FAUNAL DIVERSITY AND WATER QUALITY OF THE BEESHAZAR LAKE, CHITWAN, NEPAL

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Submitted To

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Institute of Science and Technology

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Nepal

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DECLARATION

I hereby declare that the work presented in this thesis entitled "**Faunal Diversity and Water Quality of the Beeshazar Lake, Chitwan, Nepal"** has been done by myself, and has not been submitted elsewhere for the award of any degree. All Sources of information have been specifically acknowledged by reference to the author(s) and information(s).

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RECOMMENDATION

This is to inform that the thesis entitled **"Faunal Diversity and Water Quality of the Beeshazar Lake, Chitwan, Nepal"** has been carried out by Ms Namrata Shrestha for the partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper **Ecology and Environment**. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of professor and supervisor Khadga Basnet, Ph.D., this thesis submitted by Namrata Shrestha entitled **"Faunal Diversity and Water Quality of the Beeshazar Lake, Chitwan, Nepal"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper **Ecology and Environment**.

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CERTIFICATE OF ACCEPTANCE

This thesis work was submitted by Ms Namrata Shrestha entitled **"Faunal Diversity and Water Quality of the Beeshazar Lake, Chitwan, Nepal"** has been accepted as a partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper **Ecology and Environment**.

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ABSTRACT

A survey of the Beeshazar Lake was conducted for the abundance and distribution of macro-invertebrates and their relationship between physico-chemical factors at three different sites (Outlet, Clear and Inlet channel). A total of 11 faunal species represented by five groups were recorded during the investigation viz, Oligochaetes, Hirudins, Insects, Gastropods and Bivalves. The overall macroinvertebrates recorded in the study area are comprising dominant groups such as Oligochaetes (34%), Insects (26%), Gastropods (24%), Bivalves (13%) and Hirudins (3%). The faunal density (ind.m^2) ranged from 63 to 106, 56 to 76 and 66 to 100 at sites 1-3 respectively, with highest value in June at S_1.The Shannon diversity and dominance index was ranged from 1.178-1.487 and 0.241-0.336. The species diversity and density were significant positive correlation with temperature, pH, free Co_2, and hardness but significant negative correlation with dissolved oxygen and alkalinity. The result showed that the variations in physico-chemical factors affects the distribution of the macroinvertebrates.

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LIST OF ABBREVIATIONS

Abbreviated from	Details of abbreviations
BOD	Biological Oxygen Demand
BPP	Biodiversity Profiles Project
CNP	Chitwan National Park
DO	Dissolved Oxygen
GoN	Government of Nepal
GPS	Global Positioning System
ICIMOD	Integrated International Centre for integrated Mountain Development
IUCN	International Union for Conservation of Nature
KM	Kilometer
MOFSC	Ministry of Forests and Soil conservation
TDS	Total Dissolved Solid
VDC	Village Development Committee
WBC	Wetlands and Biodiversity Conservation
WHO	World Health Organization

1. INTRODUCTION

1.1 Background

Lakes and wetlands are important features of Earth's landscape. They provide valuable habitats to plants and animals, moderate hydrological cycles, influence microclimates, enhance the aesthetic beauty of landscape and extend many recreational opportunities to human kind (Sharma *et al*., 2010). Nepal is home to a wide range of wetlands. The total area of wetlands has been estimated to be 3827Km^2 covering approximately 2.6% of total area of Nepal (GoN/MFSC, 2010). Natural succession aggravated by over growth of macrophytes like water hyacinth (*Eicchornia crassipes*) and water caltrop (*Trapa* sp.) is commonly seen in many lakes of the Tarai and mid-hills. The excessive amounts of nutrients favour the growth of algae and weeds leading to eutrophication (Thilaga *et* al., 2005). Eutrophication is enriched nutrients condition in water body. Eutrophication is driven by factors such as high nutrient concentration and stagnation for prolonged periods with suitable temperature, oxygen concentration and proper light regime (Ginkel, 2011).The eutrophication results in direct and indirect biological changes. With increases in nutrients levels, the algal species composition change. Noxious blooms of algae become major problem (Jonge *et* al., 2002). The algal bloom use the oxygen and cause decreased dissolved oxygen. Eutrophication threatens not only ecology and potential recreational opportunities of the sensitive ecosystem of wetlands but also lifestyle and livelihood of local community (Kairu, 2001).

Water quality refers to the physical, chemical and biological characteristics of water. Water quality in wetland is important aspect for conservation and development, because it determines spatio-temporal dynamics of aquatic organism. The physico-chemical characteristics of the water are of great significances for any aquatic life. Each species has certain tolerance level and reflex action towards particular type and content of physico-chemical parameters. The floristic and faunal diversity of wetland is influenced by several physico-chemical parameters such as water transparency, velocity depth, pH, nutrients etc (Burlakoti, 2004).

The community of organisms that live on, or in, the bottom of a water body is known as benthos. The benthic community is complex and includes a wide range of organisms from bacteria to plants (Phytobenthos) and animals (zoobenthos) and forms the different levels of the food web. Benthic animals are generally classified according to size; microbenthos <0.063mm, meiobenthos 0.063 - 1.0 (or 0.5mm), macrobenthos >1.0 and sometimes megabenthos >10.0 mm (Tagliapietra, 2010).

The composition of the benthic fauna has largely been considered as a good indicator of water quality. The major macro invertebrates found in freshwater are flatworms, annelids, mollusks, crustaceans and insects. In pattern of macro invertebrate community structure, four types of environmental changes have been documented as increased inorganic micronutrients, increased organic loading, substrate alteration and toxic chemical pollution. In some cases severe organic pollution, siltation or toxic chemical pollution may reduce or even eliminate the entire macro invertebrate community from an affected area (APHA, 1998).

Macrobenthos are as an indicator organisms of an aquatic ecosystems (Ganesh and Raman, 2007). Various kinds of macro-invertebrates like Oligochaeta, Diptera, Orthoptera, Ephemetroptera, Neuroptera, Hemiptera etc. occur in lakes. A survey of the Beeshazar Tal showed 37 species of aquatic insects found (IUCN, 1998).

The chemical analysis was used to determine the presence and concentration of most inorganic and organic chemicals that pollute water. Temperature is an important factor to consider when assessing water quality. Water temperature directly affects the metabolic rates and biological activity of aquatic organisms.

Dissolved Oxygen (DO) refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because its influence on the organisms living within a body of water. A DO level that is too high or low can harm aquatic life and affect water quality. Oxygen concentration is important for benthic animals and there are strong correlations between the occurrence of particular species and the lowest oxygen concentration reached at the surface of the sediments in summer (Moss, 1998).

pH is a measure of the concentration of hydrogen ions in a solution and thus expresses the intensity of an acid or base. And increase in acidity results in a lower pH, where an increase in alkalinity (base) raises the pH. The alkalinity of water also plays an important role in daily pH levels. The process of photosynthesis by algae and plants uses hydrogen thus increasing pH levels. Maintaining a stable, moderate pH is very important for wetlands because they serve as fish and amphibian breeding grounds.

The Co_2 concentration can influence pH levels. Carbondioxide is the most common cause of acidity in water. Photosynthesis, respiration and decomposition all contribute to pH fluctuations due to their influences on Co_2 levels. pH also changes diurnally and seasonally due to the variation in photosynthetic activity which increases the pH due to consumption of Co_2 in the process (Trivedy and Goel, 1984).

1.2 Objectives

The main objective of the study is to analyze the relationship between physico-chemical factors and faunal diversity of the Beeshazar Lake at Chitwan. The Specific objectives were:

- To determine the abundance and distribution of macro-invertebrates.
- To analyze the monthly variations of physical and chemical factors
- To asses physico-chemical parameters that affect macro invertebrate and their distribution.

1.3 Justification

These objectives are important for several reasons. Wetland area is the main water reserve for the wildlife living in that area. The Beeshazar Lake and associated wetlands has been recently listed as a Ramsar site in Nepal (13 August 2003), establishing its global environmental significance. The aquatic vegetation is represented by mainly water hyacinth (*Eichhornia crassipes*), water chestnut (*Trapa bispinosa*), water velvet (*Azolla imbricata*), duckweed (*Lemna spp*.) etc. were spreading and seriously damaging most parts of the lake. Information on physical, chemical and biological characteristics of water is very important as these characteristics determine the Spatio-temporal dynamics of the water quality, aquatic biodiversity, health quality and sustainable use of the lake. The study will explore such information of the lake and make an important contribution to understand the relationship between the benthic organisms and water quality.

1.4 Statement of the Problems

The Beeshazar and associated lakes provide excellent habitat as water hole and corridor for globally threatened species of birds and endangered wildlife species (Kafle & Savillo, 2009; Siwakoti & Karki, 2009). Intense anthropogenic and natural factors have put wetlands of Nepal under adverse pressure (Kafle & Savillo, 2009). It has degraded water quality and its amenity value. Information on wetlands macro-invertebrates is useful to their management. Realizing these facts, my research is intended to record the inventory of aquatic fauna and to analyze the seasonal limnological parameters such as physico-chemical components, composition and distribution pattern of macro-invertebrates community of the Beeshazar Lake so as to identify the ecological status of Beeshazar Lake. It establishes biota-environmental relationship, which very useful information for conservation and sustainable management of the lake. The obtained data and analysis can be further utilized for prosperous management of lake.

2. LITERATURE REVIEW

2.1 Abundance and distribution of macro invertebrates

Basaula (2000) studied low abundance of Tubificidae, Chironomidae, Ephemeroptera, and Plecoptera showed that the water quality of the Baghmati River near the Baghdaur was not polluted because of presence of May flies and caddis flies were indicated unpolluted water condition of the Baghmati River near Baghdaur.

Dutta and Malhotra (1986) observed Oligochaetes in the Gadhigarh stream, which is free of pollution. They were of the bottom was organically rich and the current was slow. Highest number of Oligochaetes has been observed during April. In the course of present investigation, peak period of aquatic vegetation recorded from February to April, followed by a decline in the following months.

Gawad (2013) studied the spatial-temporal variations of macrobenthic fauna in Lake Nasser Khors at four seasons. Annelida, Arthropoda and Mollusca were the most dominant groups in the lake during the study period being 72.65%, 26.09% and 1.35% respectively.

Ghosh (1993) studied that the physico-chemical parameters and benthic fauna of Bagmati river. Several parameters in upstream of river were found within the range expected in a clean running water system but it was not founding downstream. Altogether 10 taxa of benthos were identified in the river.

Mahapatro et al. (2009) studied the abundance of macrobenthos in outer channel area of Chilika lagoon in the East Coast of India. They found total 27 species of macrobenthos organisms were collected during the study period. Crustacea was emerged as the most dominate group representing 9 species followed by Polychaetes with 8 species while 5 species belonged to Bivalvia and 3 species to Gastropoda.

Thilagavathi et al. (2013) studied that the distribution and diversity of macrobenthos in

different Mangroove ecosystems of Tamil Nadu Coast, India. Among the three stations, benthic macrofauna species comparatively higher in station I than Station II and III. Benthic population density positively correlated with temperature, pH, salinity, dissolved oxygen, nitrate, nitrite and inorganic phosphate.

Udash (1996) studied the ecological characteristics of Tamar Lake in Royal Chitwan National Park and analyzed some physico-chemical parameters such as temperature, pH, conductivity, total alkalinity, total hardness, dissolved oxygen, free carbon-dioxide, calcium, magnesium, nitrate and orthophosphate. Do was found below permissible values (WHO standard of water quality). The composition of benthic fauna and parameters of lake indicated that the water of study sites was polluted.

Vaidya (1988) studied pollution of the Bagmati River in the Pashupati area on the basis of diversity index macroinvertebrate fauna and found the level of pollution rising from low at upstream sites to moderate and high at the downstream sites. The higher population of pollution tolerant species in each sampling site during the month of May to August indicated that the pollution level increased in summer.

Welch (1980) studied that benthos were those organisms, which were attached or resting on the bottom or living under beneath the sediment. Zoobenthos includes micro and macro-invertebrates. The macro invertebrate of running water was dominated by insects and their diversity was the greatest.

Yadav (1989) in his dissertation work had found that the zooplankton in the lake was contributed by five genera of protozoa, three genera of Rotifer, three genera of Ostracoda, three genera of Copecoda and two genera of Cladocera. Among the five genera of major groups of zooplankton, protozoa dominate over other group.

Yadav (1995) studied the physico-chemical parameters and benthos of Bagmati River. The physico-chemical parameters and presence of macro-invertebrates showed that the water quality of Bagmati river is unpolluted in upper streams. But the water qualities gradually decrease in Pashupati area. Most of the physico-chemical parameters have been exceeded the range of risk threshold value at downstream and created unfavorable environment for the disappearance of various species Plecoptera, Ephemeroptera, Trichoptera and favorable environment to the species like Chironomidae and Tubificidae.

