1. INTRODUCTION

1.1 General Background

The fresh water environment of Nepal has been divided into two groups; “Lotic and Lentic water environment. In Nepal, wetlands occupy approximately 5% of the total land area (Fisheries Development Division, 1992). The lacustrine environment of Nepal has been divided into three categories on the basis of its topography and climate: High land glacial lakes; Midland Tectonic lakes; and Lowland Ox-bow Lake (Rajkarnikar, 1998).

According to the DOAD (1992) reports, there are around 5000 lakes, 1380 reservoirs and 5183 village ponds in the country while IUCN inventory (1996), reports 163 wetlands in Terai and 79 in the hills and mountains. Similarly 3252 glaciers and 2323 glacial lakes have been identified in the high mountain region (Mool *et al*., 2001).

In Kathmandu valley there are different types of wetlands. Among the lotic type there are rivers, streams such as Bagmati River, Bishnumati River, Godawari River, Manahara River, Hanumante River. While lentic types are such as Taudaha Lake, pond inside national Zoo, Rani pokhari, Siddhi pokhari, Na pukhu (Rajkarnikar, 1998).

Ponds are common features of many landscapes and often contribute the bulk of regional fresh water biodiversity (Collinson *et al*., 1995; Williams *et al*., 2004; Scheffer *et al*., 2006). The study of the pond have started to shed interesting new light on its ecosystem structure and function which was necessary to improve pond conservation strategies and increasing interest in fundamental aspects of pond ecology (Biggs *et al*., 2005; McAbendroth *et al*., 2005). As a result, there is growing evidence that ponds are functionally different from larger lakes (Oertli *et al*., 2002) and despite their small size; they are collectively rich in biodiversity terms (Williams *et al*., 2004). Ponds also show greater biotic and environmental amplitudes than rivers and lakes (Davies, 2005).

1.2 Aquatic Insect Diversity

Insects comprise at least 75% of total animal species recorded globally. They are the most species-rich and often the most abundant group of substrate-dwelling macro-invertebrates, and have successfully invaded virtually all aquatic habitats. Although there are many specialized habitats, most aquatic insects are found either in lotic or lentic habitats (Hershey *et al*., 2010). Unspoiled head water streams are considered to be one of the most important habitats for aquatic life such as insects, mollusks and fishes, while small spring-fed streams are known to be unique habitat of obligate species (Illies and Botosaneanu, 1963).

Aquatic insect can be found almost in every type of aquatic habitat throughout the world including lakes, torrential streams, highly saline pools, phytotelmata, coastal waters and estuaries, acid peat swamps, groundwater, hot springs and even pools of crude oil seeping from the ground (Yule and Yong, 2004).

Diversity refers to the number of different kinds of organisms found in a biological community (Voshell and Reese, 2002). Species diversity in many of the aquatic insect orders is very high. Ponds, lakes, and wetlands can also exhibit very high diversity, depending on water quality conditions; littoral development, and substrate characteristics (Hershey *et al*., 2010). In general, communities with a high diversity are more stable. Pollution and frequent habitat disturbance can eliminate intolerant species, and therefore reduce diversity. So if an area becomes polluted, the total number of organisms may stay the same, but diversity may decrease (Voshell and Reese, 2002).

The physical environment of aquatic ecosystem exerts substantial control over the population abundances and hence community composition of insects. The physical factors of particular importance to aquatic insects includes: dissolved oxygen concentration, water temperature, water chemistry.

Dissolved oxygen- As aerobic organisms, all insects must obtain sufficient oxygen to drive their metabolic machinery. Seasonal and spatial variation in oxygen concentration greatly restricts the types and diversity of insects found in aquatic environments. Dissolved oxygen concentrations are highly variable over time and space, and oxygen may be totally lacking from some aquatic habitats (Hershey *et al*., 2010). The optimum value of DO for survival of aquatic animals is 2-11 mg/l (Behar, 1997).

Water temperature- Water temperature also imposes constraints on aquatic insects. Temperature fluctuation can limit the types of insects found within a habitat. Any significant change in water temperature, as may result from thermal pollution or climate change will likely alter the species composition of aquatic insects. Temperature, and its variation, can influence aquatic insect diversity in any freshwater habitat.

Water chemistry- Many aspects of water chemistry can restrict the occurrence or abundance of aquatic insects, including pH, salinity, and concentrations of specific ions or elements. Low pH, as is found in acidified lakes and streams of $pH < 5$ (due to acid deposition, mine drainage, organic acids, or poor buffering), can alter community composition such that only acid-tolerant taxa are found. Salinity gradients that form in coastal estuaries, along saline lakes, and even from runoff after road salting, can affect insects, most of which are salt-intolerant (Hershey *et al*., 2010). The largest varieties of freshwater aquatic organisms prefer a pH range of 6.5 to 8.0 (Behar, 1997).

