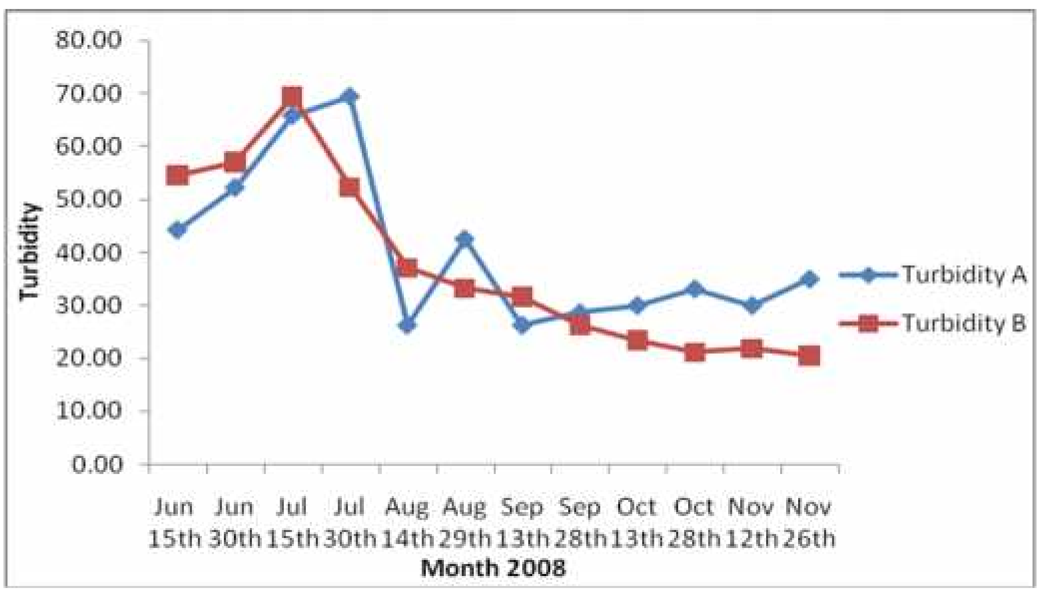


Fig 8.Fortnightly variation of Turbidity (cm) at sample site A & B.

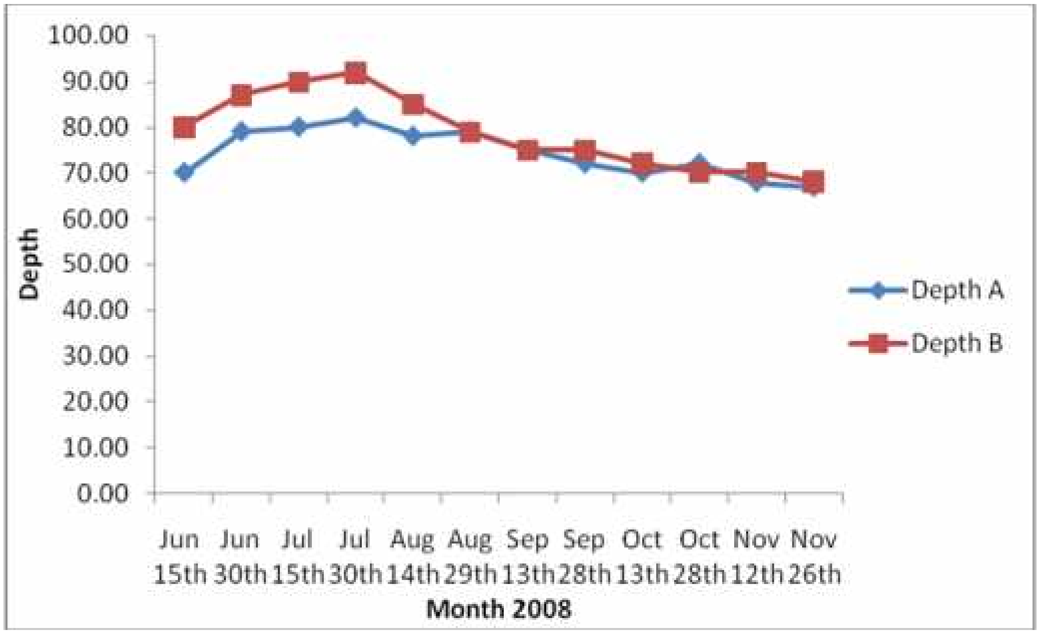


Fig.9. Fortnightly variation of Depth (cm) at sample site A & B

Plankton analysis (Qualitative and Quantitative)

Phytoplankton

The phytoplankton comprised of 14 genera belonging to four major groups such as cyanophyceae, chlorophyceae, bacillariophyceae and euglenophyceae. Cyanophyceae comprised *Anabaena cylindrica*, *Aphanizomenon sp.*, *Gloeotrichia sp.*, *Gomphosphaeria sp.* and *Oscillatoria sp.* Chlorophyceae consist *Zygnema sp. Ulothrix sp.*, *Spirogyra sp.*, *Oeogonium sp. and Mougeoti sp.* bacillariophyceae included two genera like *Surirella sp.*and *Navicula sp.* Euglenophyceae also consisted only genera like *Phacus sp.* and *Euglena sp.* Among them, chlorophyceae was found most dominant comprising 27.72% followed by cyanophyceae, 23.02%, bacillariophyceae, 7.67% and euglenophyceae, 6.44% of the total population. The plankton in the present investigation showed seasonal fluctuating pattern. The plankton was minimum on 15th June and 14th August and the total count was 2500/lit and maximum on October 28th with 6500/lit. The average planktons count during present study period was 4500/lit.

Phytoplankton in the site A

In cyanophyceae, *Anabaena sp.* was found in between 125-625/lit with an average of 375/lit and comprised 7.18 %. On 13th October, the abundance of *Anabaena sp.* was the highest recorded i.e. 625 and the lowest population on July (30^{th}) to August (29th) with 125/lit. *Aphanizomenon sp.* was collected regularly except from June to September 13th. The population of *Aphanizomenon sp.* ranged from 125 to 250/lit with an average value of 187.50/lit and percentage 2.72 %. The minimum *Aphanizomenon sp.* was collected on

15th June and 13th October but maximum recorded on 30th July, 28th September, 28th October and 12th November (Table 7). The number of *Gloeotrichia sp.* varied from 125 to 875/lit with an average population of 500/lit. The minimum *Gloeotrichia sp.*was recorded on 28th September and 28th October while maximum was on 13th October (Table 7). It was absent in June to August and in November. The total percentage of *Gloeotrichia* was 1.73%. *Gomphosphaeria sp.* was absent in August. The number of *Gomphospharia sp.* varied from 125 to 250/lit with an average number of 187.5/lit. The minimum number of *Gomphospharia sp.*was recorded on 30th June, 30th July, 13th September, 13th October and 12th November. while the maximum number was on 15th June, 15th July, 28th September 28th October and 26th November. The total percentage of *Gomphospharia sp.* was 3.71%. *Oscillatoria sp.* was collected regularly ranging from 125 to 625/lit with an average population of 375/lit. The minimum number of *Oscillatoria sp.* was recorded on 15th June and maximum on 15th July and total percentage of it was 7.67%. The total percentage of cyanophyceae present in present study was found to be 23.02%.

In chlorophyceae, *Zygnema sp.* was absent in 15th June and August and its population varied from 125 to 375/lit with an average number 250/lit. The minimum number/lit of *Zygnema* sp.was recorded on July and 28th September while maximum on 28th October and the percentage composition was 3.71%. The number of *Ulothrix sp.* ranged from 125 to 375/lit with an average of 250/lit and percent of total *Ulothrix sp.*was 4.95%. The minimum number of *Ulothrix sp.*was found in August and 19th August and maximum on 28th October (Table 7). It was absent in June. The number of *Spirogyra sp.* ranged from 125 to 625/lit with an average of 375/lit and percent composition was 8.91%. *Spirogyra sp.* was found lowest on 30th June and highest on 13th October (Table 7). The number of *Oedogonium sp.*varied from 125 to 500/ lit with an average of 312.5/lit. It was found minimum on July and maximum on 26th November. The total percentage composition was 5.2%. *Oedogonium sp.* was absent on 15th June and August. *Mougeotia sp.*was absent in June and was found in between 125 to 375/lit with an average of 250/lit. The number was found minimum on 30th July and 28th September while maximum on 28th September, 28th October and 12th November. The total percentage composition was accounted to be 4.95 %. The total percent of Chlorophyceae was recorded to be 27.72 % (Fig. 11).