2.2 Physico-chemical parameters

Bastakoti (2007) studied the physico-chemical characteristics of the Beeshazar Lake and found the highest concentration of orthophosphate (0.094667±0.034443mg/lt) and total nitrogen (2.026733±0.044049 mg/lt) in the monsoon season than other seasons. The study concluded that high phosphorus concentrations was often associated with algal blooms, cyanotoxin accumulation and reduced recreational use of freshwater lakes.

Bhattarai (1996) studied the physico-chemical environment and macro-invertebrates of Lami Lake of Royal Chitwan National Park. Water temperature, pH, conductivity, Total alkalinity, Total hardness, free carbon-dioxide, calcium, Magnesium, Nitrate etc of water sample of lake were made monthly and these were found normal range necessary for aquatic biota but most important parameter DO was found above the permissible level throughout the study period.

Burlakoti (2004) studied the physico-chemical characteristics of the water are of great significances for any aquatic life. Each species has certain tolerance level and reflex action towards particular type and content of physico-chemical parameters. The floristic and faunal diversity of wetland is influenced by several physico-chemical parameters such as water transparency, velocity depth, pH, nutrients etc.

Chhetry *et al*. (2004) studied the physico-chemical parameters like air temperature, water temperature pH, transparency, DO, free co_2, alkalinity, chloride and BOD of the Titrigachhi Daha. Transparency, pH, total hardness, DO and total alkalinity were recorded maximum in winter season.

ICIMOD (2007) reported the Beeshazar Lake to have oligotrophic state in terms of the low content of Chlorophyll-a due to the rich growth of macrophytes that prevents the penetration of sunlight needed for photosynthesis.

Jayana (1997) studied on the physico-chemical analysis of water, riparian vegetation and aquatic vegetation, primary productivity, benthic fauna, fish composition and decomposition of macrophytes. The parameters like temperature, pH, conductivity, total alkalinity, total hardness, free carbon-dioxide, calcium, Magnesium, Nitrate and orthophosphate were analyzed. All these parameters meet WHO standard of water quality but the value of dissolved oxygen was found below the permitted level of 5mg/lt in

January, May and June during study period indicates accumulation of organic materials in the lake as well as Oligochaetes are least dominant groups.

Karmacharya (1990) studied that the Manohara, Dhobikhola and Vishnumati were found polluted which was clearly indicated by the analysis of physico-chemical, biological and bacteriological quality of the river water.

Karki and Chhetri (2007) identified various factors as threats to the Nepalese wetlands. The threats identified were succession, pollution, dam construction, siltation, lack of awareness, alarming rate of groundwater extraction, population pressure, inappropriate wetland management and climate change.

Khopkar (2004) studied that the water temperature affects the physical, chemical and biological environment of the lake directly or indirectly. The pH is the measures of intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water

Mc Eachern (1994) studied the physico-chemical characteristics of water in six sites in Chitwan district. The study observed pH 7.2-7.5 and dissolved oxygen ranging from 0.5-4.3 mg/lt in Devital. The value of dissolved oxygen was found below permitted level indicates the lake tending to be polluted.

Niraula (2012) studied water quality in the Beeshazar Lake and found less favorable to aquatic organisms with low pH and transparency, low dissolved oxygen and high nutrient concentration (Nitrogen and Phosphorus) challenging the conservation of critically endangered Gharial, a vulnerable marsh Crocodile and many species of fishes. The lake was found eutrophic in nature by nitrogen concentration, transparency and hyper-eutrophic condition based on phosphorus criteria. Lake sediments were high in organic matter content and nutrient concentrations, signifying a potential internal source of nutrient loading in the overlying water.

Pradhananga *et al*. (1987) studied some physico-chemical parameters of water quality of the Bagmati River. They found parameters like pH, conductivity, orthophosphate and ammonical nitrogen not exceeding permissible values and Do above permissible value (Japanese, EEC and WHO standards). On the other hand parameters like suspended solids and BOD exceeded the permissible values.

Sisodia *et al*. (2004) studied the water quality in reference to its physico-chemical characteristics in Jamwa Ramgarh Lake, India. The constituents monitored included temperature, pH, TDS, hardness, Do, alkalinity and chloride ion. A significant variation in theses parameters were observed throughout the study period. And the study revealed that if such marked variation in parameters prevailed then it will soon become an ecologically inactive lake.

Sharma *et al*. (1979) studied that the physico-chemical characteristics of freshwater to be increased in polluted than non-polluted ones. Conductivity was high and almost twice in polluted water. Ammonia, nitrate, nitrite chloride, phosphate were also found high in polluted water. In contrast, DO was high in unpolluted ones than in polluted. It was found the maximum DO in summer and the lowest in winter in unpolluted water bodies. On the other hand in polluted water bodies the oxygen was less in summer than in winter.

Thomas (1975) noted Chemical tests apply to the moment of Sampling. Both approaches i.e. Physico-Chemical and biological Parameters are necessary to define water quality.

Trivedy and Goel (1884) noted that the increasing industrialization, Urbanization and development activities and consequent pollution of water has brought a veritable water crisis. Most of the rivers of the world receive mullions of liters of sewage, domestic waste, industrial and agricultural effluents containing substances varying in characteristics from simple nutrients to highly toxic substances.

Upadhaya and Rao (1980) reported Manohara to be less polluted than Dhobi Khola Vishumati and Baghmati. They found Vishnumati and Baghmati had higher specific conductivity and chlorine concentration among the six rivers in the Kathmandu valley. The chemical parameters were found within the tolerable limits for domestic use and could be classed as good quality for irrigation purposes. Dry months had higher values for the chemical parameters than other seasons.

Wagh *et al*. (2012) studied that monitoring water quality of Nandur Madhmeswar wetland. He observed the water quality of the wetland was found to be suitable to aquatic and wildlife.

2.3 Relationship between physico-chemical parameters and fauna

Fouzia *et al*. (2013) studied aquatic biodiversity as ecological indicators for water quality criteria for River Yamuna. The influences of physico-chemical parameters and its biological diversity revealed that the quality of water has been slightly deteriorated showing a fairly good diversity. The correlation of hydrological attributes and biological diversity was good to some extent. However the condition of hydrological attributes had a great effect on biotic diversity.

Mohammad *et al*. (2015) studied that the effect of physico-chemical factors of water on the distribution of macrobenthic invertebrate fauna in the Hadejia-Nguru wetlands. They found the altered physico-chemical properties of water together with growing occurrence of the pollution indicator species, like Cryptochironomus sp. allows the wetland is tending towards eutrophication.

Neku (1997) studied the effect of physico-chemical parameters and distribution of some benthic macro-invertebrates of Vishumati river. The composition of macro-invertebrates and physico-chemical parameters of the river indicates that the water of the Vishumati river was polluted. During the study period group of animals such as Annelida, Mollusca and Arthropoda phyla were recorded.

Pant *et al*. (1980) reported that the increase in eutrophication was accompanied by increase in concentration of nitrogen, phosphorus and free carbon dioxide. These factors greatly disturbed the ecological balance and biological life of the lake. The dominating benthos was the members of Tubificidae and Chironomous species, which are the indicators of organic pollution.

Tamrakar (1996) conducted a physico-chemical parameters, distribution and abundance of zoobenthos in Manohara river for six months. The abundance and distribution of zoobenthos in relation to different sites were determined by correlating them with physico-chemical parameters of water.

Sharma (1997) studied the effect of physico-chemical factors on benthic fauna of Bhagirathi River. He observed the lowest DO in August and the highest in January. The highest value of benthic fauna was recorded in February and lowest in July and August.

He found insect population 96% of the total population. Among insects Coleoptera, Diptera, Ephemeroptera, Hemiptera, Odonata, Plecoptera, and Trichoptera Contributing 12.18, 0.26, 47.93, 1.29, 11.14 and 22.02 respectively. The maximum in abundance of lotic benthos was observed in winter and early summer phase of water current, riverine, temperature, high content of DO and clarity of water during these months.

Shrestha (2004) studied the faunal diversity and water quality in the Trishuli river water shed at Kurintaar in the study period, three stations (Pandure Khola of Thaguware VDC, Dharapani and riverside spring) were taken for detection of water quality of spring water. The physico-chemical parameters like temperature, pH, conductivity, total alkalinity, total hardness, calcium, magnesium, nitrate and orthophosphate had no parameters of water indicated that the spring water of the study sites was unpolluted.

Tamrakar (1996) conducted a physico-chemical parameters, distribution and abundance of zoobenthos in Manohara River for six months. The abundance and distribution of zoobenthos in relation to different sites were determined by correlating them with physico-chemical parameters of water.

3. MATERIALS AND METHODS

3.1 Study Area

3.1.1 Physical features

3.1.1.1 Location

The Beeshazar Lake is located in the Chitwan district of Nepal and is the central Tarai of a subtropical lowland region of Nepal. The geographical location of the lake is and 27^0 37' 04.6''' N Latitude 84^0 26' 11.3'' E Longitude at an elevation of 286 m. The Beeshazar Lake Complex occupies an area of about 3.2 km^2 including mosaics of diverse habitat; open water bodies, marshes, swamps, grasslands and forests. Lake has an open water area of about 1 km^2 and represents the second largest lake in Nepal (Niraula, 2012). The Beeshazar just because it is about 20,000 feet away from the Tikauli Barrage (headwork of Khageri Irrigation Canal) on the Mahendra Highway (Bhandari, 1996). The wetlands lie 7.2 km south from the East West Highway following Khageri canal in Gitanagar and Bachhauli VDC's, Bharatpur and Ratnanagar municipalities; and 15 km from Narayangarh Bazaar, Chitwan district, Narayani zone.

3.1.1.2 Climate

The lake area has a humid and subtropical monsoonal type of climate. Normally, January is the peak of winter and May is the peak of summer in Nepal. The highest average monthly maximum and minimum temperature recorded during the study period were 34^oC in May and 5.5^oC in January. The highest precipitation was recorded 7.3 mm in May and the lowest was 0.0 in January 2005 (Bharatpur municipality, Chitwan).

3.1.1.3 Hydrology

Water is received from direct precipitation during the monsoon and through inflow from the Khageri irrigation canal. Lake water is supplied through the canal and the stream during the dry season. The catchment area of the Lake helps control flooding in the khageri Canal, and recharges the ground water and streams (GoN/MFSC/DNPWC/CNP, 2010). According to the survey of IUCN Nepal, shows that its depth in the center varies from 3m in dry season to 5m in rainy season which is subjected to the flow of canal water (Bhandari, 1996).