1.3 Importance of Insect Fauna

Aquatic insects have been intensively studied from various perspectives, reflecting their abundance, diversity and important role in the communities and ecosystems they inhabit. They are abundant in most freshwater habitats and often exhibit high diversity (Hershey *et al*., 2010). They are extremely important part of food-web, bio-indicators and bio-control agents in aquatic ecosystem. They are main food for many larger animals including fish, frogs and birds. Some acts as scavengers, some are useful in increasing the oxygen percentage of ponds and also removal of harmful bacteria. Some like diving beetles, naids of dragon-fly, water scorpion etc, are harmful to us in being the predator of fingerlings. High temperature is mostly favorable for the insects hence their abundance is high in summer than in winter. They pupate, burrow or remain in other inactive stages hence are found in less number (Shrestha, 2006).

1.4 Objectives

The general objective of the study is to explore the aquatic insect fauna of the 'Na pukhu' pond. The specific objectives are:

1. To study the species richness and species evenness of the pond in pre monsoon and monsoon period.
2. To compare the pre monsoon and monsoon abundance of the aquatic insects.
3. To analyze the relation between diversity index of insect fauna with reference to physical parameters of the pond.

1.5 Rationale

Water is very important for all living beings for their survival. Aquatic insects are the source of food, bio-indicators and bio-control agents in an aquatic ecosystem. The sample of aquatic insects taken can serve as indicator of water quality and in bio-monitoring of human impact. It is important to study aquatic macro-invertebrates so that the communities surrounding the watershed know about the health of their water.

The aquatic ecosystem of pond is affected by many physiological parameters which also affect the abundance of the insects. Through this study the population diversity and abundance of insects and their role in aquatic ecosystem will be evaluated. The study area 'Na pukhu' pond was selected as was convenient with sufficient area for study, field work and was not studied previously.

1.6 Limitations

The study area was greatly influenced by human activities so it was difficult to collect the samples in the field. The detail study was difficult to carry on due to lack of sufficient budget and time. Identification of the collected insects was difficult due to lack of keys.

2. Literature Review

2.1 Studies of Aquatic Insects in Nepal

According to literatures on the aquatic insects in Nepal, the study of aquatic insects was first described by Hope in "Synopsis of Nepal Insects'' published in 1831 (Atkinson, 1980). Later on a short observation of aquatic insect was carried out by McDonald (1976) along the foothills of central Nepal and Everest/ Khumbu region. The records state seven orders of aquatic insects from different altitude from 915 m to 4267 m above sea level.

Takgawadyl and Namikawa (1952-53) compiled the insect fauna of Nepal Himalayas containing a number of species from different parts of Nepal. Mishra (1975) reported a short list of aquatic insects of Nepal. Malla *et al*. (1978) carried out the studies on the aquatic insects of Kathmandu valley. He had collected altogether 61 species of insects from various water bodies in Kathmandu valley; of these 37 were new generic and specific records from Nepal. Yadav *et al*. (1980, 1981, and 1983) studied macro-invertebrates of Rajdal Pond, Godawari Khola and Godawari fish pond. Yadav and Rajbhandari (1982) studied the benthic fauna of Bansbari Khola and Dhobi Khola.

Similarly, Yadav (1994) recorded 50 taxa of aquatic insects from feeding streams of the Kulekhani reservoir. Suren (1994) studied about the macro invertebrate communities from the streams of Western Nepal and listed 138 macro invertebrates belonging to 53 families under eight orders. Rajkarnikar (1998) studied about the biotic and abiotic components of Jagmuru pond and insect species collected belonged to 13 families under four orders.

Furthermore, Sharma *et al*. (2005) studied about the impacts of dam on the macro invertebrates in Tinau River and listed out 2120 macro invertebrates representing 22 families under ten orders of which Chironomidae family was most abundant. In 2006, Yadav collected aquatic insects from the Palung Khola. He described 21 species of aquatic insects belonging to seven orders and the most abundant order was Ephemeroptera. Niroula *et al*. (2010) discussed about seasonal variations of biodiversity and physico-chemical parameters in Betana pond. The parameters like pH, alkalinity was higher in summer, DO and temperature were recorded higher in winter and rainy season respectively.

Shah *et al*. (2011) studied about the diversity and community assemblage of Littoral benthic macro invertebrates from Jagdishpur Reservoir in pre and post monsoon. The study described 50 taxa belonging to 15 orders and higher number of taxa belonged to order Heteroptera. According to his study the diversity index was recorded higher in post monsoon compare to pre monsoon. Rana and Chhetri (2015) worked on the water quality assessment using macro-invertebrates as indicators in Bhalu Khola, Gorkha. The study revealed the presence of 103 macro-invertebrates distributed under 11 families with five orders. Maximum number of individuals found was from order Ephemeroptera.