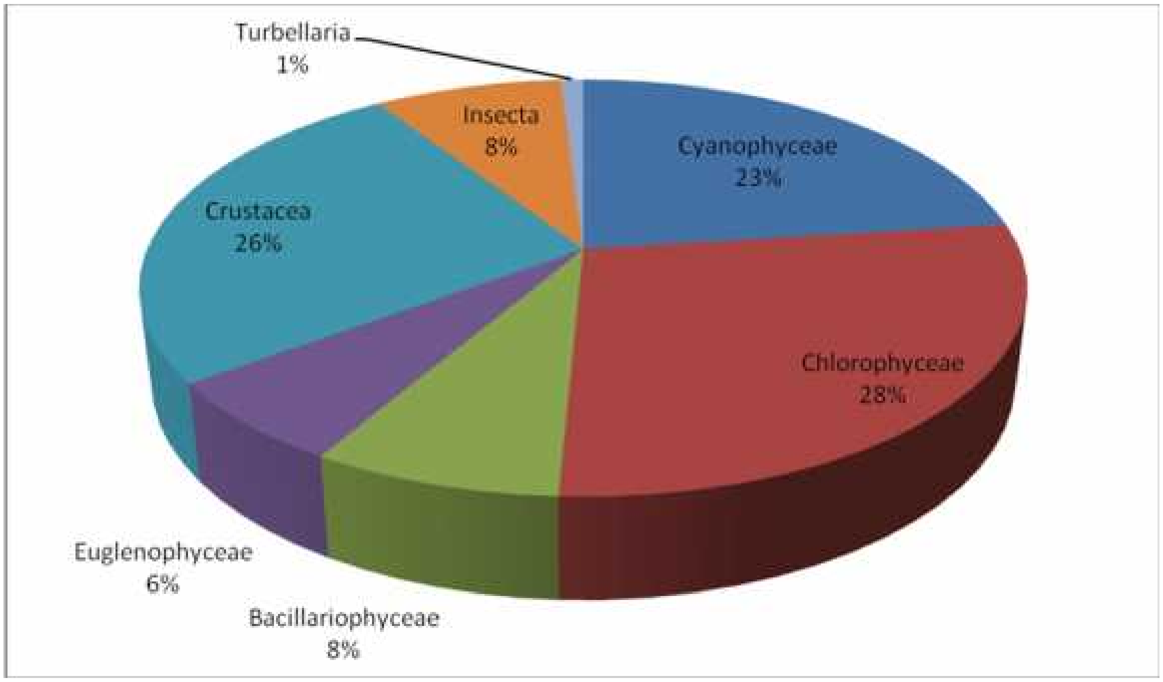


Fig 11. Pie-diagram showing plankton composition at sampling site A.

In bacillariophyceae, *Surirella sp.* was found in between 125 to 375/lit with an average of 250/ lit and percentage calculated to be 3.71%. *Surirella sp.*was found lowest on 14th August and 13th September and highest on 28th October and absent in June and July (Table 7). The number of *Navicula sp.* varied from 125 to 250/lit with an average of 187.50/lit. The minimum number of *Navicula sp.*was recorded on 13th October, 26th November and August and maximum on July, September, 28th October and 12th November and percentage composition constituted 3.96%. Thus the total percentage of bacillariophyceae was found to be 7.67 %.

In euglenophyceae, *Phacus sp.*was found within the range of 125 to 250/lit with an average of 87.50/lit. The minimum number of *Phacus sp.*was recorded on 30th June, 15th July, 13th October and maximum on November. The percentage of *Phacus* sp. was 2.23%. The number *of Euglena sp.*varied from 125 to 375/lit with an average number 250/lit. The minimum number of *Euglena sp.*was found on 15th July, 28th September, 13th October and maximum on 26th November. The percentage of *Euglena sp.* was calculated to be 4.21%. The total percentage composition of it was found to be 6.44 %.

Table 7. Monthly abundance and composition (%) of phytoplankton (cells L-1) at sample site A

Phytoplankton	June 15-08	June 30-08	July 15-08	July 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Max.	Min.	Average	%
Anabaena cylindrica	375	250	250	125	125	125	250	375	625	500	375	250	625	125	375.0	7.18
Aphanizomenon sp.	−	−	125	250	−	−	−	250	125	250	250	125	250	125	187.5	2.72
Gloeotrichia sp.	−	−	−	−	−	−	250	125	375	125	−	−	875	125	500.0	1.73
Gomphosphaeria	250	125	250	125	−	−	125	250	125	250	125	250	250	125	187.5	3.71
Oscillatoria sp.	125	250	125	250	250	250	375	500	375	625	500	250	625	125	375.0	7.67
Cynophyceae	**750**	**625**	**750**	**750**	**375**	**375**	**1000**	**1500**	**1625**	**1750**	**1250**	**875**	**1750**	**375**	**1062.5**	**23.02**
Zygnema sp.	−	250	125	125	−	−	250	125	250	375	250	125	375	125	250.0	3.71
Ulothrix sp.	−	−	250	250	125	125	125	375	250	375	250	375	375	125	250.0	4.95
Spirogyra sp.	250	125	250	375	500	250	375	375	625	500	500	375	625	125	375.00	8.91
Oedogonium sp.	−	250	125	125	−	−	250	375	250	375	375	500	500	125	312.5	5.20
Mougeotia sp.	−	−	250	125	250	250	250	125	250	250	375	375	375	125	250.0	4.95
Chlorophyceae	**250**	**625**	**1000**	**1000**	**875**	**625**	**1250**	**1375**	**1625**	**1875**	**1750**	**1750**	**1875**	**250**	**1062.5**	**27.72**
Surirella sp.	−	−	−	−	125	250	125	250	250	375	250	250	375	125	250.0	3.71
Navicula sp.	−	−	250	250	125	125	250	250	125	250	250	125	250	125	187.5	3.96
Bacillariophyceae	**0**	**0**	**250**	**250**	**250**	**375**	**375**	**500**	**375**	**625**	**500**	**375**	**625**	**0**	**312.5**	**7.67**
Phacus sp.	−	125	125	−	−	−	−	250	125	250	125	125	250	125	187.0	2.23
Euglena sp.	250	250	125	−	−	250	250	125	125	375	250	125	375	125	250.0	4.21
Euglenophyceae	**250**	**370**	**250**	**0**	**0**	**250**	**250**	**375**	**250**	**625**	**375**	**250**	**625**	**0**	**312.5**	**6.44**

Phytoplankton in the site B

In cyanophyceae, *Anabaena sp.* was found in between 125-625/lit with an average of 375/lit. On 13th October the number of *Anabaena* sp.was highest i.e. 625/lit lowest on 30th July i.e.125/lit and the percentage composition of *Anabaena* was 5.88%. *Aphanizomenon sp.*was found regularly except in June, August and on 13th September. The number of *Aphanizomenon sp.* ranged from 125 to 275/lit with an average of 250/lit and total percentage composition of 2.66%. The minimum *Aphanizomenon sp.* was recorded on 28th October and on 26th November while maximum on 30th July and 13th October (Table 8). The number of *Gloeotrichia sp.* varied from 125 to 375/lit with an average of 250/lit. The minimum number of *Gloeotrichia* was recorded on 13th September and 28th October while maximum on 13th October (Table 8). It was absent on June, July 14th August and November. The total percent of *Gloeotrichia* sp. was 1.71%. *Gomphosphaeria* was absent in August. The number of *Gomphospharia* sp. varied from 125 to/lit with an average of 250/lit. The minimum number of *Gomphospharia* was recorded on 30th June and 12th November while the maximum number on 30th July, 28th September and 13th October. The total percent of *Gomphospharia sp.* was 3.98 %. *Oscillatoria sp.* was present regularly collected and the count was found ranging from 125 to 625/lit with an average 375/lit. The minimum number of *Oscillatoria sp.*was recorded on 14th August and maximum on October with a total percentage of 6.64%. The total percent of Cyanophyceae present in present study was calculated to be 20.87 %.

In chlorophyceae, *Zygnema sp.*was absent in 15th June and August and its distribution varied from 125 to 375/lit with an average number 250/lit. The minimum number/ lit of *Zygnema sp.* was seen on 15th July and 26th November while maximum on 28th September and 28th October. The percent constitued was 3.42. The number of *Ulothrix sp.* ranged from 125 to 375/lit with an average of 250/lit and percent of total *Ulothrix sp.*was 3.8%. The minimum number of *Ulothrix sp.* was collected on 14th August and 13th September and maximum on 29th August, 28th September, 28th October and 26th November(Table 8). It was absent in June and 15th July. The number of *Spirogyra* sp. ranged from 125 to 875/lit with an average of 500/ lit and total percentage was 8.16 %. *Spirogyra sp.*was found lowest on 30th June and highest on 28th October (Table 8). The number of *Oedogonium sp.*varied from 250 to 500/lit with an average of 375/lit. It was found minimum on 30th June, 30th July and 13th September and maximum on 13th October and 26th November. The total percentage composition was 4.93 %. *Oedogonium sp. was* absent on 15th June and August. *Mougeotia sp.*was absent in June, August and 13th September and ranged in between 125 to 375/lit with an average of 250/lit. The number of it was found lowest on 30th July and highest on 28th September and November. It accounted 3.04 percent of total plankton composition. The total percent of chlorophyceae was found to be 23.34 % (Fig 12).