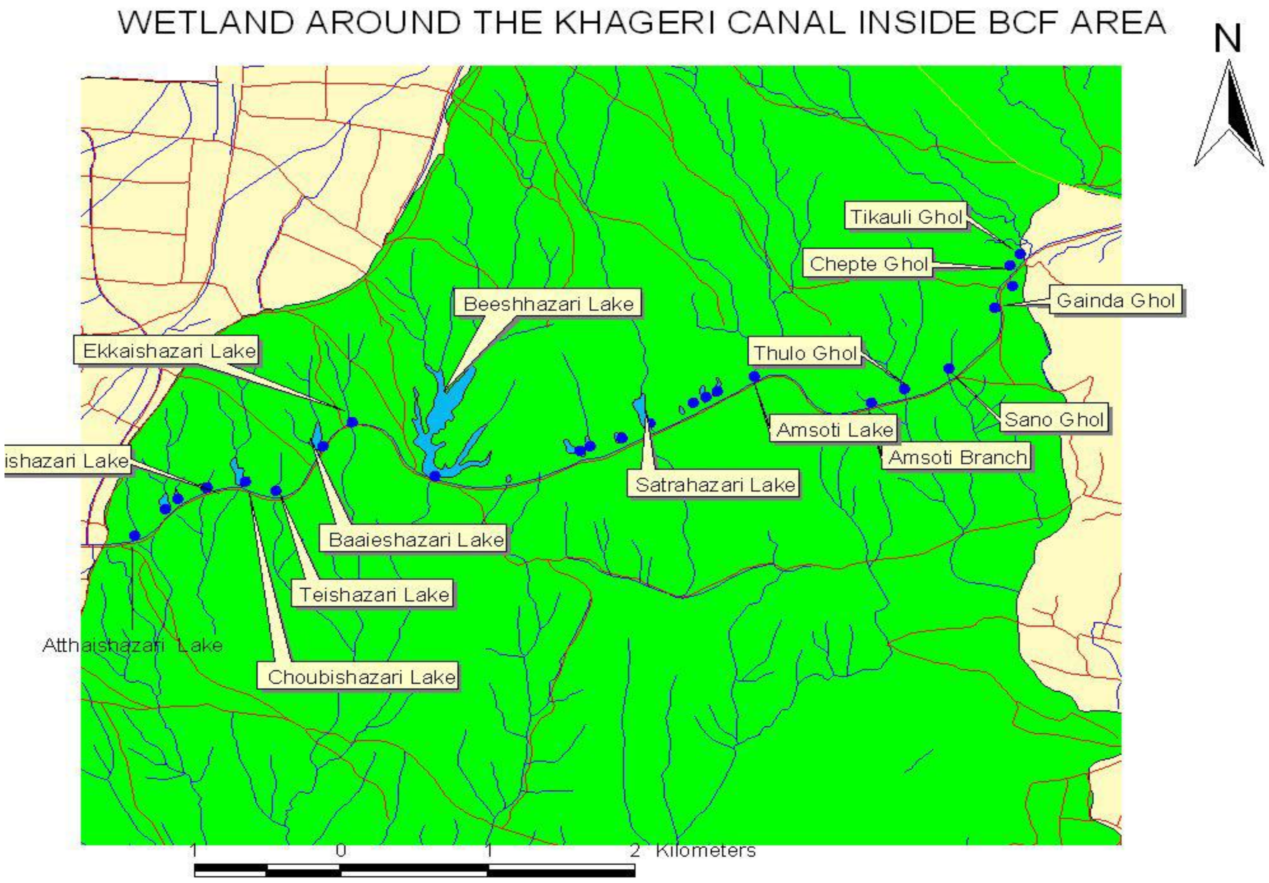
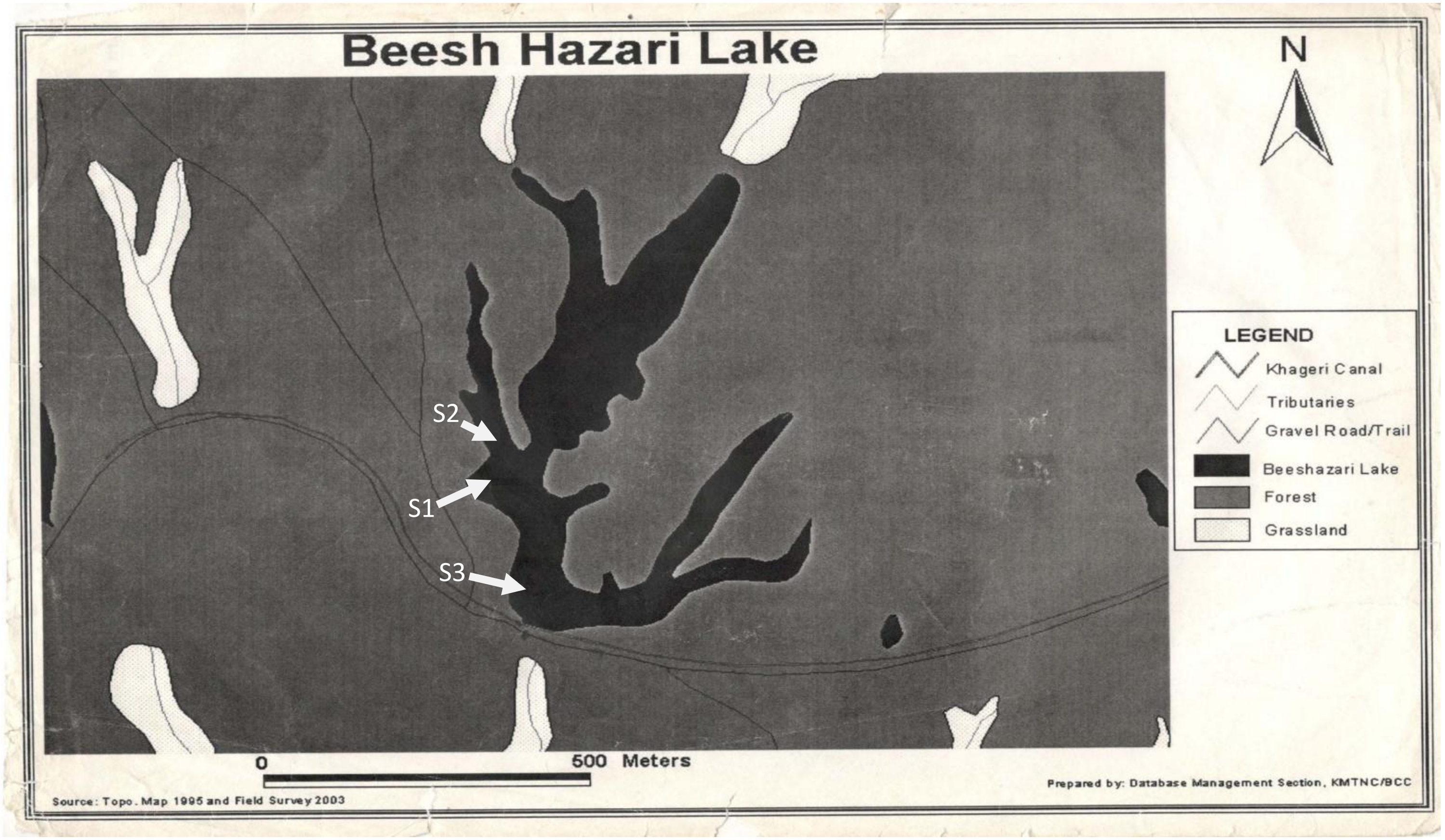


Figure 1. Location map of Beeshazar and associated Lakes



S1 = Outlet

S2 = Eastern Part

S3= Inlet Channel

Figure 2. Location of three sampling sites of the study Area

3.1.1.4 Geology

The lake bed is situated on laterite soil. Its oligotrophic state is indicated by the low content of Chlorophyll ‘A’ due to the rich growth of macrophytes; this prevents the penetration of sunlight needed for photosynthesis. Land use patterns; 30% open forests, 40% dense forests, 15% grasslands and 15% pasturelands.

3.2 Biological Features

3.2.1 Flora

The terrestrial vegetation is dominated by Sal (*Shorea robusta*) forest. The prominent associated species include Myrobalan (*Terminalia alata*), Slik Cotton (*Bombax ceiba*) and Bot Dhainyaro (*Lagerstroemia parviflora*). The area records 37 vascular plants; 1 pteridophyte, 26 dicots and 10 monocots. The wetland vegetation consists of Sedge (*Cyperus spp*.), Common Reed (*Phargmites karka*), Morning Glory (*Lpomea carnea spp. fistulosa*) and Mikania (*Mikania microrantha*). The aquatic vegetation is represented by extensive coverage of floating leafed species mainly Water Hyacinth (*Eichhornia crassipes*), Water Chestnut (*Trapa bispinosa*) followed by Evening Primrose (*Ludwigia adscendens*). The free floating species include Water Velvet (*Azolla imbricata*) and Duck Weed (*Lemna spp*.). The abundant submerged species include Hornwort (*Ceratophyllum demersum*), Hydrilla (*Hydrilla verticillata*) and Water Nymph (*Najas minor*). In general, the vegetation is in floating leafed succession stage. Reed swamp formations are found in backwaters in finger like projections, characteristic of an Ox-bow lake system (GoN/MFSC, 2010).

3.2.2 Fauna

Altogether 26 species of mammals, 18 species of herpeto-fauna, 25 species of fishes, 37 species of aquatic insects, 273 species of birds (60 species being wetland dependent) and 131 species plants (including 99 species are aquatic) have been identified in and around the Beeshazar Tal (Bhandari, 1998). Some of the charismatic fauna and flora in the area is the Royal Bengal Tiger (*Panthera tigris tigris*), one-horned rhino (*Rhinoceros unicornis*), Gharial (*Gavialis gangeticus*), Mugger crocodile (*Crocodylus palustris*), Asiatic rock python (*Python molurus*), vulnerable smooth-coated otter (*Lutrogale perspicillata*), sloth bear (*Melursus ursinus*), Band-tailed Fishing Eagle (*Haliaeetus leucoryphus*) and lesser adjutant stork (*Leptoptilos javanicus*) a globally threatened bird etc. (Himalayan Journal of science, 2004). Due to its rich biodiversity value, especially with regards to the birds, both local residents and migrants, the lake is designated as a Ramsar site (Ramsar site no. 1313) on 13th August, 2003.

3.3 Socio-economic and Cultural features

Socio-economic condition of the wetland area entirely depends upon the population and their activities. Approximate population of the wetland area was 99,299. The major ethnic groups were Brahmin, Chhetri, Damai, Kami, Newar, Tamang, Magar Tharu and other indigenous people. The major crops grown in this area includes paddy during the Monsoon followed by wheat and mustard during the winter in low land. Most of people have farming as their primary occupation as well as farming of livestock includes cows, buffaloes and goats (BPP, 1995).

3.4 Methods of Sampling

3.4.1 Sampling Sites

Sampling sites of the lake were selected on the basis of distance, easier to take water samples, availability of light, human activities and flow of incoming and outgoing of water.

On the basis of these reasons, three sampling sites were selected for the study of the Beeshazar Lake by the help of Global positioning system (GPS).

Site S_1: This site is situated near the outlet and is located at 27^0 37’ 03.5" N and 84^0 26 '16.5" E at an elevation of 111m on GPS. In this site, there is availability of light, human disturbance is low.

Site S_2: This site is situated in the eastern part of the lake (clear) and is located at 27^0 38' 50.2"N and 85^0 17' 03.4" E at an elevation of 183m on GPS. This site is clear and less affected by vegetation. Bottom of this site was muddy.

Site S_3: This site is situated near the inlet and is located at 27^0 36' 53.2" N and 84^0 26' 21.7" E at an elevation of 147m on GPS. This site is joined with Khageri irrigation canal from where lake receives the runoff and shadow of the tree directly falls on the lake.

3.4.2 Biological Characteristics

3.4.2.1 Sampling of Macro invertebrates

The regular samplings of fauna were carried out from January to June 2005. The samples were collected by using the Peterson's Grab Sampler having an area of 0.025 m^2. The collected samples were first washed from the sediment and transferred with some water to a coarse sieve with a mesh size of 0.5 mm. The macro invertebrates were treated with 5% formalin and kept for further analysis. The identification of animals was carried out by the publication of Standard Literature of Mullar (1774), Pennak (2001), Hickin (1945), Lamarck (1822), Hutton(1849), Edmondson (1966), Brown (1980) etc. Population density was made by individual counting of animals and their abundance was expressed as ind. / m^2.

3.4.2.2 Collection of water Samples

The physico-chemical parameters of the lake were studied from January to June 2005. The surface water was collected from three sampling sites of wetland, once in every month in pre-cleaned sample bottles. While collecting the water samples these bottles are again rinsed with the water of same sites. The bottle was allowed to sink up to the desired depth (5-10cm) and its mouth was opened and filled up and the cap locked underwater before taken out of water. Immediately after collection the water samples, some parameters such as temperature, pH, DO, free Co_2 , alkalinity and total hardness of the lake were analyzed in field by using methods of Trivedy and Goel (1984).

3.5 Analysis of physico-chemical parameters

3.5.1 Temperature

Water temperature was measured with the help of a Mercury thermometer. For the measurement of water temperature, the bulb of the thermometer was dipped in a beaker filled with water sample for about 2 minutes and reading was noted.

3.5.2 pH

pH of the water sample was measured by a digital pH meter (Hanna Instrument with an accuracy of ±0.01). Before measuring the pH meter was first calibrated with standard buffer solution of pH 4.0 and 9.2.The glass electrode was washed with distilled water and dipped in a beaker containing fresh water sample until the reading stabilized at a certain point. Then the reading was noted.