2.2 Studies in the Global Context

In 2009, Jana *et al*. identified 20 species belonging to three orders while studying diversity and community structure of aquatic insects in a pond in Midnapore town; West Bengal, India. Order Odonata was found to be abundant in their study. Later on, Wahizatul *et al*. (2011) worked on the distribution of aquatic insects with relation to water quality. He identified 42 families of aquatic insects under nine orders from two freshwater streams of Terengganu.

Similarly, in 2012, Sharma and Agrawal examined the faunal diversity of aquatic insects in Surha Tal of Ballia, India and listed out 29 species of aquatic insects belonging to 14 families under four orders. Purkayastha and Gupta in the same year investigated about the insect diversity and water quality parameters of ponds of Chatla wetland, Assam and described the presence of aquatic insects belonging to five families under three orders.

In 2013, Leelahakriengkrai collected 46 families of aquatic insects under six orders from two streams of Thailand and studied about the diversity of insects. Abhijna *et al*. in the same year discussed about the distribution and diversity of aquatic insects from Vellayani Lake in Kerala. The diversity was represented by 60 species classified under 37 families and eight orders. Among the orders classified, Coleoptera was most diverse group.

Furthermore, Gupta and Purkayastha (2013) investigated on the ecosystem health of shallow water pond of Barak Valley, Assam. They enlisted three species belonging to two families of order Hemiptera. Further, they also examined aquatic insects for their use in water quality assessment from the ponds around two cement factories of Assam in the same year. The study revealed five families under two orders, Hemiptera and Odonata. At the same time, Majumder *et al*. studied aquatic insect fauna in urban fresh water lakes of Tripura, Northeast India in the same year and identified 31 species belonging to 15 families under four orders. Insect belonging to order Hemiptera showed higher species richness.

Thereafter, Nasiruddin *et al*. (2014) explained the abundance and diversity of aquatic insects from water bodies of Chittgong University Campus. The collected species represented by 32 genera of insects belonging to 20 families under six orders with Hemiptera and Odonata as most abundant. Then after, in the same year, Santhosh *et al*. examined the contribution of macro invertebrates in biological water quality status from Meenachil River, Southern Kerala. The study was done in pre monsoon and monsoon period and 36 genera of aquatic insects belonging to 31 families and nine orders were reported with Ephemeroptera as dominant taxa. Also Dalal and Gupta in the same year calculated the aquatic insect diversity and conservation value from ponds of Assam. They recorded 22 taxa of aquatic insects. Next Samweel and Nazir monitored diversity pattern from Song river of Rajaji National Park, India in the same year. Altogether 28 genera belonging to six orders were identified. At the same time, Vasantkumar and Roopa studied about the physico-chemical and aquatic insect diversity of pond ecosystem in

Karwar, India and identified 15 species belonging six orders with most abundant order Coleoptera.

Similarly, Choudhary and Gupta (2015) discussed about the aquatic insect community form Deepor beel, Assam. The study stated the presence of 31 species belonging to 18 families of five orders having largest order Hemiptera in terms of aquatic diversity. Later on Purkayastha and Gupta (2015) described the ecology of Monabeel flood plain, Assam with reference to aquatic insect diversity. The study investigated about the diversity and distribution of insects in relation to physical properties of water like pH, DO, free CO_2, nitrate etc. The insects recorded were 11 species belonging seven families under four orders. Hossain *et al*. in the same year also did similar type of investigation from two highly polluted rivers Sitalakkhya and The Buriganga, Bangladesh. The representative of family Culicidae were dominant of the total species belonging 22 families under six orders. Gupta and Barman (2015) explained aquatic insects as bio-indicator of water quality from Bakuamari stream, Assam. The study reported 21 species of aquatic insects belonging to 14 families under seven orders and significant relation between the diversity and water quality parameters.

Thereafter, Maneechan and Prommi (2015) described the diversity and distribution of aquatic insectsin streams of Mae Klong watershed, Western Thailand. The examined sample of insects belonged to 64 families under nine orders with most diversed order Trichoptera. Later, Prommi and Payakka in the same year encounted 59 families representing nine orders from Northern Thailand in similar type of study. Next Medona *et al*. mentioned aquatic insects in Southparai Reservoir; Theni, Tamilnadu belonging to 43 genera under 32 families and nine orders in the same year.

3. MATERIALS AND METHODS

3.1 Study Area: Na pukhu, Bhaktapur.

3.1.1. Location

Geographically Bhaktapur is situated in eastern rim of Kathmandu Valley. It is about 13 km Far-East from Kathmandu, the capital of Nepal and also known as Bhadgaon of “The city of Devotees”. It lies between 85º 21” to 85º 32” E longitudes and 27º 36” to 27º 44” N latitude on Nepal. The altitude of the city ranges from 1372 m to 2166 m above the sea level with the area of 119 km^2. This is the smallest district among the 75 districts of Nepal (District Profile of Nepal, 2007/2008). The study site – Na pukhu is located in Itachhen, Bhaktapur Municipality which lies on the way to Bhaktapur Durbar Square and near to Bhaktapur Cancer Hospital. It has a length of 0.41 km and area 107750 sq. ft. The area is densely populated with the local resident people. Most of the people use the pond water for washing, cleaning and some for bathing too.