In bacillariophyceae, *Surirella sp.* was found in between 125 to 500/lit with an average of 312.5/lit and percentage was calculated to be 3.98. *Surirella sp.*was found minimum on 29th August while maximum on 13th October and 12th November and absent in June and July (Table 8). The number of *Navicula sp.* varied from 125 to 375/lit with an average of 250/lit. The minimum number of *Navicula sp.*was recorded in August and 26th

November while maximum on 28th September and 12th November and percentage constituted 3.61%. Thus the total percentage of bacillariophyceae was found to be 7.59%.

In Euglenophyceae, *Phacus sp.* was found within the range of 125 to 375/lit with an average of 250/lit. The minimum *Phacus sp.*was recorded on 30th June and 15th July while maximum on 13th October and 12th November. The percentage of *Phacus sp.*was 2.66 %. The number *of Euglena* sp. varied from 125 to 625/lit with an average number 375/ it. The minimum number of *Euglena sp.*was found on 15th July and 26th November while maximum on 28th October. The percentage of *Euglena sp.*was recorded to be 4.74 %. The total percentage composition of it was found to be 7.40%.

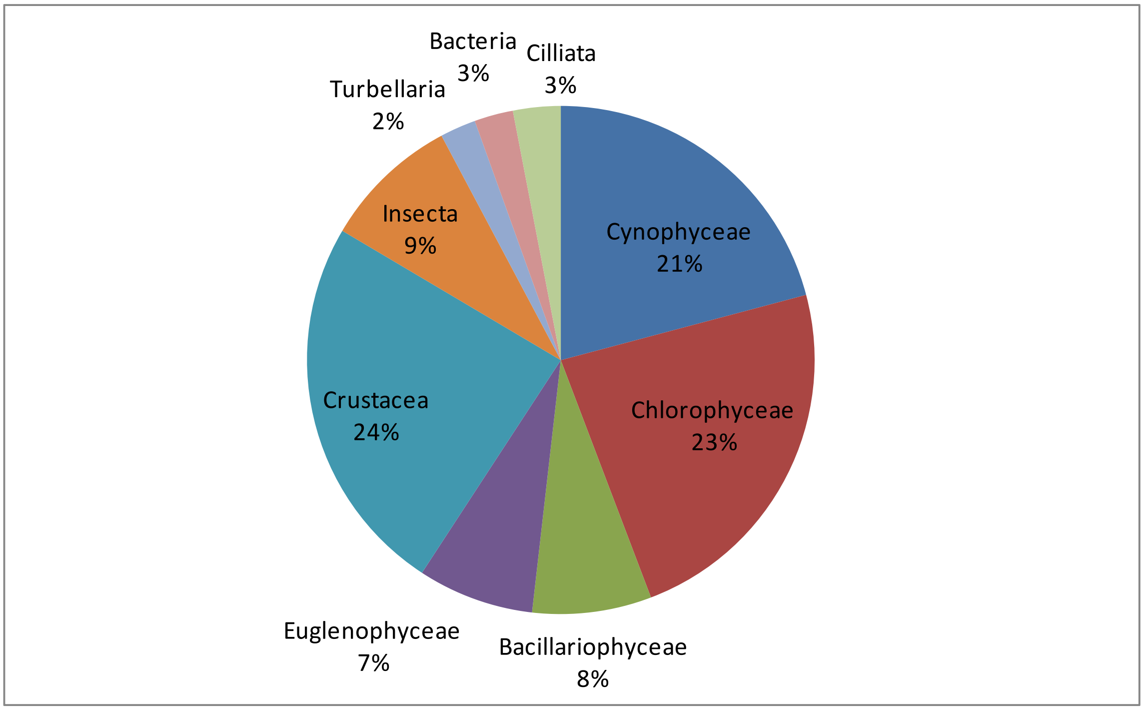


Fig 12. Pie- diagram showing plankton composition at sample site B.

Table 8. Monthly abundance and composition (%) of phytoplankton (cells L-1) at sample site B

Plankton group	Jun 15-08	Jun 30-08	Jul 15-08	Jul 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Max.	Min.	Average	%
Anabaena cylindrica.	375	250	250	125	250	250	250	375	625	500	375	250	625	125	375.00	5.88
Aphanizomenon sp.	−	−	250	375	−	−	−	250	375	125	250	125	375	125	250.00	2.66
Gloeotrichia sp.	−	−	−	−	−	250	125	250	375	125	−	−	375	125	250.00	1.71
Gomphosphaeria sp.	250	125	250	375	−	−	250	375	375	250	125	250	375	125	250.00	3.98
Oscillatoria sp.	250	375	375	250	125	250	375	500	500	625	500	250	625	125	375.00	6.64
Cynophyceae	**875**	**750**	**1125**	**1125**	**375**	**750**	**1000**	**1750**	**2250**	**1625**	**1250**	**875**	**2250**	**375**	**1312.50**	**20.87**
Zygnema sp.	−	250	125	250	−	−	250	375	250	375	250	125	375	125	250.00	3.42
Ulothrix sp.	−	−	−	250	125	375	125	375	250	375	250	375	375	125	250.00	3.80
Spirogyra sp.	250	125	250	375	500	250	500	625	750	875	500	375	875	125	500.00	8.16
Oedogonium sp.	−	250	375	250	−	−	250	375	500	375	375	500	500	250	375.00	4.93
Mougeotia sp.	−	−	250	125	−	−	−	375	250	250	375	375	375	125	250.00	3.04
Chlorophyceae	**250**	**625**	**1000**	**1250**	**625**	**625**	**1125**	**2125**	**2000**	**2250**	**1750**	**1750**	**2250**	**250**	**1250.00**	**23.34**
Surirella sp.	−	−	−	−	250	125	250	375	500	375	500	250	500	125	312.50	3.98
Navicula sp.	−	−	250	250	125	125	250	375	250	250	375	125	375	125	250.00	3.61
Bacillariophyceae	**0**	**0**	**250**	**250**	**375**	**250**	**500**	**750**	**750**	**625**	**875**	**375**	**875**	**0**	**437.50**	**7.59**
Phacus sp.	−	125	125	−	−	−	−	250	375	250	375	250	375	125	250.00	2.66
Euglena sp.	250	250	125	−	−	250	250	375	375	625	500	125	625	125	375.00	4.74
Euglenophyceae	**250**	**375**	**250**	**0**	**0**	**250**	**250**	**625**	**750**	**875**	**875**	**375**	**875**	**0**	**437.50**	**7.40**

Zooplankton

The zooplankton comprised 12 genera under three major groups - crustacea, insecta and turbellaria. Crustacea was recorded dominant among zooplankton comprising 25.99%, insecta, 8.17% and turbellaria, 0.99% at site A. Crustacea included *Daphnia sp. Alona sp. Bosmina sp. Cyclops bicolor, Diaptomus sp.*, *Halicyclops sp.*, *Mesocyclops sp.* and *Gammarus sp.* Insecta consisted *Chaoborus sp.* and *Tabanus sp.* and turbellaria consisted only one species like *Mesostoma virginianum.*

Zooplankton at sample site A

In crustacea, *Daphnia sp.* was absent in June. The density of *Daphnia sp.* ranged 125 to 250/lit. with an average of 187.5/lit. The lowest *Daphnia sp.*was recorded on 14th August, 28th September, 28th October and November (Table 9). The percentage composition of *Daphnia sp.* was 3.71%. The number of *Alona sp.*was ranged from 125 to 250/lit with an average of 187.5/lit. The minimum number of *Alona sp.*was found in June, 30th July and 13th October while maximum on 15th July, 28th September, 28th October and November (Table 9). The percentage composition of *Alona sp.*was found to be 3.47 %. *Bosmina sp.*was absent in June, 15th July but when present, it ranged from 125 to 250/lit with an average of 187.5/lit. The minimum number of *Bosmina* sp.was found 30th July, 14th August, 28th September, 28th October and November while maximum number was recorded on 29th August, 13th September and 13th October (Table 9). The percentage composition of *Bosmina sp.*was found to be 2.97 %. The density of *Cyclops bicolor* ranged from 125 to 250/lit with an average of 187.50/lit. The minimum number of *Cyclops bicolor* was found on 15th June and 13th October while maximum on 30th June, 15th July, 28th September, 28th October and November with the percentage composition of 3.47 %. *Diaptomu sp.* was absent in June, July and 26th November. The percentage composition of *Diaptomus sp.*was found to be 2.72 %. The number of *Diaptomus sp.*varied from 125 to 250/lit with an average of 187.5/lit. The minimum density of *Diaptomus* sp.was recorded on 14th August and October while maximum on 29th August, September and 12th November (Table 9). The percentage composition of it was found to be 2.72 %. *Halicyclops sp.* population ranged from 125 to 375/lit with an average of 250/lit and percentage composition was found to be 4.72/lit. The lowest number of *Halicyclops sp.*was recorded on July, 14th August, 28th September, 28th October and 26th November and maximum number on 13th October. The number of *Mesocyclops sp.*varied from 125 to 250/lit with an average of 187/lit and the percentage of it was found to be 3.71 %. The minimum number was recorded on 13th June, 15th July, 13th September and November while maximum on 15th June, 30th July, 28th September and October (Table 9). *Gammarus sp.*was absent in June and July and percentage composition of it was found to be 1.24 %. It was completely absent in June, July 28th September, October and November. The number of *Gammarus* sp.varied from 125 to 250/lit with an average of 187.5/lit. The minimum number was recorded on 14th August and maximum on 29th August and 13th September (Table 9). Thus, the total percentage composition of *Gammarus sp.*was found to be 25.99 %.