3.5.3 Dissolved Oxygen (DO)

DO was determined by Winkler's titration method by taking 300 ml sample of water with 2ml of $Mnso_4$ and 2ml of alkaline potassium iodide (KI) in BOD bottle. The brown precipitate was formed on the bottle which was shaken well and left to settle down precipitate sufficiently. Then 2ml of concentrated sulphuric acid (H_2So_4) was added and stopper was placed and inverted several times until the dissolution of precipitation was completed. Then 100ml of sample from BOD bottle was taken in conical flask and titrated against (0.025N) sodium thiosulphate ($Na_2S_2O_4$) solution until a coffee brown color appeared. At the moment a drop of a starch solution was added as indicator and again titrated with sodium thiosulphate solution until blue color disappeared. The volume of sodium thiosulphate solution consumed in getting the end point was noted. Three readings were taken and mean was calculated out to determine the concentration of dissolved oxygen as mg/lt by using the given formula,

$$\text{Dissolved oxygen (mg/lt)} = \frac{(\text{ml} \times \text{N}) \text{ of titrant} \times 1000 \times 8}{\frac{V_2(V_1 - V)}{V_1}}$$

Where V_1 =Volume of sample bottle after placing the stopper

V_2=Volume of part of content titrated

V =Volume of $MnSO_4$ and KI used

3.5.4 Free Carbondioxide

Free carbon dioxide was determined by taking the sample of 100 ml water in a clean conical flask and a few drops of Phenolphthalein an indicator was added to it. If the sample remains colorless, it was immediately titrated against 0.05N Sodium hydroxide (NaoH) solution stirring with a glass rod until pink color appeared. The volume of sodium hydroxide consumed in getting the end point was noted. Three readings were taken to get mean reading for the determination of the free carbondioxide as mg/litre by using following equation, Free Co_2 (mg/liter) = $\frac{(ml \times N) \text{ of NaOH} \times 1000 \times 44}{\text{ml of sample used}}$

Phenolphthalein acidity as $Caco_3$ (mg/lt) = $\frac{B \times N \text{ of NaoH} \times 1000 \times 50}{\text{ml of sample used}}$

Where, A= ml of NaoH used with methyl orange indicator

B = ml of NaoH used with Phenolphthalein indicator.

3.5.5 Total Alkalinity

Total alkalinity was determined by taking 100ml of sample in a conical flask and 2 drops of Phenolphthalein indicator was added on it. The sample remains colorless which indicated that the Phenolphthalein alkalinity zero. Immediately 2 or 3 drops of methyl orange was added to the same sample and titrated against HCL (0.1 N) until the yellow color changed to pink at the end. The volume of HCL consumed was noted which gave the total alkalinity. Three readings were taken and the mean was taken out to convert total alkalinity later as mg /liter by using the following equation,

TA as $CaCo_3$ (mg/liter) = $\frac{(B \times \text{Normality}) \text{ of Hcl} \times 1000 \times 50}{\text{ml of sample used}}$

Where, B = ml of total Hcl used with Phenolphthalein and Methyl orange

TA =Total Alkalinity

Whenever the color changed to pink after addition of Phenolphthalein it was titrated with 0.1 Hcl until the color disappeared. PA alkalinity was calculated by the following equation,

PA = $\frac{(A \times \text{Normality}) \text{ of Hcl} \times 1000 \times 50}{\text{ml of sample used}}$

Where, A = ml of Hcl used with Phenolphthalein

PA = Phenolphthalein Alkalinity

3.5.6 Total Hardness

Total hardness was determined by taking 50ml sample in a clean conical flask in which 2ml of ammonia buffer was added and 200mg of Erichrome Black as indicator was added to it and shaken well. Then the sample was titrated against standard EDTA solution of 0.01 N till the color changed from wine red to blue. The volume of EDTA consumed was noted. Three readings were taken and mean was carried out to convert total hardness as mg/lt by following equation,

$$\text{Total hardness as } Caco_3\text{, mg/lt} = \frac{\text{ml of EDTA used} \times 1000}{\text{ml of sample used}}$$

3.6 Statistical Analysis

All the statistical analysis was carried out with the help of the Microsoft Excel. Diversity indices such as Shannon's index of diversity (H) and index of dominance (D) reflects the occurrence of species within community. This helps to understand how the macro invertebrates were distributed in the collected samples. Correlations between the fauna and physico-chemical parameters of water were evaluated by using Pearson's correlation analysis. Multivariate analysis such as Principal component analysis (PCA) was based on the macro faunal abundance, diversity indices and with physico-chemical parameters. This was determined by using R package (version 3.3.2).

4. RESULTS

4.1. Occurrence of macro invertebrates

4.1.1 Total numbers of animals

All total of 1456 animals were recorded in six months from all three sampling sites of the Beeshazar Lake during the study period from January to June 2005. By site, faunal density (ind.m^2) ranged from 63 to 106, 56 to 76 and 66 to 100 at sites 1-3 respectively, with highest value in June at S_1. Comparatively, S_1 supported higher abundance 35.98% and than 35.92% and 28.09% in S_3 and S_2 respectively.

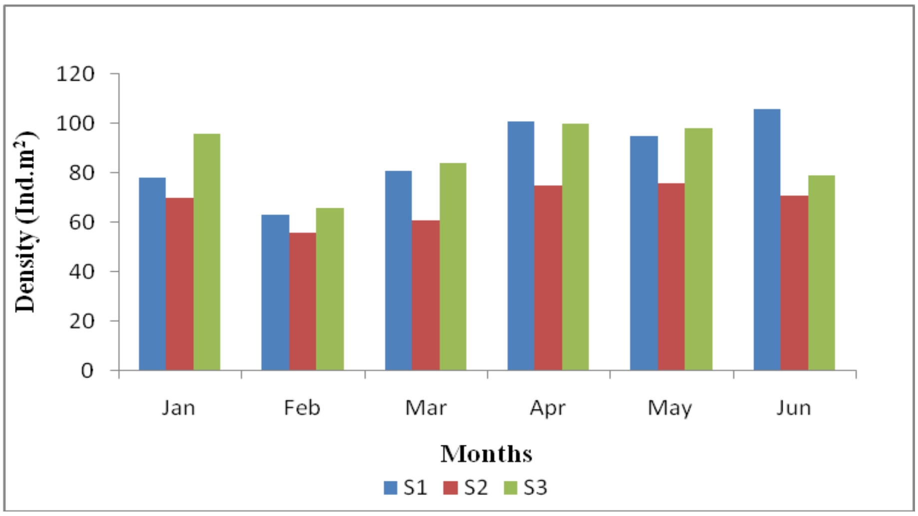


Figure 3. Total counting of fauna at three sites of the Beeshazar Lake during the study period

4.1.2 Species composition of Macro-invertebrates

A total of 11 macroinvertebrates represented by five groups were recorded during the investigation viz, Oligochaetes, Hirudins, Insects, Gastropods and Bivalves. From the results obtained that Oligochaetes was dominant (493 ind/m^2) consisting of 2 species and contributed to 34% of the total fauna during the study period. The other groups like hirudins consists of 1 species and contribute to 3%, insects consist of 3 species and contribute to 26%. Gastropods consist of 4 species and contribute to 24% and also bivalves consist of 1 species and contribute to 13% of total faunal population was shown in Figure 4.

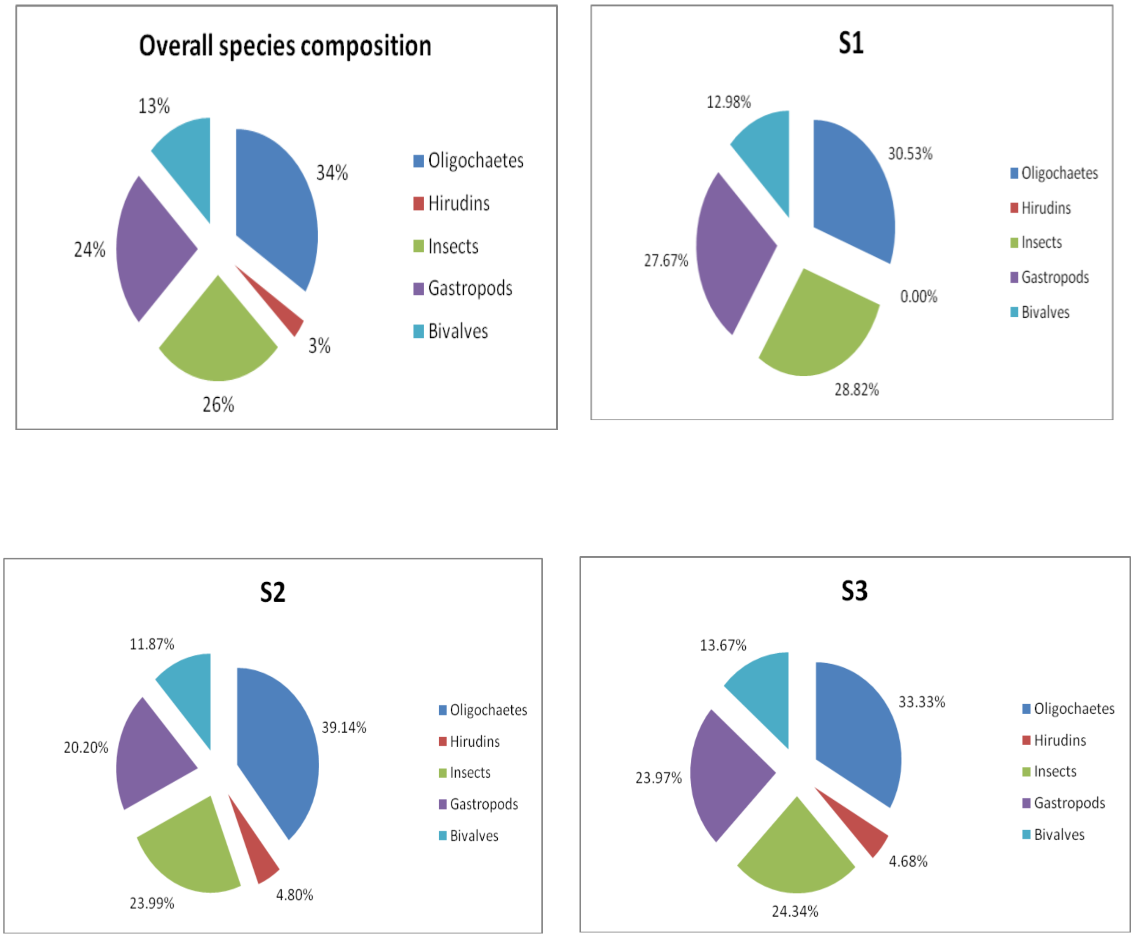


Figure 4. Relative abundance of different faunal groups at three sites during the study period

Oligochaetes and insects were more abundant in all three sites and hirudins was less abundant in S_2 and S_3 but it was not recorded at S_1. The highest relative abundance of oligochaetes was 30.53%, 39.15% and 33.33% at S_1, S_2 and S_3. Similarly, abundance of gastropods was 27.67%, 20.20% and 23.97% and insects was 28.82%, 23.99% and 24.34% at S_1, S_2 and S_3 respectively (Figure 4).

Table 1. Sitewise occurrence of macro-invertebrates (+ Present, - Absent).

Dominant Taxa	S_1	S_2	S_3
Annelida			
Oligochaeta			
Tubificidae			
Branchiura sowerbyi (Beddard, 1892)	+	+	+
limnodrilus hoffmeisteri (Claparede, 1862)	+	–	+
Hirudinea			
Glossiphonidae			
Glossiphonia sp.	–	+	+
Arthropoda			
Hemiptera			
Nepidae			
Nepa sp. (Linnaeus, 1758)	+	+	+
Ranatra sp. (Fabricius, 1790)	+	+	+
Diptera			
Chironomidae			
Chironomus sp.	+	+	+
Mollusca			
Gastropoda			
Viviparidae			
Bellamya bengalensis (Lamarck, 1882)	+	+	+
Lymnaeidae			
Lymnaea acuminata (Lamarck, 1822)	+	+	–
Planorbidae			
Indoplanorbis exustus (Deshayes, 1834)	+	+	+
Gyraulus convexiusculus (Hutton, 1849)	+	+	+
Bivalvia			
Unionidae			
Lamellidens sp. (Lamarck, 1819)	+	+	+

Annelida

Phylum Annelida was represented by two classes Oligochaeta and Hirudinea.

The family belonging to class Oligochaeta was Tubificidae. *Branchiura sowerbyi* and *limnodrilus sp*. were recorded in this family. *Branchiura sowerbyi* was recorded at all three sites but *limnodrilus sp.* was recorded only at sites S_1 and S_3.

The family belonging to class Hirudinea was Glossiphonidae. The species belonging to this family includes *Glossiphonia* sp. recorded only at S_2 and S_3 but it was found at $S_{1.}$

Arthropoda

Phylum Arthropoda was represented by two orders Hemiptera and Diptera. The family belonging to order Hemiptera was Nepidae and the species belonging to this species family were *Nepa* sp. and *Ranatra* sp. only at S_1 and $S_{3.}$ Similarly the family belonging to order Diptera was Chironomidae and the species belonging to order Diptera includes *Chironomus* sp. at all S_1, S_2 and S_3.

Mollusca

Phylum Mollusca was represented by two classes Gastropoda and Bivalvia.