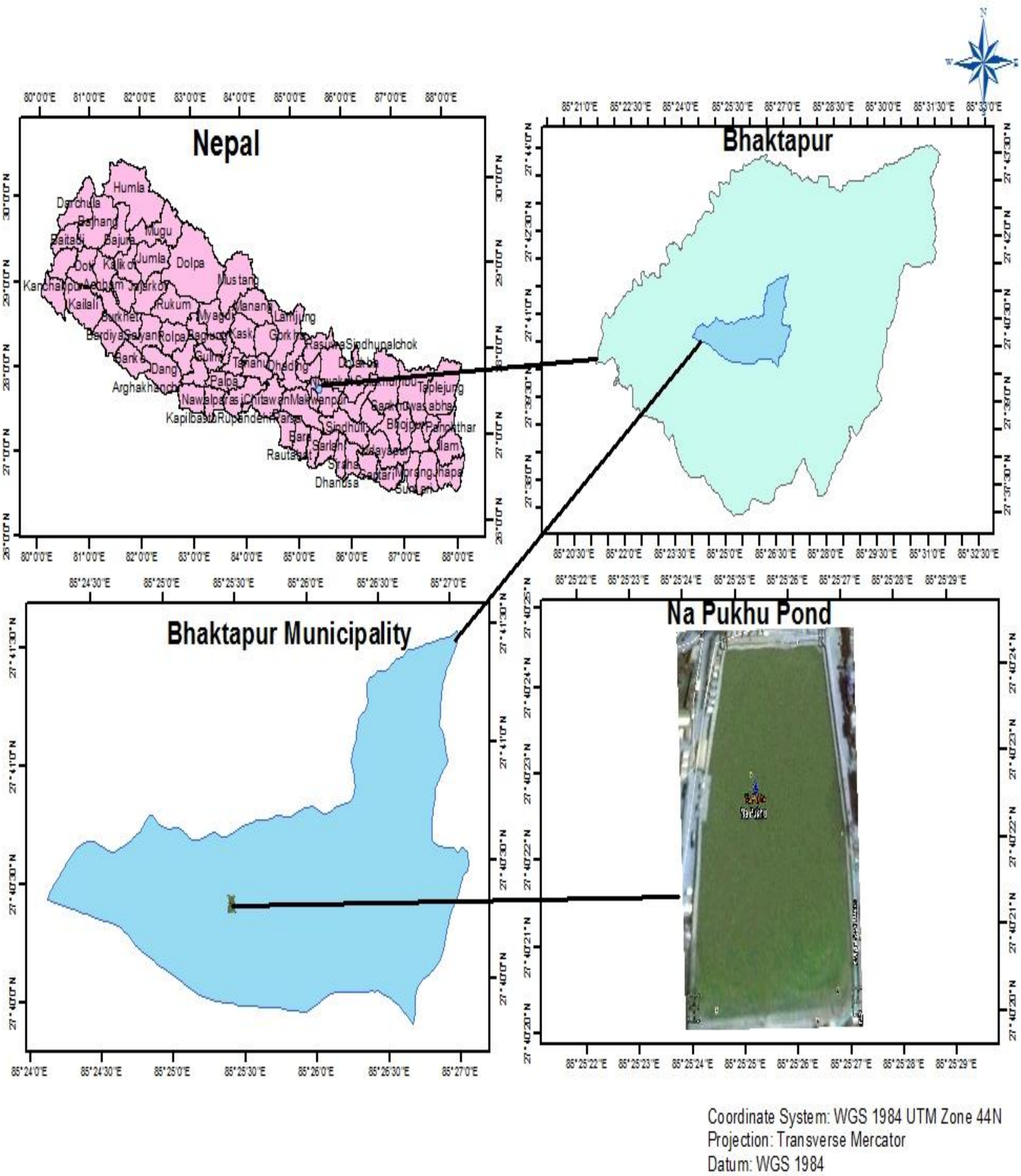


Figure 3.1 Map of study area (Na Pukhu pond)

3.2. Field Survey

3.2.1. Reconnaissance Survey

The reconnaissance survey was done on February 2014 in the pond area to observe the availability of insects.

3.2.2. Site Selection

Three sampling sites of each 100 sq. ft. were selected with the help of field measuring tape for taking replicate sample of aquatic insects from the pond. All three sampling sites consist the surface water and below the surface up to 20 cm.

3.2.3. Sampling Frequency

The sampling sites were visited from March, 2014 to August, 2014 for the collection of aquatic insects. The insects were collected monthly from each sampling site during first week of every month between 8 am to 12 noon.