In insecta, *Chaoborus sp.* was absent in June, July, August and 13th September and when present in other seasons the total percentage composition was found to be 0.99 %. The number of it varied from 125 to 250/lit with an average of 187.50/lit. The minimum number of it was recorded on 28th September and 28th October and maximum on 13th October (Table 9). *Chironomus* sp.was regularly present during study period ranging from 125 to 375/lit with an average of 250/lit. The minimum number was found on 30th June, August, 13th September and maximum on 13th October with a percentage composition of 5.2%. *Tabanus sp* ranged from 125 to 250/lit with an average of 187.5/lit. It was found minimum on 15th June, 13th September and maximum in August and 28th September. The percentage composition was found to be 1.98 %. The total percentage composition was found to be 8.17 %. In turbellaria, *Mesostoma virginianum* was only one species collected so far all throughout the study period and its density ranged from 125 to 250/lit with an average of 187.5/lit. The minimum number was found in June and maximum on 15th July with 0.99% composition.

Table 9. Monthly abundance and composition (%) of zooplankton (cells L-1) at sample site A

Zooplankton	Jun 15-08	Jun 30-08	Jul 15-08	Jul 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Max.	Min.	Average	%
Daphnia sp.	−	−	250	250	125	250	250	125	250	125	125	125	250	125	187.50	3.71
Alona sp.	125	125	250	125	−	−	−	250	125	250	250	250	250	125	187.50	3.47
Bosmina sp.	−	−	−	125	125	250	250	125	250	125	125	125	250	125	187.50	2.97
Cyclops bicolor	125	250	250	−	−	−	−	250	125	250	250	250	250	125	187.50	3.47
Diaptomus sp.	−	−	−	−	125	250	250	250	125	125	250	−	250	125	187.50	2.72
Halicyclops sp.	250	250	125	125	125	250	250	125	375	125	250	125	375	125	250.00	4.70
Mesocyclops sp.	250	125	125	250	−	−	125	250	250	250	125	125	250	125	187.50	3.71
Gammarus sp.	−	−	−	−	125	250	250	−	−	−	−	−	250	125	187.50	1.24
Crustacea	**750**	**750**	**1000**	**875**	**625**	**1250**	**1375**	**1375**	**1500**	**1250**	**1375**	**1000**	**1500**	**625**	**1062.50**	**25.99**
Chaoborus sp.	−	−	−	−	−	−	−	125	250	125	−	−	250	125	187.50	0.99
Chironomus sp.	250	125	250	250	125	125	125	250	375	250	250	250	375	125	250.00	5.20
Tabanus sp.	125	−	−	−	250	250	125	250	−	−	−	−	250	125	187.50	1.98
Insecta	**375**	**125**	**250**	**250**	**375**	**375**	**250**	**625**	**625**	**375**	**250**	**250**	**625**	**125**	**375.00**	**8.17**
Mesostoma virginianum	125	125	250	−	−	−	−	−	−	−	−	−	250	125	187.50	0.99
Turbellaria	**125**	**125**	**250**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**250**	**0**	**125.00**	**0.99**

Zooplankton in site B

In crustacea, *Daphnia* sp. was absent in June. The density of *Daphnia* sp. found was ranged from 125 to 750/lit with an average of 437.5/lit. The lowest density of *Daphnia sp.*was recorded on 14th August while highest on 12th November (Table 10). The percentage composition of *Daphnia* sp. was 5.69%. The number of *Alona sp.* was ranged from 125 to 375/lit with an average of 250/lit. The minimum number of *Alona* sp.was found on 13th June, 30th July and 13th October and maximum on 28th October and 26th November (Table 10). The percentage composition of *Alona sp.* was found to be 2.85 %. The density of *Cyclops bicolor* ranged from 125 to 375/lit with an average of 250/lit. The minimum number of *Cyclops bicolor* was found on 15th June and 13th October and maximum on 12th November with the percentage composition of 2.85 %. *Diaptomus* sp. was absent in June, July and 26th November. The percentage composition of *Diaptomus sp.*was found to be 3.23 %. The number of *Diaptomus sp.*varied from 125 to 500/lit with an average of 312.5/lit. The lowest density of *Diaptomus sp*. percent was recorded on 14th August and the highest on 13th October (Table 10). The percentage composition of it was 4.74 %. *Halicyclops* sp. ranged from 125 to 500/lit with an average of 312.5/lit and percentage composition was found to be 3.8%. The lowest number of *Halicyclops sp.* was recorded in July and highest number on 28th October. The number of *Mesocyclops sp.* varied from 125 to 500/lit with an average of 312.5/lit and the percentage composition was found to be 3.8%. The minimum number of it was recorded on 30th June, 15th July while maximum on 13th October (Table 10). *Gammarus sp.*was absent in June and July, 28th September, October and November and percentage composition of it was found to be 1.14 %. The number of *Gammarus sp.* varied from 125 to 375/lit with an average of 250/lit. The minimum number was recorded on 13th September while maximum on 29th August (Table 10). Thus, the total percentage composition of Crustacea was found to be 24.29 %.

In insecta, *Chaoborus sp.*was absent in June, July, August and 13th September and 26th November when present in other seasons, the percentage composition was found to be 1.9%. The number of it varied from 250 to 375/lit with an average of 312.5/lit. The minimum number of it was recorded on 28th September and 12th November and maximum on October (Table 10). *Chironomus sp.* was regularly collected during present study period and its density was found ranging from 125 to 500/lit with an average of 312.5/lit. The minimum number was found on 30th June, 14th August and maximum on 28th September with a percentage composition 5.12 %. *Tabanus sp.* ranged from 125 to 375/lit with an average of 250/lit. It was found minimum on 15th June, 13th September and maximum on 14th August (Table 10). The percentage composition was found to be 1.71 %. The total percentage composition of insecta was found to be 8.73 %. In turbellaria, *Mesostoma virginianum* was the only species collected and its density ranged from 250 to 375/lit with an average of 312.5/lit. The minimum number of it was found in 15th June, 15th July and 14th August and maximum on 30th June and 30th July with 2.28 % composition.

Bacteria like *Micrococcus sp.* were found in June, July and August and absent in September, October and November in site B. Its density was found ranging from 125 to

375/lit with an average of 250/lit. It was recorded minimum on 30th June while maximum on 30th July and 14th August (Table 10). The percentage composition of it was found to be 2.47 %. Similarly ciliate like *Paramecium sp.*was also found site B in present study and its density ranged from 125 to 375/lit with an average of 250/lit. The minimum number of *Paramecium* sp.was recorded on 30th July and 13th September while maximum on August (Table 10).The percentage composition of it was found to be 3.04 %.

Table 10. Monthly abundance and composition (%) of zooplankton (cells L-1) at sample site B.

Zooplankton	June 15-08	June 30-08	July 15-08	July 30-08	Aug 14-08	Aug 29-08	Sep 13-08	Sep 28-08	Oct 13-08	Oct 28-08	Nov 12-08	Nov 26-08	Total	Max.	Min.	Average	%
Daphnia sp.	−	−	250	250	125	250	250	375	750	500	625	375	3750	750	125	437.50	5.69
Alona sp.	−	125	250	125	−	−	−	250	125	375	250	375	1875	375	125	250.00	2.85
Cyclops bicolor	125	250	250	−	−	−	−	250	125	250	375	250	1875	375	125	250.00	2.85
Diaptomus sp.	−	−	−	−	125	250	250	375	500	375	250	−	2125	500	125	312.50	3.23
Halicyclops sp.	−	250	125	125	250	250	375	250	375	500	250	375	3125	500	125	312.50	4.74
Mesocyclops sp.	−	125	125	250	−	−	250	375	500	250	375	250	2500	500	125	312.50	3.80
Gammarus sp.	−	−	−	−	250	375	125	−	−	−	−	−	750	375	125	250.00	1.14
Crustacea	**125**	**750**	**1000**	**750**	**750**	**1125**	**1250**	**1875**	**2375**	**2250**	**2125**	**1625**	**16000**	**2375**	**125**	**1250.00**	**24.29**
Chaoborus sp.	−	−	−	−	−	−	−	250	375	375	250	−	1250	375	250	312.50	1.90
Chironomus sp.	250	125	250	250	125	375	250	500	250	375	375	250	3375	500	125	312.50	5.12
Tabanus sp.	125	−	−	−	375	250	125	250	−	−	−	−	1125	375	125	250.00	1.71
Insecta	**375**	**125**	**250**	**250**	**500**	**625**	**375**	**1000**	**625**	**750**	**625**	**250**	**5750**	**625**	**0**	**312.50**	**8.73**
Mesostoma virginianum	250	375	250	375	250	−	−	−	−	−	−	−	1500	375	250	312.50	2.28
Turbellaria	**250**	**375**	**250**	**375**	**250**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1500**	**375**	**0**	**187.50**	**2.28**
Micrococcus sp.	250	125	250	375	375	250	−	−	−	−	−	−	1625	375	125	250.00	2.47
Bacteria	**250**	**125**	**250**	**375**	**375**	**250**	**0**	**0**	**0**	**0**	**0**	**0**	**1625**	**375**	**0**	**187.50**	**2.47**
Paramecium sp.	−	250	250	125	375	375	125	250	250	−	−	−	2000	375	125	250.00	3.04
Cilliata	**0**	**250**	**250**	**125**	**375**	**375**	**125**	**250**	**250**	**0**	**0**	**0**	**2000**	**375**	**0**	**187.50**	**3.04**