The family belongings to class Gastropoda were Lymnaeidae, Viviparidae and Planorbidae. In Lymnaeidae family *Lymnaea acuminata* were recorded only at site $S_1$and S_2 but not found in S_3. The species belonging to family Viviparidae was *Bellamya bengalensis* at all three sites. The species belonging to family Planorbidae includes *Indoplanorbis exustus* and *Gyraulus convexiusculus* were recorded at all three sites.

Class Bivalvia was represented by the family Unionidae. The species belonging to this family includes *Lamellidens* sp. recorded at all three sites $S_{1,}$ S_2 and S_3.

4.1.3 Shannon index of diversity (H)

In the month of January the highest Shannon diversity index (H) was found to be 1.317 at S_2 and the lowest value was found to be 1.178 at S_1. In the month of February the highest Shannon diversity index was found to be 1.470 at S_3 and the lowest diversity was found to be 1.291 at S_1. In the month of March the highest Shannon diversity index was found to be 1.487 at S_3 and the lowest diversity was found to be 1.336 at S_1. Similarly in the month of April the highest Shannon diversity index was found to be 1.437 at S_3 and the lowest diversity was recorded to be 1.307 at S_1. In the month of May and June the highest diversity index was recorded to be 1.465 and 1.383 at S_3 and S_2 and the lowest diversity was 1.269 and 1.258 at S_1.Within the period of six months the highest Shannon diversity index was found to be 1.487 in the March at S_3 and the lowest value was found to be 1.178 in January at S_1.

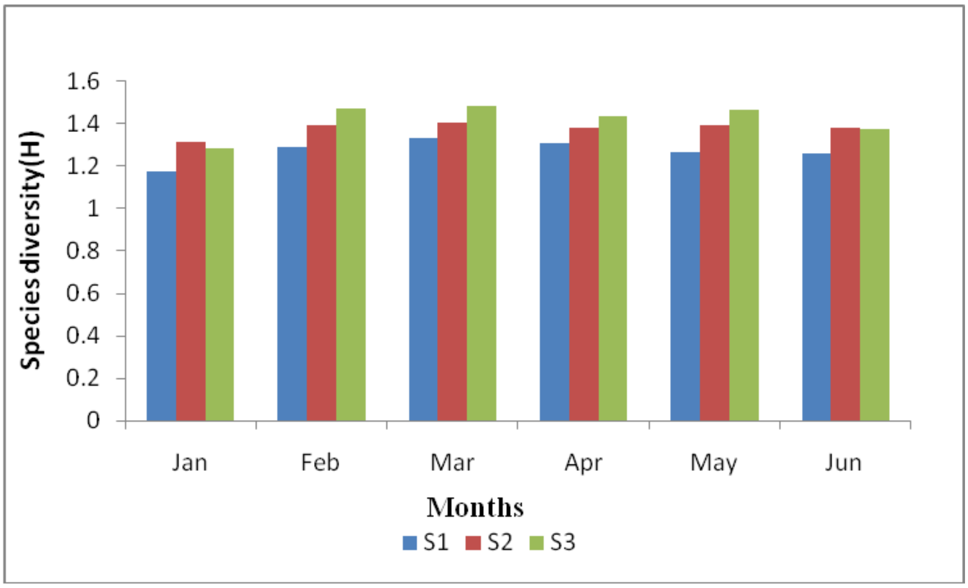


Figure 5. Monthly variations in Shannon diversity index (H) of macro-invertebrates in the Beeshazar Lake during the study period

4.1.4 Index of dominance (D)

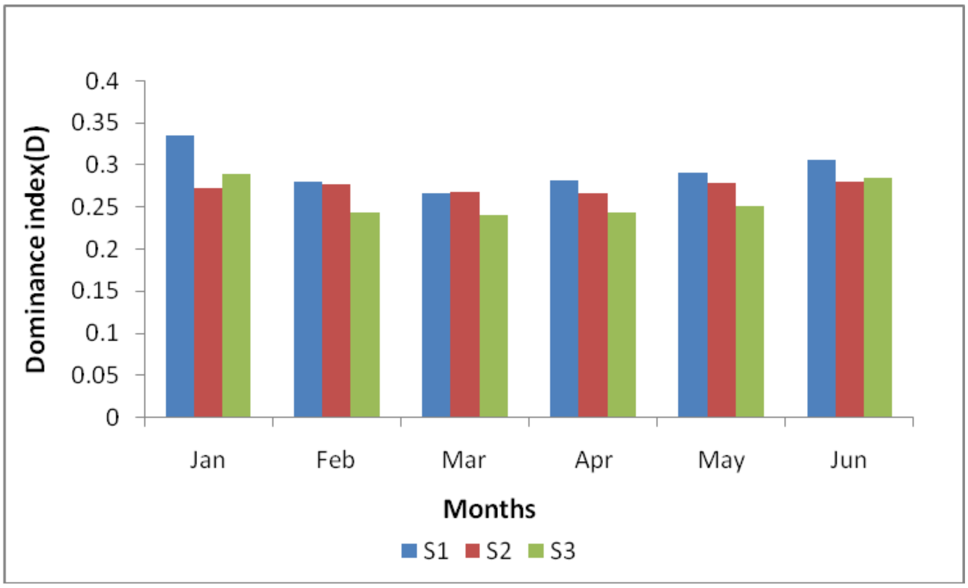


Figure 6. Monthly variations in index of dominance (D) of macro invertebrates in the Beeshazar Lake during the study period

In the month of January the highest index of dominance was found to be 0.336 at S_1 and the lowest dominance was found to be 0.273 at S_2. In the month of February the highest index of dominance was found to be 0.281 at S_1 and the lowest dominance was found to be 0.243 at S_3. In the month of March the highest index was found to be 0.268 at S_2 and the lowest dominance was found to be 0.241 at S_3. Similarly in the month of April the highest index of dominance was found to be 0.282 at S_1 and the lowest dominance was recorded to be 0.243 at S_3. In the month of May and June the highest index of dominance was recorded to be 0.291 and 0.307 at S_1 and the lowest dominance was 0.251 and 0.281 at S_3 and S_2.Within the period of six months the highest value of dominance was recorded in the month of January at S_1 and the lowest value was found in the month of March at S_3.

4.2 Physico-chemical Parameters of lake Water

The results of physico-chemical parameters from the three sampling sites S_1, S_2 & S_3 of the Beesh Hazari Lake during the study period.

4.2.1 Physical parameters

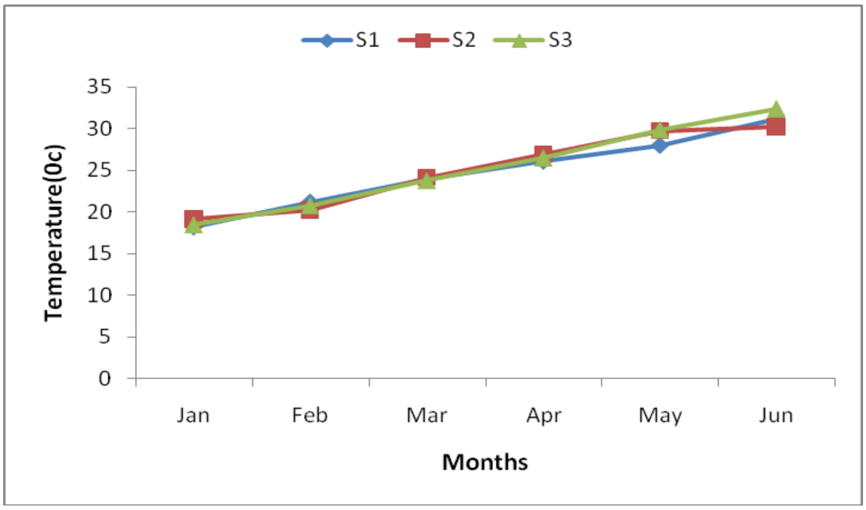


Figure 7. Monthly variations in temperature of water of three sites of the Beeshazar Lake during the study period

At S_1 the temperature of water was recorded 18.2°C in January gradually increased and reached maximum level 31.2°c in June. In other months the temperature was ranged from

21.2°C to 28°C. At S_2 the temperature was recorded 19.1°C in January and increased and reached maximum level 30.2°C in June. In other months the temperature was ranged from 20.2°C to 29.7°C. At S_3 the temperature was recorded 18.5°C in January and increased and reached maximum level 32.4°C in June. In other months the temperature was ranged from 20.8°C to 29.9°C.

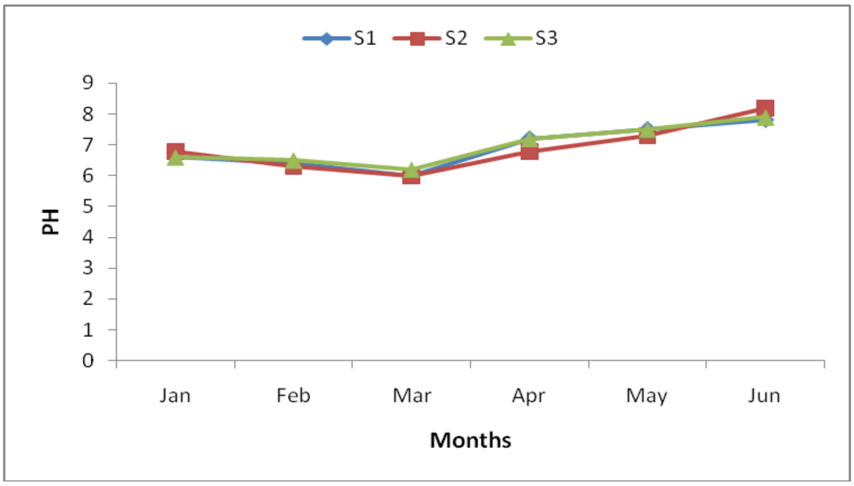


Figure 8. Monthly variations in pH of water of three sites of the Beeshazar Lake during the study period

At site $S_{1,}$ pH of water was recorded 6.6 in January and gradually increased and reached to the maximum level 7.8 June. In other months, the pH was ranged from 6.0 to 7.5. At site S_2 the pH of water was recorded 6.8 in January and gradually increased and reached to the maximum level 8.0 in June. In other months, the pH was ranged from 6.0 to 7.3. At site S_3 the pH of water was recorded 6.6 in January and gradually increased and reached to the maximum level 7.9 in June. In other months, the pH was ranged from 6.2 to 7.5.

4.2.2 Chemical parameters

At site S_1 the concentration of DO was recorded 5.23 mg/lt in January and decreased to minimum level of 3.77 mg/lt in May. In other months, it ranged from 3.91mg/lt to 4.61mg/lt. At site S_2 the value was recorded 4.61mg/lt in January and decreased to minimum level of 3.36 mg/lt in May. In other months, it ranged from 3.63mg/lt to 4.05mg/lt. At site S_3 the dissolved oxygen was recorded 4.40 mg/lt in January and decreased to minimum level of 2.77 mg/lt in June. In other months, it ranged from 3.70 mg/lt to 4.16mg/lt.