3.3. Materials Used

i. Long handled plankton net (mesh opening: 500 µm; diameter: 30 cm; depth: 15 cm)
ii. 70% alcohol,
iii. Forceps,
iv. Brush,
v. White enameled tray,
vi. Dropper,
vii. Field note book,
viii. Hand lens,
ix. Cello tape,
x. Field measuring tape,
xi. 250 ml BOD bottle,
xii. Bottles for collection of water samples,
xiii. Mercury thermometer,
xiv. Compound microscope (10x magnification),
xv. Canon digital Camera (5.0-40.0 mm, 1:3.2-6.9) (Subramanian and Sivaramakrishnan, 2007).

3.4. Species Collection Method

The dip net or plankton net was swiped in the pond water for approximately one minute and lift out (Purkayastha and Gupta, 2012). Five subsequent sweeps were taken repeatedly at each site (Di Franco, 2014). The collected insects were drained out in the white enamel tray. The insects were washed and were sorted out in different vials containing 70% alcohol as preservative.

3.5. Preservation, Identification and Photography

All the collected insects were preserved in 70% alcohol in separate vials. The vials were labeled with location of site and date of collection. Those collections were identified on morphological basis in entomology laboratory (CDZ) by observing morphological features with the help of compound microscope and hand lens, using relevant keys (Borror *et al*., 1981 and Imms *et al*., 1977).

The photographs of the insects were taken in compound microscope under 10x magnifications using Canon digital camera. The species were deposited in entomology laboratory (CDZ).

3.6. Physico-chemical Analysis of pond water

The temperature and pH were recorded in the study site and the pond water was collected in the bottles by dipping them in the pond and was brought to CDZ (entomology lab) for further examination of water quality.

3.6.1. Hydrogen Ion Concentration (pH)

The hydrogen ion concentration of water was measured by dipping the portable pH meter directly into the collected sample of water at study site. The readings shown by the pH meter were noted down in the field record sheet.

3.6.2. Temperature

The temperature of air as well as water was measured with the help of a standard mercury thermometer. The temperature of surface water was taken by simply dipping the thermometer bulb into the water body. The air temperature was measured by keeping the thermometer near to the study site for about two minutes (Yadav, 1996).

3.6.3. Dissolved Oxygen (DO)

The dissolved oxygen in water was determined by Winkler's method (Swarup *et al*., 1981). The water sample was collected in 250 ml BOD bottle and was air tightened. The collected sample was titrated in the lab.

3.6.4 Alkalinity

Alkalinity of the collected sample was determined by adding Sulphuric acid to decrease the pH of the sample. In 100 ml of sample 2 drops of phenolphthalein indicator was added. The solution either changed to pink or remains colorless. The total alkalinity was measured by adding methyl orange indicator to the colorless sample solution and titrated until yellow color changed to pink. The amount of acid used was recorded and converted to the equivalent weight for alkalinity (Swarup *et al*., 1981).

3.7. Statistical Analysis

The abundance (%) and diversity indices were calculated for each sampling month, pre monsoon and monsoon.

Abundance was calculated as percentage of an order, being calculated from the total number of individuals of all the samples during study period.

Shannon–Wiener's Species Diversity index (H′): The simplest measure of species diversity is to count the number of species. In the present study Shannon-Wiener diversity index (Shannon and Weiner, 1949) has been calculated using the following formula:

$H = -SUM [(p_i) \times \ln (p_i)]$
Where, SUM= summation
p_i= proportion of total sample represented by species i (Divide no. of individuals of species i by total number of samples)

Species richness: The species richness was based solely on the number of taxa found in the given area and does not reflect the relative dominance of species.

Species richness = number of species, denoted by 'S' (Hossain *et al*., 2015)

Species evenness: Using species richness (S) and the Shannon-Wiener index (H), evenness of taxa was computed using following formula

Evenness (E) = H/H_{max}

Where, H = Shannon Diversity index

H_{max}= ln (S) Maximum diversity possible. (Hossain *et al*., 2015)

Correlation: The relation between the diversity and the physical parameters was calculated by Karl Pearson Correlation method.

$r = N (\sum xy)-(\sum x)(\sum y) /\sqrt{} [N\sum x^2-(\sum x)^2] [N\sum y^2-(\sum y)^2]$

4. RESULTS

The aquatic insects collected during the study period (March 2014 to August 2014) from the pond are listed in table 1. The list includes three orders, five families and five genera and also one unidentified species. The orders were Coleoptera, Hemiptera and Diptera. Three genera (*Gerris* sp., *Notonecta* sp. and *Corixa* sp.) of the order Hemiptera were identified. One genus *Dysticus* sp. of Coleoptera and one genus *Chironomus* sp. of Diptera were identified. The study showed that the order Hemiptera was most diversified with three genera followed by Coleoptera and Diptera with single genus of each.