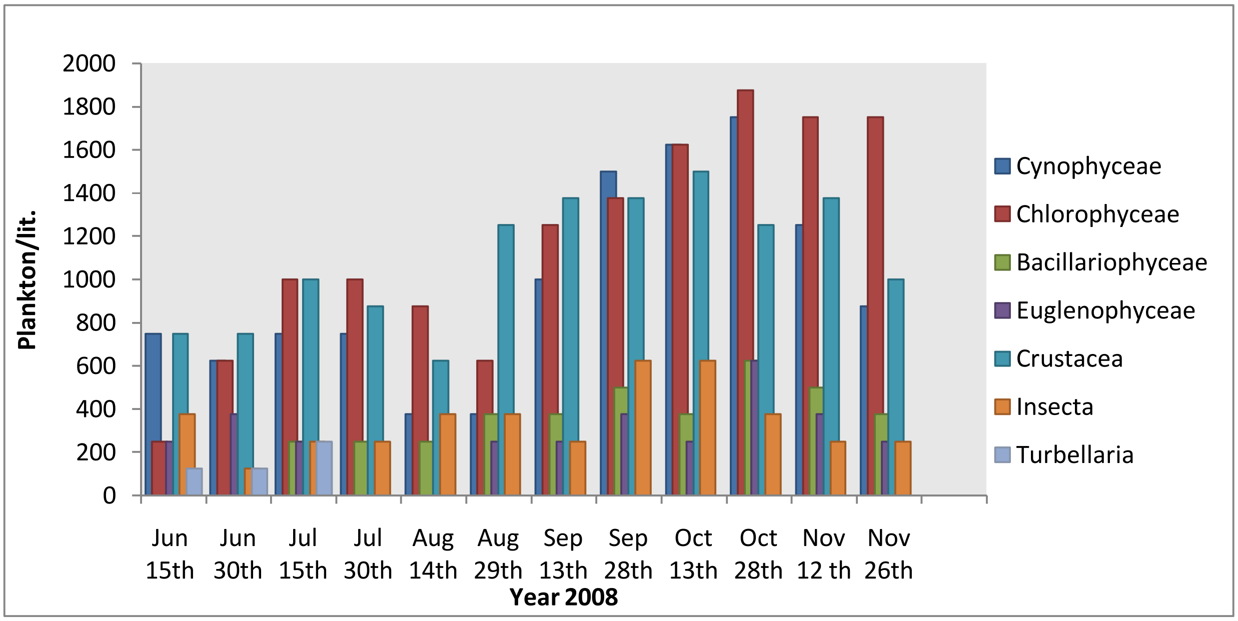


Fig13. Bar-diagram showing fortnightly variation of Plankton at site A

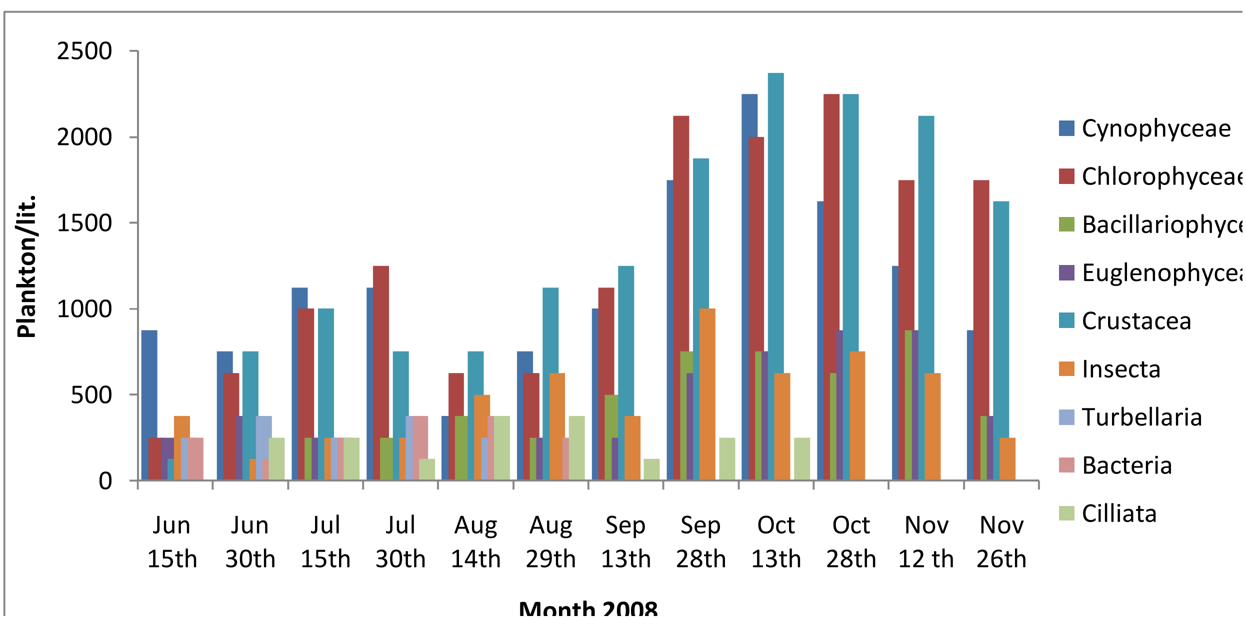


Fig. 14. Bar-diagram showing fortnightly variation of plankton at sample site B.

Physicochemical parameters and plankton

The distribution of planktons both phytoplankton and zooplanktons were found correlated with different physicochemical parameters in both sites A and B in present study. Dissolved oxygen (DO), hardness, alkalinity, chlorides and transparency showed positive correlation; but, water temperature, free CO_2, turbidity, pH and depth on the other hand showed negative correlation with planktons in present study in both sites (Tables 11 and 12). In both sites, dissolved oxygen showed highly correlated positively with plankton distribution (>0.01 level). In site A, total alkalinity showed strong correlation with plankton significant at >0.01 level. In site B, transparency showed strong correlation with planktons significant at >0.01 level; but positive correlation between transparency and planktons was not statistically significant in site A. Total hardness and chloride level showed positive correlation significant at >0.05 level.

In site A, free CO_2 showed strong negative correlation with plankton density (significant at >0.01 level); water temperature and water depth had also significant negative correlation with planktons mass (significant at >0.05 level); but turbidity and pH showed insignificant negative correlation with planktons. While in site B, free CO_2, water depth and turbidity showed negative correlation with planktons significant at >0.05 level; but negative correlation between water temperature and pH was statistically insignificant here (Tables 11 and 12).

Species Diversity Index

The diversity index analysis showed high abundance and diversity of planktons in both sites A and B. The species diversity was recorded slightly higher in Site B in comparison to site A during July, August, September 28, October 13 and November 12; and almost equal during September 13, October 28 and November 26. But in June month, species diversity was noted slightly higher in site A than site B. Species diversity was recorded lower during June, July and August in comparison to September, October and November. The species diversity was recorded in increasing trend from June month onward reaching peak level on September 28 and from then onward species diversity was noted in slight decreasing trend till November in both sites (Table 13). From present investigation, the total Plankton abundance was highest in autumn than summer season.