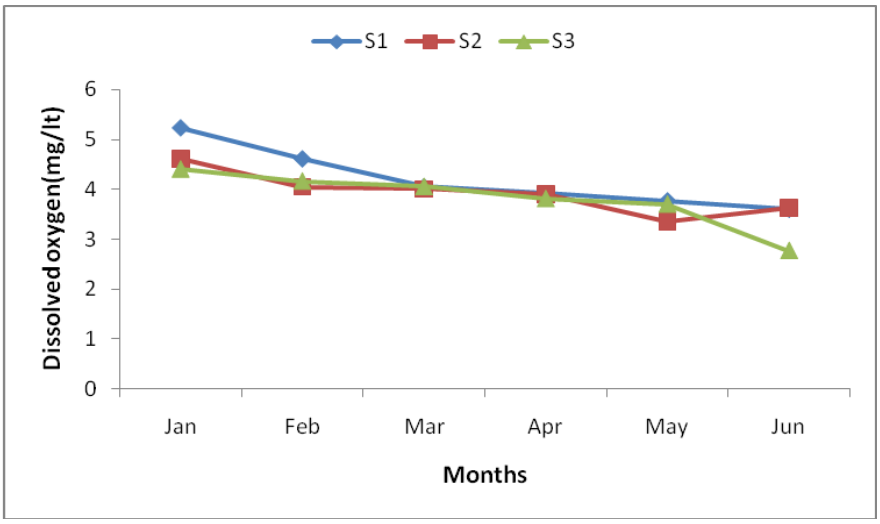


Figure 9. Monthly variations in DO of water of three sites of the Beeshazar Lake during the study period

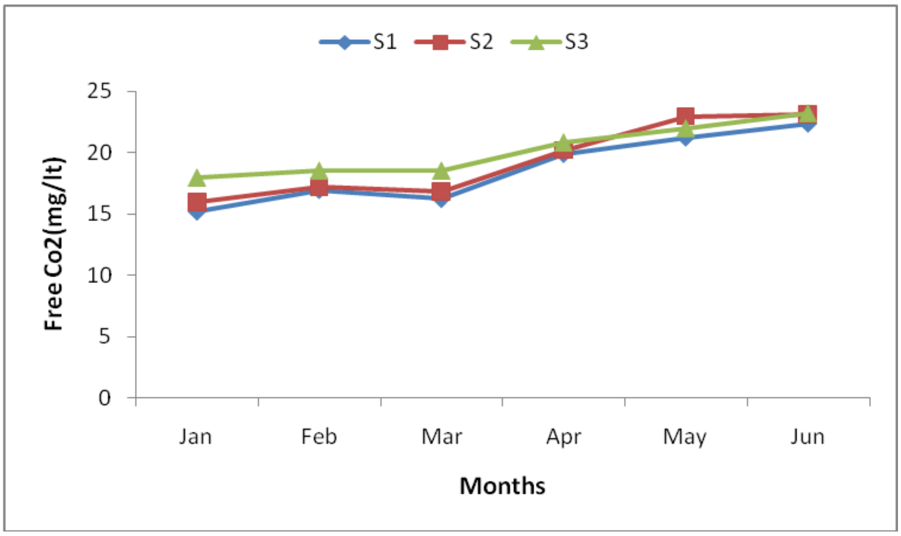


Figure 10. Monthly variations in free Co_2 of water of three sites of Beeshazar Lake during the study period

The free Co_2 of the lake water was recorded regularly during the study period. At S_1 the free Co_2 was recorded 15.23 mg/lt in January and increased to maximum level of 20.16 mg/lt in June. In other months, it ranged from 15.99 mg/lt to19.85mg/lt. At S_2 the free Co_2 was recorded 15 mg/lt in January and increased to maximum level of 23.16 mg/lt in June. In other months, it ranged from 16.98 mg/lt to 21.85 mg/lt. At S_3 the free Co_2 was recorded 16.96 mg/lt in January and increased to maximum level of 22.20 mg/lt in June. In other months, it ranged from 17 mg/lt to 21.20 mg/lt.

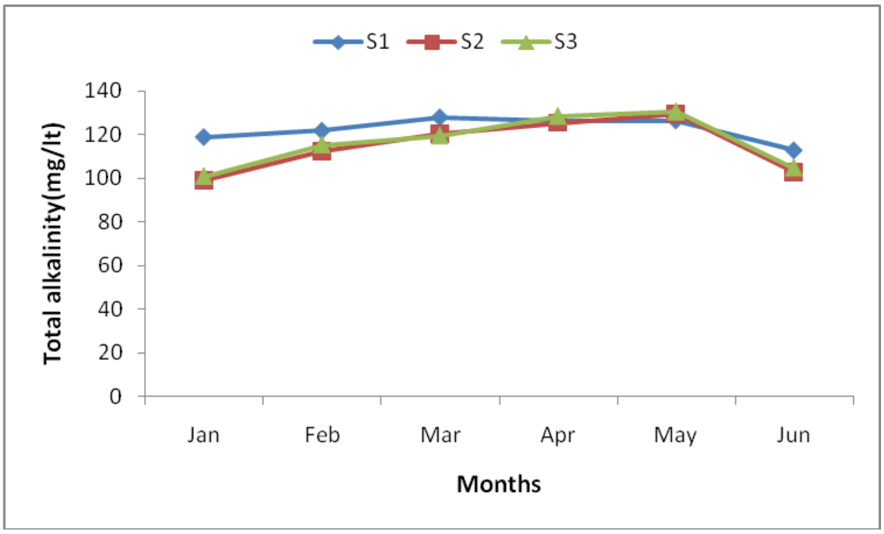


Figure 11. Monthly variations in total alkalinity of water of three sites of the Beeshazar Lake during the study period

At S_1 the total alkalinity of the lake water was 119.9 mg/it in January and increased to 128 mg/lt in March. In other months, it ranged from 121.9 mg/lt to 126.6 mg/lt. At S_2 the total alkalinity was recorded 98.8 mg/lt in January and increased to maximum level of 129.6 mg/lt in May. In other months, it ranged from 102.8 mg/lt to 125.5 mg/lt. At S_3 the total alkalinity was recorded 100.9 mg/lt in January and increased to maximum level of 130.6 mg/lt in May. In other months, it ranged from 104.8 mg/lt to 128.6 mg/lt.

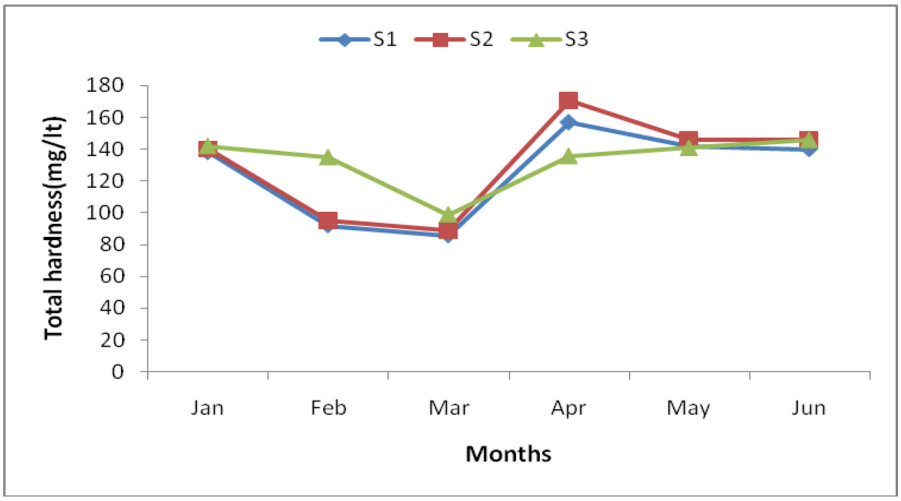


Figure 12. Monthly variations in total hardness of water of three sites of the Beeshazar Lake during the study period

At S_1 the total hardness of the lake water was 138.11 mg/it in January and increased to reached 156.77 mg/lt in May. In other months, it ranged from 92.11mg/lt to 141.88mg/lt. At S_2 the total hardness was recorded 140.11 mg/lt in January and increased to maximum level of 170.77 mg/lt in April. In other months, it ranged from 95.11 mg/lt to145.88 mg/lt. At S_3 the total hardness was recorded 142.11 mg/lt in January and increased to maximum level of 146 mg/lt in June. In other months, it ranged from 98.77 mg/lt to 140.88 mg/t.

4.2.3 Relationship between faunal diversity and physico-chemical parameters

Table 2. Pearson's correlation (r) showing relationship between fauna and physico-chemical parameters

	Temp.	pH	DO	Free co_2	TA	TH
Branchiura	0.995	0.473	-0.992	0.993	-0.788	0.984
Limnodrilus	0.235	0.939	-0.017	0.257	0.495	-0.032
Glossiphonia	0.954	0.280	-0.996	0.947	-0.899	0.999
Nepa	0.010	0.838	0.208	0.033	0.677	-0.256
Ranatra	-0.491	0.454	0.669	-0.470	0.954	-0.705
Chironomous	-0.393	0.548	0.584	-0.372	0.916	-0.624
Bellamaya	-0.902	-0.139	0.974	-0.891	0.953	-0.984
Lymnaea	-0.905	-0.147	-0.906	0.895	0.950	-0.985
Indoplanorbis	-0.976	0.719	-0.976	0.981	-0.564	0.884
Gyraulus	-0.489	0.997	-0.286	0.509	0.242	0.239
Lamellidens	0.192	0.923	0.027	0.214	0.533	-0.076

Correlation analysis showed a relationship between faunal diversity and physical-chemical factors. Temperature was significant positive correlation with *Branchiura* (r = 0.995; p <0.01) and *Glossiphonia* (r = 0.954; $p < 0.01$) but significant negative correlation with *Bellamaya (*r = -0.902;*p < 0.01), Lymnaea* (r = -0.905; $p < 0.01$) and *Indoplanorbis* (r = -0.976;*p < 0.01).* pH was positively correlated with *Branchiura* (r = 0.473; $p < 0.01$), *Limnodrilus* (r = 0.939; $p < 0.01$), *Nepa* (r =0.838; p <0.01), *Ranatra* (r =0.838; p <0.01), *Chironomous* (r = 0.548; $p < 0.01$), *Indoplanorbis* (r = 0.719; $p < 0.01$), *Gyraulus* (r = 0.997; $p < 0.01$) and *Lamellidens* (r = 0.923; $p < 0.01$). DO was significant positive correlation with *Ranatra* (r = 0.669; $p < 0.01$). and *Bellamaya* (r = 0.974; $p < 0.01$) but significant negative correlation with *Branchiura* (r = -0.992; $p < 0.01$), *Glossiphonia* (r = -0.96; $P < 0.01$), *Lymnaea* (r = -0.906; $p < 0.01$) and *Indoplanorbis* (r = -0.976; $p < 0.01$). Free Co_2 was also positively correlated with *Branchiura* (r = 0.993) and

Glossiphonia (r = 0.947*; p* < 0.01), *Lymnaea* (r = 0.895*; p* < 0.01) and *Indoplanorbis* (r = -0.891*; p* < 0.01) but negatively correlated with *Ranatra* (r = -0.470*; p* < 0.01), *Chironomous* (r = -0.372*; p* < 0.01) *and Bellamaya* (r = -0.891*; p* < 0.01) The total alkalinity was positively correlated with *Nepa* (r = 0.677*; p* < 0.01), *Ranatra* (r = 0.954*; p* < 0.01), *Chironomous* (r = 0.916*; p* < 0.01), *Bellamaya* (r = 0.953*; p* < 0.01) *and Lymnaea* (r = 0.950*; p* < 0.01) but negatively correlated with *Branchiura* (r = -0.788*; p* < 0.01), *Glossiphonia* (r = -0.899*; p* < 0.01) and *Indoplanorbis* (r = 0.564*; p* < 0.01). Total hardness was significant positive correlation with *Branchiura* (r = 0.984; p<0.01) *Glossiphonia* (r = 0.999; p<0.01) and *Indoplanorbis (*r = 0.884; *p* < 0.01) but negatively correlated with *Ranatra* (r = -0.705; *p* < 0.01), *Chironomous* (r = -0.624; *p* < 0.01), *Bellamaya* (r = -0.984; *p* < 0.01) and *Lymnaea* (r = -0.985; *p* < 0.05).

4.3 Biodiversity and physico-chemical factors

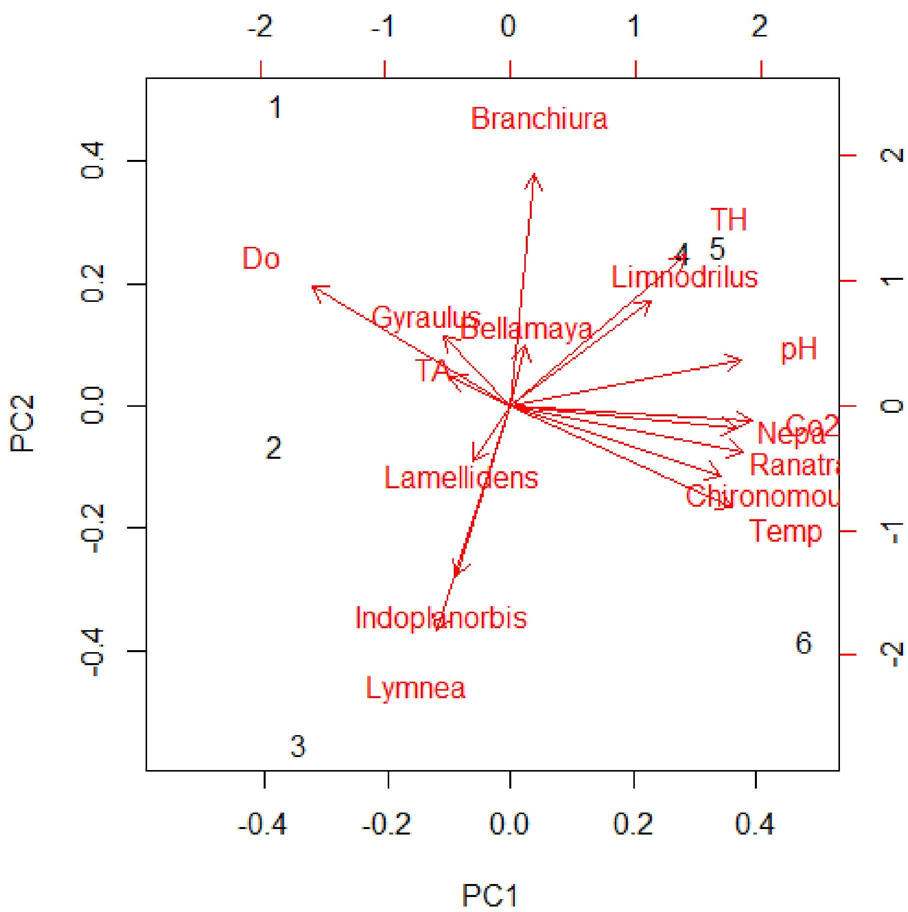


Figure 13. PCA biplot showing the relationship between the physico-chemical parameters and species in S_1 (Outlet) during the study period.