Table 4.1: Insects species collected during March to August 2014

Order	Number of individuals	Family	Species
Coleoptera	65	Dysticidae	*Dysticus* (Linnaeus, 1758) sp. (adult and juvenile)
Hemiptera	1171	Gerridae	*Gerris* (Fabricius, 1794) sp. (adult and juvenile)
		Corixidae	*Corixa* (Illiger, 1807) sp. (adult)
		Notonectidae	*Notonecta* (Linnaeus, 1758) sp. (adult and juvenile)
Diptera	2670	Chironomidae	*Chironomus* (Meigen, 1803) sp. (larva, pupa, adult and exuviae)
Unidentified Species	275		

4.1. Monthly Collection of Aquatic Insects

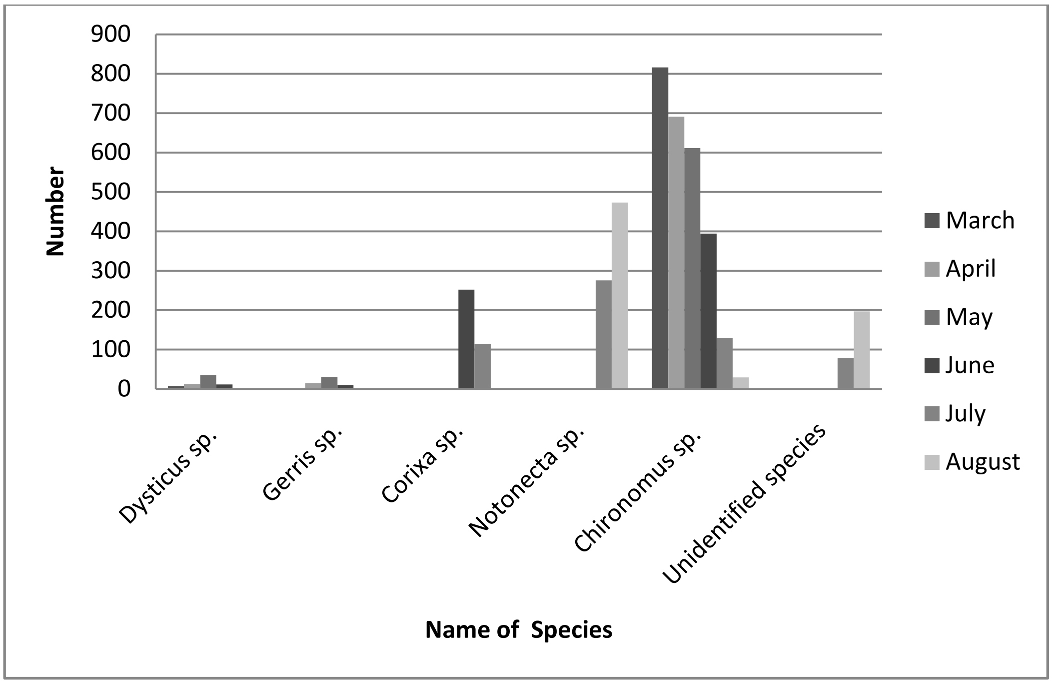


Figure 4.1 Monthly Collections of Insect species

A total of 4,181 aquatic insects were collected from the pond during the study period March to August including pre monsoon and monsoon season. The *Dysticus* species (Coleoptera) was recorded from March to June. Another species *Gerris* (Hemiptera) was recorded in April to June. *Corixa* species (Hemiptera) was found in June and July. *Notonecta* species belonging to order Hemiptera was also reported in July and August. The most abundant aquatic insect was *Chironomus* species (Diptera) which was recorded throughout study period while one unidentified species was also recorded in July and August. *Dysticus* sp., *Gerris* sp. and *Notonecta* sp. were found in both adult and juvenile forms and the *Chironomus* sp. with all the stages larva, pupa, adult and exuviae.