Table 11. **Correlation coefficient between physicochemical parameters and plankton (Phyto and zooplankton) at sample site A**						
Relation vs Planktons	**Regression equation**	**r**	**PE**	**r2**	**t- test**	**df**
Water temperature vs plankton	Y= 13429.087 - 372.932X	-0.584(*)	0.128	0.341	-2.278	11
Dissolved oxygen vs plankton	Y= -6797.143+2803.943X	0.877(**)	0.045	0.769	5.777	11
Carbondioxide vs plankton	Y= 13372.976- 1367.857X	-0.749(**)	0.086	0.561	-3.579	11
Total hardness vs plankton	Y= -1961.512+ 114.966X	0.688(*)	0.103	0.473	2.996	11
Total alkalinity vs plankton	Y= - 2431.017 +145.920X	0.812(**)	0.066	0.659	4.406	11
Chloride vs plankton	Y= -1050.656 - 416.554X	0.585(*)	0.128	0.342	2.283	11
Transparency vs plankton	Y= 2705.105 + 77.519X	0.317	0.175	0.100	1.057	11
Turbidity vs plankton	Y= 6144.831 - 47.965X	-0.494	0.147	0.244	-1.797	11
pH vs plankton	Y= 7556.319- 448.391X	-0.191	0.188	0.036	-0.616	11
Depth vs plankton	Y= 16600.774 - 166.714X	-0.589(*)	0.127	0.347	-2.302	11

r - Correlation coefficient PE - Probable error r2 - Coefficient of determination df - Degree of freedom

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

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

Table 12. Correlation coefficient between Physico-chemical parameters and Plankton at sample site B						
Relation vs Planktons	**Regression equation**	**r**	**PE**	**r2**	**t- test**	**df**
Water temperature vs plankton	Y= 17514.601 - 486.351X	-0.498	0.146597	0.248	-1.814	11
Dissolved oxygen vs plankton	Y= - 14769.4 + 4444.393X	0.897(**)	0.03797	0.805	6.415	11
Carbondioxide vs plankton	Y= 25586.082- 2847.202X	-0.647(*)	0.113131	0.419	-2.286	11
Total hardness vs plankton	Y= - 3337.624 + 198.550X	0.641(*)	0.114688	0.411	2.638	11
Total alkalinity vs plankton	Y= - 9143.012+ 389.337X	0.692(*)	0.101448	0.479	3.031	11
Chloride vs plankton	Y= - 3821.159 + 843.237X	0.642(*)	0.114494	0.412	2.648	11
Transparency vs plankton	Y= 1070.993+ 209.992X	0.759(**)	0.08256	0.576	3.688	11
Turbidity vs plankton	Y= 8896.430 - 91.161X	-0.685(*)	0.103395	0.469	-2.972	11
pH vs plankton	Y= 47484.150 - 5839.337X	-0.424	0.159668	0.180	-1.482	11
Depth vs plankton	Y= 18815.481 - 169.577X	-0.629(*)	0.117609	0.396	-2.558	11

r - Correlation coefficient   PE - Probable error   r2 - Coefficient of determination df - Degree of freedom

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

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

Table 13. Shannon - Wiener's diversity index of plankton at sites A and B of Barakune Daha (June-Nov, 2008)						
Site A				Site B		
MONTH	**H**	**Hmax**	**J**	**H**	**Hmax**	**J**
Jun 15th	3.484	3.584	0.972	3.259	3.322	0.981
Jun 30th	3.725	3.807	0.979	3.883	4.000	0.971
Jul 15th	4.063	4.245	0.957	4.249	4.322	0.983
Jul 30th	3.891	4.000	0.973	4.064	4.169	0.975
Aug 14th	3.619	3.807	0.951	3.744	3.907	0.959
Aug 29th	3.851	3.907	0.986	3.939	4.000	0.985
Sep 13th	4.146	4.322	0.960	4.141	4.322	0.958
Sep 28th	4.456	4.584	0.972	4.530	4.641	0.976
Oct 13th	4.329	4.521	0.958	4.393	4.584	0.958
Oct 28th	4.363	4.521	0.965	4.318	4.521	0.955
Nov 12th	4.270	4.392	0.972	4.313	4.458	0.967
Nov 26th	4.162	4.322	0.963	4.141	4.322	0.958

Photo A: Filtering water through net

Photo B: Titration of D0

Photo C: Titration of D0

Photo D: Study site

Photo E: Taking water sample

Photo F: Precipitate of water sample

Photo G: Side view of study area

Photo H: Flowering of lotus plant

Photo I: Fixing of plankton on Rafter Cell

Photo J: Analysis of plankton through microscope

Photo K: Sedgwick Rafter Cell

Photo 1. *Alona sp.* (10x10)

Photo 2. *Anabaena sp.* (10x10)

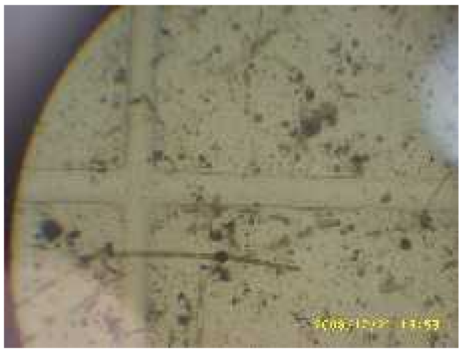


Photo 3. *Aphanizomenon sp.* (10x10)

Photo 4. *Bosmina sp.* (10x10)

Photo 5. *Chaoborus sp.* (10x10)

Photo 6. *Chironomus* sp. (10X10)

Photo 7. *Cyclops bicolor* (10X10)

Photo 8. *Daphnia sp.* (10x10)

Photo 9. *Diaptomus* sp.(10x10)

Photo 10. *Gammarus sp.* (10x10

Photo 11. *Gloeotrichia* sp.(10x10)

Photo 12. *Gomphosphaeria* sp.(10x10)

Photo 13. *Halicyclops sp.* (10x10)

Photo 14. *Mesocyclops* sp.(10x10)

Photo 15. *Mesostoma virginianum* (10x10)

Photo 16. *Micrococcus sp.* (10x10)

Photo 17. *Navicula sp.* (10x10)

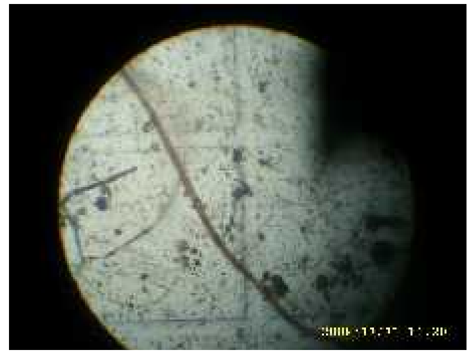


Photo 18. *Oedogonium sp.* (10x10)

Photo 19. *Oscillatoria sp.* (10x10)

Photo 20. *Paramecium sp.* (10x10)

Photo 21. *Phacus sp.* (10x10)

Photo 22 . *Spirogyra* (10x10)

Photo 23. *Surirella sp.* (10x10)

Photo 24. *Tabanus sp.* (10x10)

CHAPTER VI

Discussion

Aquatic biota consists of plant and animal communities which form the biological basis of aquatic productivity. The quality and quantity of the biota is determined by the combined effect of the physicochemical parameters of the water and it varies from season to season. The interaction of these physicochemical parameters causes favorable and unfavorable condition for the growth, development, production and distribution of any biotic community. Physiological activities such as assimilation of food, respiration, movement and reproduction of the biotic community is affected by the condition of the environment – temperature, light, oxygen content and other physicochemical properties of the water (Ruttner, 1953). Water quality includes all physical, chemical and biological characteristic of water which is important variable for aquatic organism. Primary production is the most important biological phenomenon in nature on which the entire diverse array of life depends either directly or indirectly. Physicochemical properties of water show a direct relation with primary production.

Physical analysis of Water

Colour

The color of the water in the study period changed gradually from brownish to dark green color. The changing of color may be due to swarm of planktons, algal bloom and suspended silt etc. in the pond. The color of the water remained brownish during June, July and August while green color was observed from September to November.

Depth

Depth of lake is important physical parameters which influence the physicochemical and biological properties of water i.e. the distribution of phytoplankton as well as zooplankton population. The minimum depth of water in Barkune Daha was 67 cm and 80 cm in sample site ‘A’ and ‘B’ respectively during November. This may be due to the higher rate of evaporation. The water volume was reached maximum in the both lakes i.e. 82cm and 92cm respectively in the July due to rainfall. The depth of about 2.0 m is considered congenial from the point of view of biological productivity in pond (Jhingran, 1975).

Air temperature

It is known that air temperature influence the water temperature. So it is an important limiting factor of the aquatic ecosystem. It is directly or indirectly affects the population Temperature had important role on the production of planktons in a lake. The variation in air as well as water temperature of the lake was recorded during the study period. The air temperature ranged from 20^{o}C to 26.50 and maximum air temperature was recorded on from June to August and minimum air temperature on November.

Water temperature

The temperature of surface water during the study period ranged between 19.50 to 26°C in sample site 'A' and 19.20 to 26.20°C at sample site 'B'. The water temperature was minimum on November and maximum from June to August in both sites A and B (Table 2 and 4). Water temperature was noted correlated with the air temperature in both sites.

The temperature had indirect effect on the other factors of aquatic ecosystem like dissolved oxygen and frees carbon dioxide, ultimately influencing indirectly on plankton density. The correlation coefficient between temperature and plankton was found to be negatively correlated in both sample sites. The value of correlation coefficient (r) was calculated to be -0.584 with probable error 0.128 in site 'A' while at sample site 'B', correlation coefficient between water temperature and plankton was found to be -0.498 and probable error 0.146. The correlation coefficient in both sites was greater than probable error showing significant correlation between temperature and plankton.