PCA showed that, physico-chemical variables associated with principal components 1 and 2 accounted for 65.9% variability among the samples in S_1 (Figure 13). DO, pH, total alkalinity and total hardness were positively correlated with high abundance of *Branchiura sp.*, *Chironomous sp. and lamellidens.*

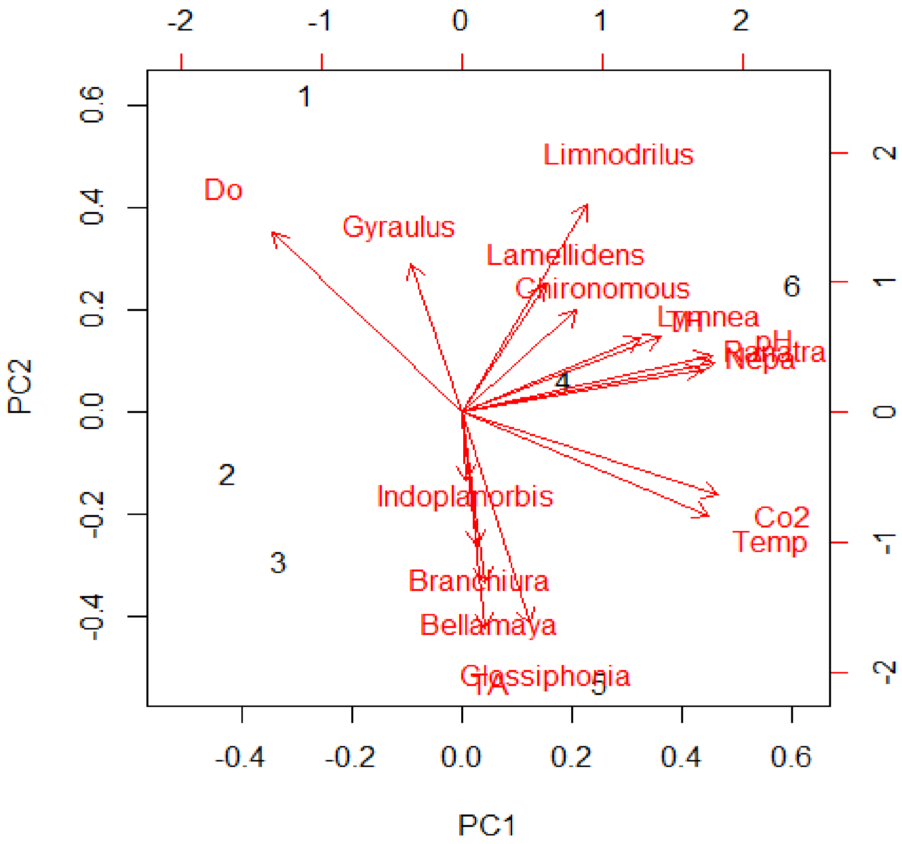


Figure 14. PCA biplot showing the relationship between physico-chemical parameters and species in S_2 (Clear) during the study period.

PCA showed that physico-chemical variables associated with Principal components 1 and 2 accounted for 63.6% variability among the samples in S_2 (Figure 14). DO, pH and hardness were positively correlated with *Limnodrilus, Nepa, Ranatra, Lymnaea, Chironomous, Gyraulus and Lamellidens.* The temperature and total alkalinity were negatively correlated with *Branchiura, Indoplanorbis, Bellamaya and Glossiphonia.*

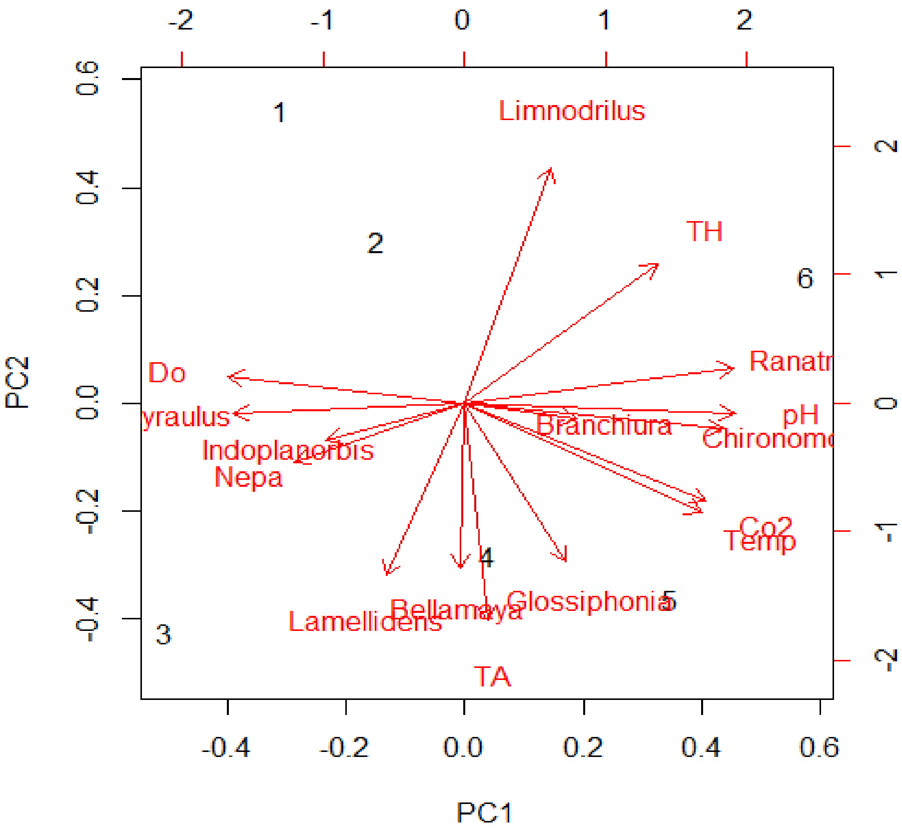


Figure 15. PCA biplot showing the relationship between the physico-chemical parameters and species in S_3 (Inlet) during the study period.

PCA showed that physico-chemical variables associated with Principal components 1 and 2 accounted for 68.8% variability among the samples in S_3 (Figure 15). DO, pH, free Co2, and hardness were positively correlated with *Limnodrilus, Nepa, Ranatra, Chironomous, Branchiura, Gyraulus and Indoplanorbis* but temperature and total alkalinity were negatively correlated with *Lamellidens*, *Bellamaya* and *Glossiphonia.*

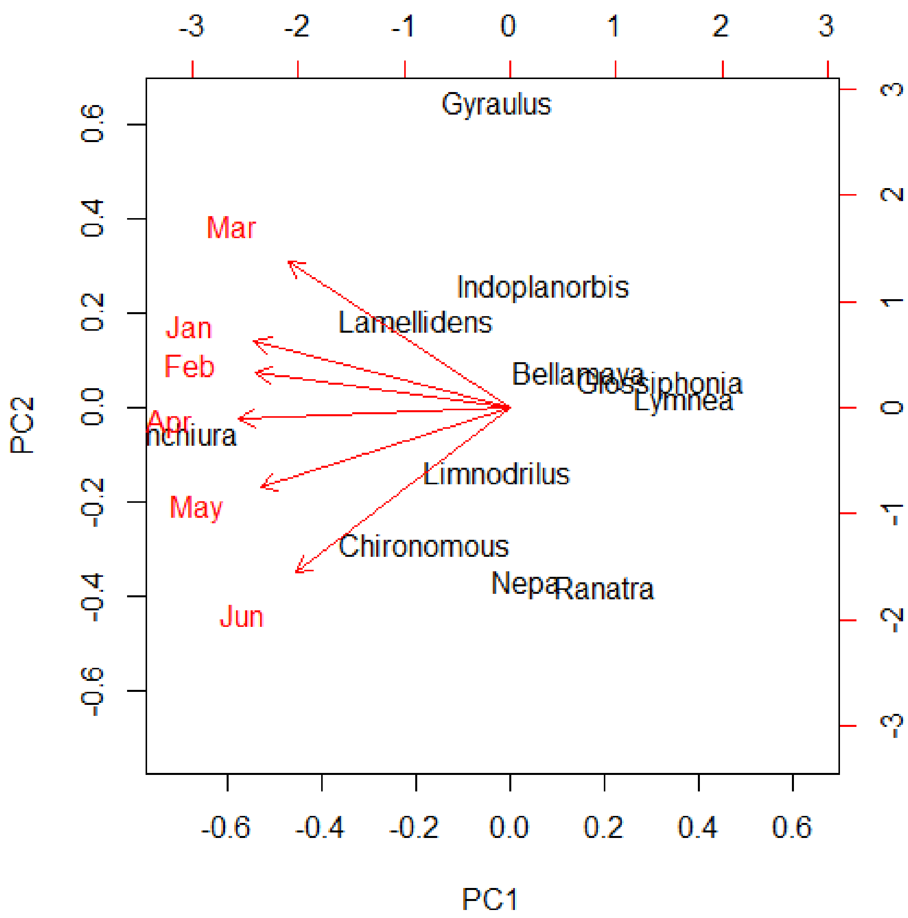


Figure 16. PCA biplot showing the relationship between the species and months during the study period.

PCA showed that species variables associated with Principal components 1 and 2 accounted for 76.2% variability among the samples between species and months (Figure 16). High abundance of *Branchiura* in May and low abundance of *Bellamaya, Lymnaea and Glossiphonia*.

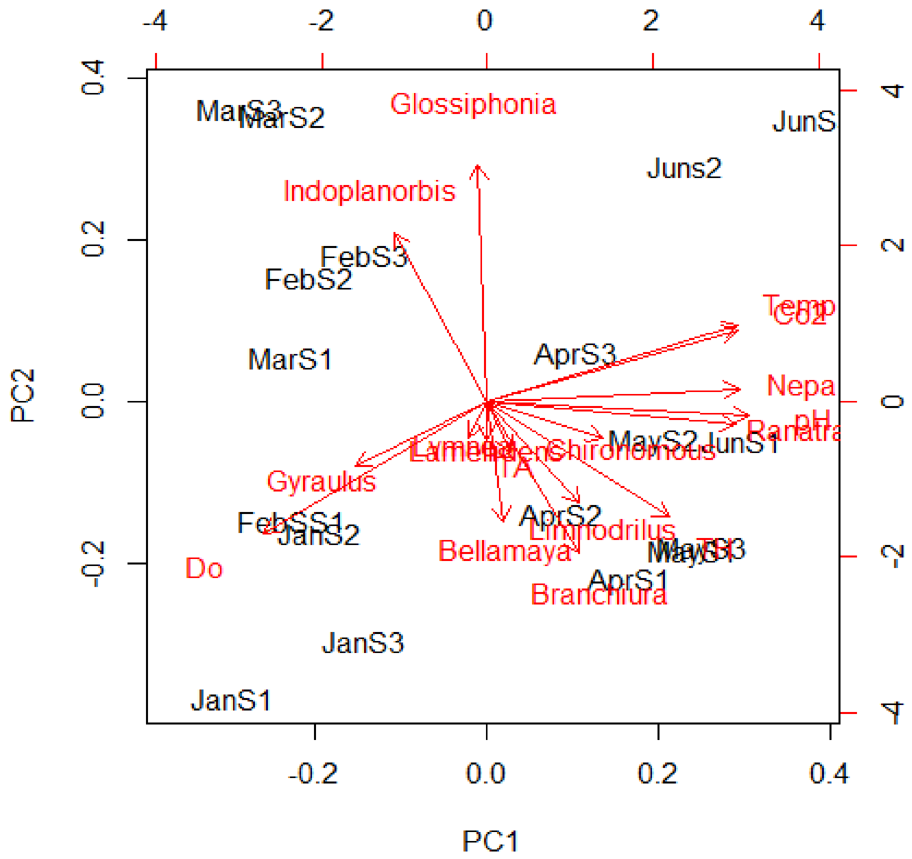


Figure 17. PCA biplot showing the relationship between the species, sites and physico-chemical parameters during the study period.