4.2. Monthly fluctuations of Species Diversity, Species Richness and Species Evenness of the Pond

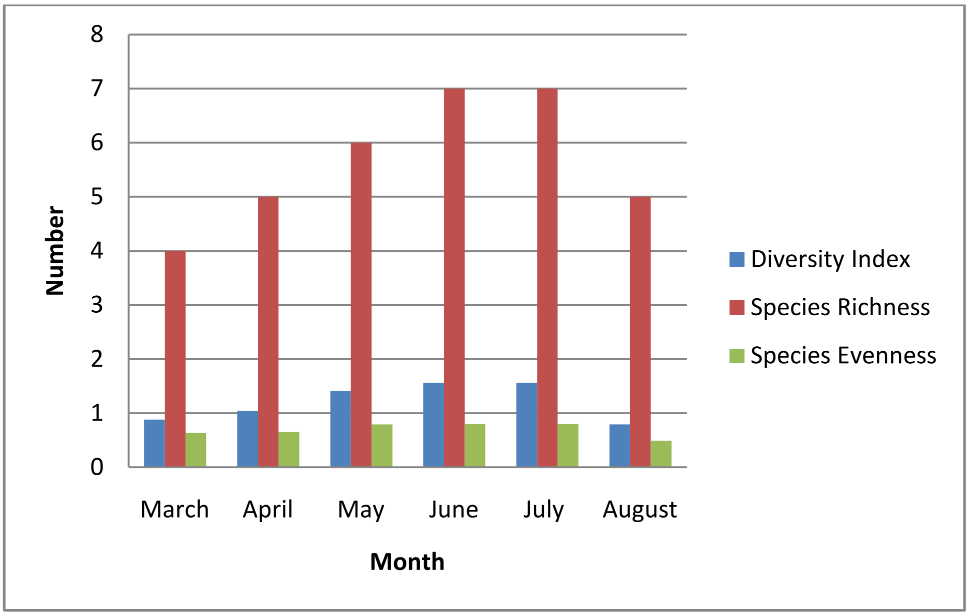


Figure 4.2 Variations in Diversity Index, Species Richness and Evenness

The diversity index of the aquatic insects was found to be varied from month to month. The highest diversity index value (1.56) was observed in monsoon period in the month of June and July. The lowest value (0.79) was observed in the month of August.

Species richness value of the aquatic insects was also found to be in irregular pattern. The highest value (7) was recorded in monsoon in the month of June and July. The lowest value (4) was observed in pre monsoon period in the month of March.

Species evenness value was recorded as highest (0.8) in the month of June and July and lowest (0.49) in the month of August.

4.3. Abundance of the Aquatic insects

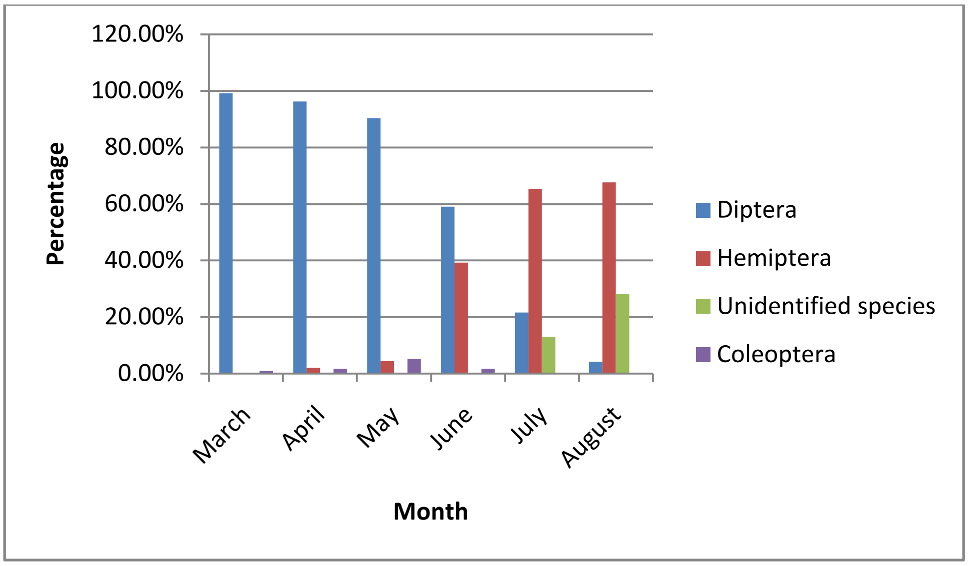


Figure 4.3 Monthly Abundance of Insect Orders

In the pond, the abundance of specimens under the order Diptera was 99.15% (March), 96.24% (April), 90.38% (May), 59.07% (June), 21.57% (July) and 4.15% (August). The order Hemiptera was found to be abundant in the month of August (67.67%) and the order Coleoptera was abundant in the month of May (5.18%).