Transparency

Transparency is due to the suspended matters like silt and clay or due to planktonic organism. During the study period, transparency was variable. The lowest transparency was recorded on July on both sites but highest transparency was found August at sampling site 'A' and on November at sampling sites 'B' (Table 3 and 4). Transparency is inversely proportional to the turbidity of water which in turn is directly proportional to the amount of suspended organic and inorganic matters. Hutchinson (1957) found that the transparency of the pond depends upon the turbidity. Banerjee and Roy Chaudhary (1961) reported lower transparency during the monsoon in Chilka Lake due to the entry of silt, silt laden rain water and rise of phytoplankton content of water. During autumn season, transparency showed higher values, might be due to setting down of suspended silt and solid particles. From the statistical analysis, there was positive correlation between transparency and plankton. The value of correlation coefficient (r) at sample site 'A' was 0.317 and at sample site 'B' was 0.759. There was a high correlation between transparency and plankton in site B in comparison to site A.

Turbidity

The turbidity is inversely proportional to the transparency and turbidity is directly proportional to the amount o f suspended organic and inorganic matter. Water becomes turbid when the rain and flood water enters the pond restricting the penetration of light and thus reducing photosynthetic activity. Reduced number of zooplankton and macro-invertebrate were observed in naturally and artificially turbid aquatic system of Alaska (USA) by Loyed et al. (1987). During the present investigation period, the highest turbidity value recorded was on July and lowest value on September. According to Jhingran (1975), the turbidity of natural water system may be due to the suspended inorganic substances such as silt and clay or due to planktonic organisms. Negative correlation was found between turbidity and plankton at both sample sites. The value of correlation was –0.494 at sample site 'A' and 0.685 at site 'B' which was significant at 0.05% level. This value and relation was found similar to Rijal (1994) and Jha (1994).

Chemical analysis of Water

The productivity of any lake depends on the presence of several chemical substances found in water body. Chemical parameters of water alter the physical properties of the medium and also have a significant influence on the distribution and metabolic activities of the life forms. The important chemical parameters are dissolved oxygen, free carbon dioxide and hydrogen ion concentration (pH). The other influencing chemical parameters include total alkalinity, total hardness and chlorides.

Hydrogen ion concentration (pH)

The hydrogen ion concentration of natural water is an important environmental factor. The variations of pH are linked with the species composition and life process of animal and plant communities. The pH is the important limiting factor. The pH in the surface water varied from 6.50 to 8.50. The pH value of lake water was found to be neither highly acidic nor highly alkaline at both sample sites. Ellis (1973) reported that pH value between 6.7 to 8.4 was suitable for aquatic life which was nearly equal to the present value in both sites. Hussain (1966), Verma and Shukla (1970) believed that pH would prove to be an ecological factor of major importance in controlling the activities and distribution of aquatic flora and fauna. A low degree of negative correlation coefficient (-0.191) at site 'A' and negative correlation coefficient (-0.424) was found at site 'B'. Singhal et al. (1986) reported that pH along with other physicochemical parameters showed some significant correlation between them. The present study is also congenial with his view.

Dissolved oxygen (DO)

Dissolved oxygen is the most important factor for animal and plant life in aquatic environment. It is available by absorption from the surface and from the photosynthesis of aquatic plant as well. The animal community residing in the pond requires dissolved oxygen for respiration and release carbon dioxide as a catabolic product both during day and night. Oxygen consumption in a body of water occurs by the respiration of animal and aquatic plants as well as by the putrefaction of organic matter and other cause. Ideally, the oxygen producing and oxygen consuming process in natural water should be balanced so as to keep the dissolved oxygen concentration within a range congenial to all organisms. Photosynthesis depends on the presence of sunlight, the depth up to which plant life could exist. The dissolved oxygen is the most important requirement for the growth of aquatic organism of the pond. In the present investigation, the dissolved oxygen ranged between 3.20 to 4.50 and 4.00 to 5.20 at sites 'A' and 'B' respectively. It was observed that the dissolved oxygen content was increased by decrease in temperature at both sites. Generally, the dissolved oxygen content was minimum during rainy season which may be due to the cloudy weather as result photosynthesis could not have taken place properly. Ellis (1937) reported 5 mg/lit dissolved oxygen in water necessary for maintaining aquatic life in healthy condition at $20^{o}C$. In the present study, dissolved oxygen was found to be 4.2 mg/lit at $19.5^{o}C$ at site 'A' and 5.0 mg/lit at $20^{o}C$ at sample site 'B' showing healthy water conditions at site B than site A . As site A was established in the area of high human interference like washing and bathing and this site was little shallower than site B.

Free carbon dioxide (CO_2)

Carbon dioxide is derived from various sources viz. atmosphere, respiration of animals and plants and bacterial decomposition of organic matter. The free carbon dioxide fluctuated from 5.5 to 8.0 at sample site 'A' and 6.1 to 7.8 at sample site B (Table 3 and 4). The value of free carbon dioxide was maximum during August which might be due to cloudy day affecting photosynthesis process. From the present investigation, it was found that $C0_2$ was inversely proportional to oxygen. When carbon dioxide was high dissolved oxygen was low and vice versa. Similar observation was made by Dhakal (1991), Jha (1994) and Mahato (1988). There was found high degree of negative correlation coefficient between free carbon dioxide and plankton density. The correlation coefficient at sample site 'A' was found to be -0.749 significant at 0.01 level while at sample site 'B' it was found to be -0.647 significant at 0.05 level

Total alkalinity

The total alkalinity of water is mainly due to the presence of calcium, magnesium, sodium, potassium, ammonium and iron in carbonates or bicarbonates. Alikhuni (1957) stated that total alkalinity should be over 100mg/l for high productivity. Masuda and Pradhan (1988) considered alkalinity more than 40mg/l suitable for aquaculture and aquatic organism. In present study, the total alkalinity ranged from 35 to 58 ppm and 32 to 45 ppm at sites A and B respectively. The total alkalinity was found minimum in June at site A and August in site B and maximum in November in both sites. The correlation coefficient between total alkalinity and plankton at site 'A' was found to be 0.812 which was highly correlated and significant at 0.01 level. The correlation coefficient between alkalinity and plankton was positively correlated (0.692) at sample site 'B' significant at 0.05 level.

Total Hardness

Hardness is caused by the calcium and magnesium ions present in water. Magnesium is an essential constituent for all the primary producers. Hardness directly affects the density of plankton. The total hardness influence other chemical parameters and plankton composition. When the total hardness was high, plankton density was become high. The total hardness of water ranged from 39.50 to 65.00 and 36.00 to 58.00 mg/lit at sites 'A' and 'B' respectively during present study. During the present study, the minimum value was recorded on June at site A and on August in site B and the highest value on November at both sites. According to Jhingran (1961), total alkalinity and hardness may be approximately equal since both are expressed as $CaC0_3$. There was positive correlation coefficient between total hardness and plankton. The correlation coefficient was found to be 0.688 at sample site 'A' which was significant at 0.05% level while it was found to be 0.641 at site 'B' and significant at 0.05% level.

Chloride

Chloride is generally present in all natural waters. The presence of chloride in natural waters can be attributed to the dissolution of salt deposits, irrigation drainage and sewage discharges. Human excreta, particularly urine also contributes to high amount of chlorides. Therefore, the

Chloride concentration serves as an indicator of sewage pollution. A chloride is highly soluble and combines with most of the naturally occurring cations. Chloride does not precipitate to sediment and cannot be removed biologically in the treatment of wastes. It is harmless up to 1500 mg/lit but produces a salty taste at 250-500mg/lit level. In natural freshwaters, its concentration remains quite low and generally less than that of sulphate and bicarbonates. High chloride content also has a damaging effect on agricultural crops. The chloride was found to be in the range of 9.0 to 15mg/lit at site 'A' and 8.0 to 14 mg/lit at site B. The minimum chloride value on June in both sites but maximum chloride was found from August to November at site A and on September at site B.

Plankton analysis

Planktons are the free swimming/floating microscopic living component of aquatic systems. In the Barakune Daha, 28 genera belonging to 7 groups viz cyanophyceae, chlorophyceae, bacillariophyceae, euglenophyceae, crustacea, insecta and turbellaria at site A and 9 groups viz cyanophyceae, chlorophyceae, bacillariophyceae, euglenophyceae, crustacea, insecta, turbellaria, Bacteria and cilliata at site B collected. The total planktonic population was 50500/ lit with an average density of about 4500/lit at site A and 65875/lit an average density of 5687.5/lit at site B. The total abundance of plankton was found directly correlated to physicochemical of the water. The high production of plankton might be due to the higher amount of nutrient content in Barakune Daha. Certain genus of the Plankton disappeared at certain period and reappeared at other period in the present study. In the present research work, there was quantitative and qualitative fluctuation of Plankton according to the seasons. The Plankton population in both sample sites showed its maximum peak during autumn season in the present work while minimum during summer season. Mangalo et al., (1986) reported that the fluctuation in population density in copepod, cladocera, ostracoda and rotifer can be related to many factors e.g. effluent disposal from sewage treatment plant, food availability, temperature, PH and conductivity.

Phytoplankton

Certain plankton disappeared and reappeared at different seasons in the present study along with quantitative and qualitative fluctuation of planktons. The plankton population in both sites showed maximum peak during autumn and minimum during rainy season. The total populations of cyanophyceae were 11625/lit and 13750/lit at site A and B respectively. In both sites, five genera i.e. *Anabaena cylindrica*, *Aphanizomenon sp.*, *Gloeotrichia sp.*, *Gomphosphaeria sp.*, *Oscillatoria sp.* were found. Among them, *Oscillatoria* was found highest i.e. 3875/ lit and 4375/lit. in sites A and B respectively. The total percentage composition of Cyanophyceae at sample sites A and B were 23.02% and 20.87% respectively.