PCA showed that variables associated with principal components 1 and 2 accounted for 49.9% variability among the samples between species, sites and months (Figure 17). Sites and months were closer together in the plot showing more similar species composition.

5. Discussion

5.1 Abundance and distribution of macro invertebrates

The physico-chemical parameters of water are important for the composition, abundance and distribution of macro-invertebrates because the interaction of physico-chemical parameters create either favorable or unfavorable environment conditions for faunal abundance and distribution (Dutta and Malhotra, 1986). In this study, 11 species belonging to 8 families of macro-invertebrates were recorded in Lake. The faunal density (ind.m^2) ranged from 63 to 106, 56 to 76 and 66 to 100 at sites 1-3 respectively, with highest value in June at S_1.

The relative abundance of different faunal groups such as oligochaetes(34%), insects(26%), gastropods(24%), Bivalves(13%) and hirudins(3%). The faunal density (ind.m^2) ranged from 63 to 106, 56 to 76 and 66 to 100 at sites 1-3 respectively, with highest value in June at S_1. Out of 8 families, family Tubificidae *(Branchiura sowerybi)* and Chironomidae (*Chironomous sp.)* were recorded in all three sites of lake.This might be due to high organic content of the lake as in the case of other tropical waters (Hansen, *et al.* 1998).The high abundance of *Branchiura sowerbyi* were 81 ind./m^2 observed in the month of May *and Chironomous sp.* were 45 ind./m^2 observed in the month of June respectively. Oligochaetes can also be as deposit feeders, as such more tolerant to silting and decomposition than other groups of benthic organisms(Olumukoro and victor, 2001). Among the mollusca, the abundance of *Lamellidens* sp. were 51 ind./m^2 in the month of April and *Gyraulus convexiusculus* were 43 ind./m^2 observed in the month of January. Pollution indicators such as *Chironomous sp. Nepa* sp. and *Ranatra* sp. were observed in all three sites of Six months. The high abundance of *Chironomous sp.* were 45 ind./m^2 in the month of the January whereas the abundance of *Nepa* sp. and *Ranatra* sp. were 32 ind./m^2 and 25 ind./m^2 in the month of June.

At S_1, the highest species diversity was 1.336 recorded in the month of March and the lowest was 1.178 in the month of January. At S_2, the highest species diversity was 1.407 in the month of March and the lowest was 1.317 in the month of January. Similarly, at S_3 the highest diversity was 1.487 in the month of March and the lowest was 1.284 in the month of January. The recorded Shannon diversity in the three sites were considered to be good ranged for healthy nature of ecosystems. Similar seasonal pattern was found in Beeshazar Lake by Jayana (1996).

At S_1, the highest value of dominance was 0.336 recorded in the month of January and the lowest was 0.266 in the month of March. At S_2, the highest dominance was 0.281 in the month of June and the lowest was 0.266 in the month of April. Similarly, at S_3 the highest dominance was 0.289 in the month of January and the lowest was 0.241 in the month of March.

5.2 Physico-chemical parameters

5.2.1 Temperature

Physical, chemical and biological parameter processes in the aquatic environment are affected by temperature. A rise in temperature of water leading to the speeding up of the chemical reactions in water reduces the solubility of gases and amplifies the taste and odors (Trivedy and Goel, 1986). Solubility of chemical compound increases with increase in temperature.

The result showed that water temperature of lake depends on the air temperature. Temperature of water was recorded 18.2^oC in January gradually increased and reached maximum level 32.4^oC in June. The Chemical and biological actions in aquatic environment are some way influenced by water temperature. At higher water temperature the oxygen retaining capacity of water lower. The temperature is also very important factors in the determination of various water parameters such as pH saturation level of gases and various forms of alkalinity etc. At high temperature the capacity of water to keep Oxygen in solution is decreased and biological Oxygen demand increased (Holdren and Armstrong, 1980). The air temperature play main role for the seasonal variations in temperature of the surface water of the aquatic environment. Such relations have also been observed by Hussainy (1967), Kannan and Job (1980), Sreenivasan (1964), Sumitra (1969) and Birendra (1996). The water temperature affects directly or indirectly on the dissolved oxygen and carbon dioxide. The amount of dissolved oxygen decreased due to high temperature in the lake (Ansari, 1986). The increase of temperature was inverse relation with dissolved oxygen during the study period. Bose and Gorai (1993) reported negative correlation between water temperature and dissolved oxygen.

5.2.2 pH

The Beeshazar Lake was slightly acidic to alkaline throughout the study period ranging from 6.0 to 7.9. Warm water develops increased pH levels due to conversion of Co_2 to organic carbon by photosynthesis and the rate may exceed the rate of release of Co_2 from organic carbon by the process of respiration (King, 1970). Alkaline pH was supposed to be helpful for proper growth and development of fishes and other aquatic organisms. The hydrogen ion concentrations of water below the 5 and above the 11 have been described as toxic and not suitable for aquatic fauna. pH level observed in the Beeshazar Lake was favorable for aquatic animals during the study period. Swingle (1967) reported water having from 6.5 to 9.0 is most suitable for pisciculture which is nearly equal to observed value. Also Ellis (1973) reported that pH value from 6.7 to 8.4 is suitable for aquatic life. The maximum pH in winter may be attributed to algal blooms because Hutchinson, *et al.* (1929) and Roy (1955) have shown that the higher pH is associated with the phytoplankton maxima.

5.2.3 Free Carbondioxide

The permitted level of carbon dioxide concentration has been described from 4.0mg/lt to 25 mg/lt for aquatic animals. Free carbon dioxide is one of the essential raw materials for photosynthesis activities in aquatic environment. Due to this it play a significant role in the food cycle of an aquatic ecosystem. The high concentration of Co_2 is probably due to the high rate of organic matter decomposition by microbes and respiratory activities of aquatic plants and animals (Rutter 1953, Verma 1988, Agrawal 1988). During the study period the concentration of Co_2 ranged from 15.00mg/lt to 23.16mg/lt due to such activities. The water temperature showed positive correlation with free co_2.

5.2.4 Dissolved oxygen

The average variation of DO in the Beeshazar Lake showed from 2.77 to 5.23mg/lt. It was found below permitted level. DO below 5 mg/lt is considered to be unsuitable for the life of many aquatic organisms (WHO. 1970/1971). Comparatively, the low level of DO in summer months may be due to the high temperature which accelerates the rate of bacterial decomposition of organic matter (Mortimer, 1941). The value of dissolved oxygen in water is depends upon temperature, pressure, dissolved solid, pH and salinity. The low level of DO is probably related with the nutrients and organic matter available in water bodies. The main source of nutrient is flood water and surface runoff during the monsoon period. The amount of DO decreased due to high temperature in the lake (Ansari, 1986). Such type of relation was also observed in the Beeshazar Lake during the study period.

5.2.5 Total alkalinity

The total alkalinity of the lake water was found dependent on carbonate and bicarbonate alkalinities. The carbonate alkalinity was found only in the absence of Co_2 and the pH value greater than 8.5. The total alkalinity was found higher (130.6mg/lt) in May. The value of alkalinity indicates that lake was highly productive. In higher productive water alkalinity ought to be over 100mg/lt. Usually the total alkalinity shows positive relation with carbon dioxide content in the water. The total alkalinity was mainly due to the function of bicarbonates in the Beeshazar Lake, which recorded throughout the study period.

5.2.6 Total Hardness

The Hardness depends on the amount of calcium and magnesium salts dissolved in the lake water. The water having hardness of 15 mg/lt or above may be considered suitable for the growth of aquatic animals and plants (Swingle, 1967). The maximum value of total hardness was recorded in summer and minimum value was recorded in winter. The minimum value indicates more dilution of water (Patralekh, 1994). The total hardness in the Beeshazar Lake was found higher (170.77mg/lt) in April at S_2 and lower (85.77mg/lt) in March at S_1 during the study period.

5.3 Relationship between physico-chemical parameters and fauna

Environmental factors such as temperature are one of the key factors which determine the composition of biological component in the lake water. Temperature, pH, free carbondioxide and hardness were found significant positive correlation with diversity and density of species but significant negative correlation with DO and alkalinity.

The value of dissolved oxygen was found decreased level in April, May and June during the study period indicates accumulation of organic materials in the lake as well as Oligochaetes are least dominant groups. Such type of relation was observed in the Beeshazar Lake (Jayana, 1997).

The multivariate analysis such as PCA ordination plot showed that the good representation of the interrelationship between the macroinvertebrates of each site with physico-chemical parameters.

6. Conclusions and Recommendations

Among the three sites, the macro invertebrates species assemblage is comparatively higher in sites S_1 and S_3 than in site S_2. The analysis of the Shannon diversity and dominance index clearly showed that the number of species is very high in all three sites. The increase of temperature was inverse relation with DO during the study period. The DO was recorded below the standard (permitted) level and was not suited for aquatic life. The pH level observed in Beeshazar Lake was (6.0-7.9) favorable for aquatic animals in the study period. The total alkalinity was found higher (130.6mg/lt) in May. It indicates that lake was highly productivity. The value of hardness was found within the accepted value for aquaculture; therefore, the water is suitable for aquaculture in terms of hardness. The diversity and density of species were significant positive correlation with temperature, pH, free Co_2 and hardness but significant negative correlation with DO and alkalinity. It From the study, it was concluded that the physico-chemical parameters were major facrors responsible for fluctuation in benthic macrofaunal distribution in the study area.

The recommendations are given by Site management plan of Beeshazar and associated lakes (GoN/MOFSC/DNPWC/CNP. 2010).

At Strategic Level

1 Maintain healthy wetland ecosystem in and around Beeshazar Lake.
2. Promote sustainable wetland based eco-tourism.
3. Raise community awareness on wetland conservation.
4. Promote the use of alternative energy.
5. Facilitate scientific research and monitoring.
6. Enhance the livelihood opportunities of the local communities.
7. Ensure the sustainable and perpetual water source.

At Site Level

1. Take action to control pollution of Beeshazar and associated Lakes.
2. Explore the alternative use of invasive species.
3. Discourage forest products harvest and stop poaching.
4. Study the impact of invasive species in the area.

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8. Appendices

Photo 1. Study Area

Photo 2. Outlet Channel (S_1)

Photo 3. Clear (S_2)

Photo 4. Near Inlet Channel (S_3)

I. PCA analysis data sheet (R Package 3.3.2)

Importance of components (Site 1)

	PC1	PC2	PC3	PC4	PC5	PC6
Standard deviation	2.6410	1.8912	1.5241	1.3757	1.11054	6.567e-16
Proportion of Variance	0.4359	0.2235	0.1452	0.1183	0.07708	0.000e+00
Cumulative Proportion	0.4359	0.6594	0.8046	0.9229	1.00000	1.000e+00

Importance of components (Site 2)

	PC1	PC2	PC3	PC4	PC5	PC6
Standard deviation	2.4791	2.1604	1.7522	1.4032	1.07148	9.806e-16
Proportion of Variance	0.3615	0.2745	0.1806	0.1158	0.06753	0.000e+00
Cumulative Proportion	0.3615	0.6361	0.8166	0.9325	1.000000	1.000e+00

Importance of components (Site 3)

	PC1	PC2	PC3	PC4	PC5	PC6
Standard deviation	2.7051	1.9223	1.5290	1.3490	0.91080	9.841e-16
Proportion of Variance	0.4574	0.2309	0.1461	0.1137	0.05185	0.000e+00
Cumulative Proportion	0.4574	0.8344	0.8344	0.9482	1.00000	1.000e+00

Importance of components (Species and Months)

	PC1	PC2	PC3	PC4	PC5	PC6
Standard deviation	2.1394	0.8731	0.52653	0.49470	0.32893	0.1750
Proportion of Variance	0.7628	0.1271	0.04621	0.004621	0.01803	0.0051
Cumulative Proportion	0.7628	0.8899	0.93608	0.97687	0.99490	1.0000

Importance of components between sites, species and months

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15	PC16	PC17
Standard deviation	2.4161	1.6309	1.4909	1.3633	1.22016	0.99114	0.76221	0.61659	0.53366	0.4498	0.41991	0.40729	0.30422	0.23125	0.10952	0.03865	0.004635
Proportion of Variance	0.3434	0.1565	0.1308	0.1093	0.08758	0.05779	0.03417	0.02236	0.01675	0.0119	0.01037	0.00976	0.00544	0.00315	0.00071	0.00009	0.000000
Cumulative Proportion	0.3434	0.4998	0.6306	0.7399	0.82751	0.88529	0.91947	0.94183	0.95858	0.9705	0.98086	0.99062	0.99606	0.99921	0.99991	1.00000	1.000000