The total population of chlorophyceae was 14000/lit and 15375/lit at sample sites A and B. In both sites, five genera i.e. *Zygnema sp.*, *Ulothrix sp.*, *Spirogyra sp.*, *Oeogonium sp.and Mougeotia sp.*were collected. Among them, *Spirogyra sp.*was found maximum during investigation with 4500/lit and 5375/lit at sample sit 'A' and 'B' respectively. The total percentage composition of Cyanophyceae at sample sites A and B were 27.72 % and 23.34 % respectively.

Bacillariophyceae formed 7.67% at site ‘A’ and 7.59% at site B of the total Plankton. The major genus of Bacillariophyceae at sample site ‘A’ was *Navicula sp.* forming 3.96% while at site ‘B’, *Surirella sp.* formed major genus with 3.98% of total plankton. Euglenophyceae found at both sites comprised 3250/lit and 4875/lit with *Euglena sp.* as dominant in both sites with density of 4.21/lit and 4.74/lit respectively.

Zooplankton

The ratio of copepods to other major groups of zooplankton is considered to be indicator of tropic conditions. Rotifers and crustaceans are considered as indicator of water quality. The total population of crustacea was 13125/lit at A and 16000/lit at site B comprising 24.29 and 29.99 percent, respectively. Among the Crustacea, *Halicyclops sp.* was found to be maximum i.e. 1875/lit comprising 4.70 percent at site A but *Daphnia* sp.was found maximum i.e. 3750/lit at site B comprising 5.69 percent. Insecta was recorded to be 4125/lit comprising 8.17 percent and 5750/lit comprising 8.73percent. at sites A and B respectively. Taylor and Mariam (1988) reported dominant small cyclopoid crustaceans followed by cladocera, ciliates and rotifers in Ethopian rift valley lake, quite similar to present investigation.

The total density of turbellaria i.e. *Mesostoma virginianum* at sample site ‘A’ was 500/lit constituting 0.99 percent of the total plankton population and 1500/lit with 2.28 percent at site ‘B’. Ciliates and bacteria were collected in site B only in present study. The total number of bacteria i.e. *Micrococcus sp.* was 1625/lit forming 2.47 percent of total plankton population and the number of ciliate i.e. *Paramecium sp.* was found to be 2000/lit. forming 3.04 percent. The planktons were more densely found during autumn season and their density was low in rainy season.

Physicochemical parameters and plankton

The faunal and floristic diversity of wetland is influenced by several physico-chemical parameters such as water transparency, velocity, depth, hydrogen ion concentration, nutrient etc. (CBIP, 1979). Measurement of physico-chemical parameters is the best way to assess the water quality whether suitable to aquatic life or not. The distribution of planktons both phytoplankton and zooplanktons were found correlated with different physicochemical parameters in both sites A and B in present study. Dissolved oxygen (DO), hardness, alkalinity, chlorides and transparency showed positive correlation; but, water temperature, free CO_2, turbidity, pH and depth on the other hand showed negative correlation with planktons in present study in both sites (Tables 11 and 12). In both sites, dissolved oxygen showed highly correlated positively with plankton distribution (>0.01 level). In site A, total alkalinity showed strong correlation with plankton significant at >0.01 level. Alikhunki (1957) stated that in highly productive water, the total alkalinity ought to be over 100mg/l. According to Masuda and Pradhan (1988), alkalinity more than 40mg/l is generally considered enough for aquaculture operation and aquatic organism. In site B, transparency showed strong correlation with planktons significant at >0.01 level; but positive correlation between transparency and planktons was not statistically significant in site A. Total hardness and chloride level showed positive correlation significant at >0.05 level.

In site A, free CO_2 showed strong negative correlation with plankton density (significant at >0.01 level); water temperature and water depth had also significant negative correlation with planktons mass (significant at >0.05 level); but turbidity and pH showed insignificant negative correlation with planktons. While in site B, free CO_2, water depth and turbidity showed negative correlation with planktons significant at >0.05 level; but negative correlation between water temperature and pH was statistically insignificant here (Tables 11 and 12). The value of free carbon dioxide was maximum during spring season which was due to cloudy day causing lack in photosynthesis process, respiration process of plankton and highly decomposition of organic matter as well as chopped tree leaves. From the present investigation it was found that $C0^2$ was inversely proportional to oxygen. When carbon dioxide was high dissolved oxygen was low and vice versa. Similar observation was made by Dhakal (1991), Jha (1994) and Mahato (1988). This may be due to high amount of oxygen consumed by the animals in the pond which in turn released high amount of $C0^2$.

Species Diversity Index

The diversity index analysis showed high abundance and diversity of planktons in both sites A and B. The species diversity was recorded slightly higher in Site B in comparison to site A during July, August, September 28, October 13 and November 12; and almost equal during September 13, October 28 and November 26. But in June month, species diversity was noted slightly higher in site A than site B. Species diversity was recorded lower during June, July and August in comparison to September, October and November. The species diversity was recorded in increasing trend from June month onward reaching peak level on September 28 and from then onward species diversity was noted in slight decreasing trend till November in both sites (Table 13). From present investigation, the total Plankton abundance was highest in autumn than summer season which is seasonal pattern recorded in other hypertrophic lakes in Greece: Lake Pamovotis (Romero et al., 2002), Lake Kastoria (Michaloudi, 2000). In the summer season, water at the surface has warmed rapidly and there has been built up a large temperature gradient from the top to the bottom of the lake. The consequence of this is that the cooler, denser water of the bottom does not mix readily with the warm, light, surface water. This lead to the establishment and maintenance of the thermocline and the consequent elimination of further mixing of the surface and bottom water. The water of the epilimnion continues to circulate and the hypolimnion, although isolated, does not become depleted of oxygen. However, the epilimnion is now isolated from the bottom nutrient and this may be one of the factors involved in the Plankton decline in late summer season. As fall or autumn approaches, the water on the surface and in the whole epilimnion cools. As it cools, the difference in density of the water of the epilimnion compared to that of the thermocline disappears. Strong fall winds are now able to circulate the water completely in the same manner as was done by the spring winds and thermocline is destroyed. This fall overturn once again redistribute bottom materials and frequently there are fall plankton blooms which decline as winter approaches (Field Biology and Ecology, 2000).Very low P^H is known to reduce species diversity and abundance (Goldman and Horne, 1983). The species diversity in Zooplankton is related to the alkaline nature of the water body.

Twenty eight genera were found at both sample sites. Sample site ‘A’ contain 7 Classes: Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae, Crustacea, Insecta and Turbellaria. The phytoplankton population was comprised of 14 genera, of which falling into four major groups: Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae. Within these groups, Chlorophyceae was the most dominant at27.72%, followed by Cyanophyceae 23.02%, Bacillariophyceae, 7.67% and Euglenophyceae, 6.44%. The Zooplankton populations consist of 12 genera, of which falling into three major groups: Crustacea, Insecta and Turbellaria. Crustacea was the most dominant class at 25.99%, Insecta, 8.17% and Turbellaria, 0.99%. At sample site ‘B’, Plankton consists of 9 Classes: Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae, Crustacea, Insecta, Turbellaria, Bacteria and Cilliata. The phytoplankton population was comprised of 14 genera, of which falling into four major groups: Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae. Within these groups, Chlorophyceae was the most dominant at 23.34% followed by Cyanophyceae, 20.87%, Bacillariophyceae, 7.59% and Euglenophyceae, 7.40%.The Zooplankton population consist of 13 genera, of which falling into three major groups: Crustacea, Insecta and Turbellaria. Crustacea was the most dominant class at 24.29%, Insecta 8.73%, Cilliata 3.04%, Bacteria 2.47%, Turbellaria 2.28%, and at sample site ‘A.’ The total planktonic abundance at sample site ‘A’ 50500 no./lit. with an average density was found to be 4500 no./lit. While at sample site ‘B’ it was found to be 65875 no./lit. with an average density of 5687.50 no./lit. of the total Planktonic production. Shannon’s Wiener diversity Index was comparatively maximum at sample site ‘B’ than sample site A.

CHAPTER - SEVEN

RECOMMENDATION

Some of the important recommendations are drawn from the present research work.

- Present work is a preliminary work done in six months period, further detail successive studies required on the seasonal change of water quality parameters and its effects on plankton production in the Daha round the year in future.

- Management of wall of Barakune Daha is necessary to minimize the effect of erosion during rainy season to save this cultural and historical pond of the area.

- Water quality of Daha is suitable for fish culture to utilize unused resources in economic activities.

- Physicochemical and biological parameters should be regularly monitored to Improve and maintain the pond condition.

- Water use for the domestic purpose like washing, bathing should be stopped.

- Locals people should be given awareness training to familiarize them with the importance of wetland.

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