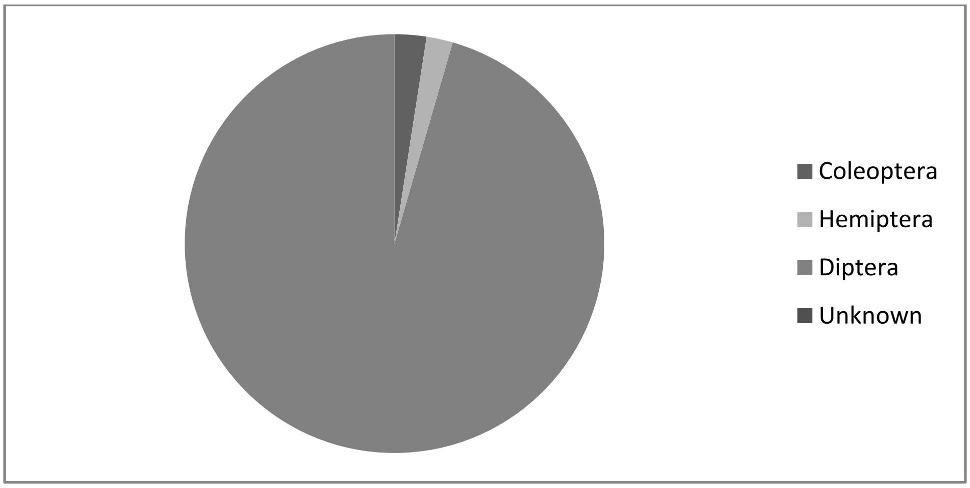


Figure 4.4 Pie-chart showing Pre-monsoon Abundance of Insect Orders

In the pre monsoon period including three months March, April and May; the most abundant order was Diptera comprising 95.33% of the total insects sampled. It was followed by Coleoptera and Hemiptera with 2.44% and 2.03% respectively. The unidentified species was not recorded from the pre monsoon period.

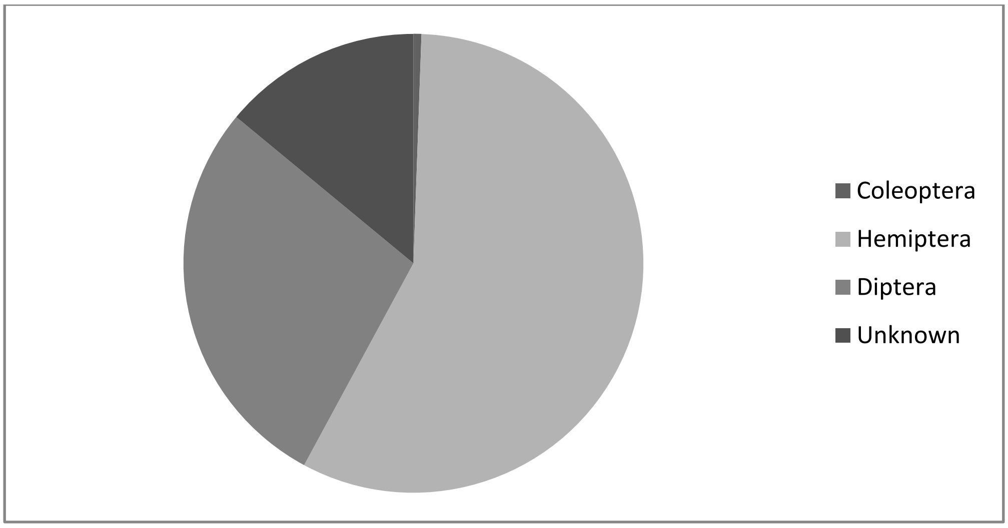


Figure 4.5 Pie-chart showing Monsoon Abundance of Insect Orders

The monsoon period including June, July and August showed Hemiptera as abundant order (57.33%). It was followed by the Order Diptera, Unidentified species and Coleoptera with 28.11%, 14% and 0.56% respectively.

4.4. Physical Parameters of the Pond

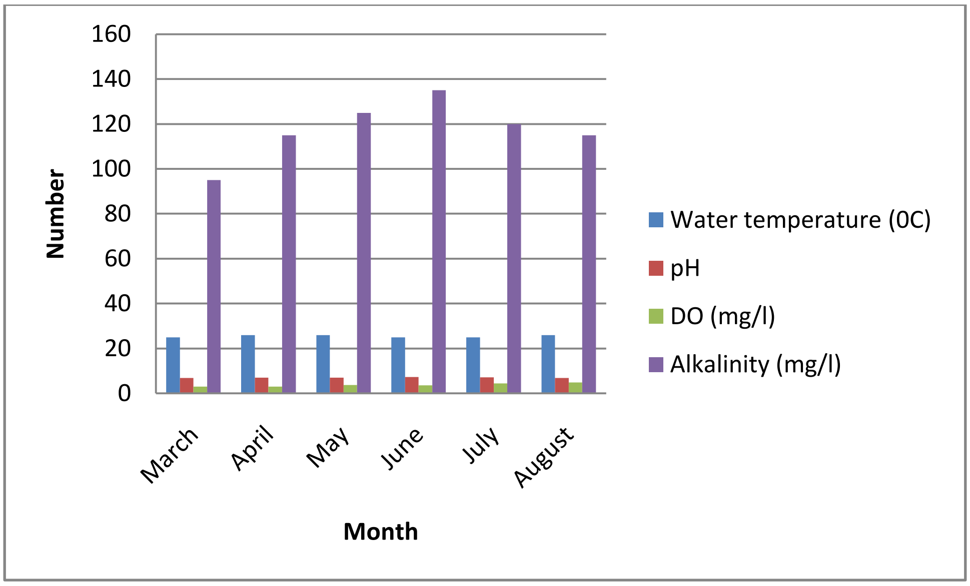


Figure 4.6 Monthly variations in Physical Parameters

4.4.1. Temperature

During the study period, water temperature recorded maximum was 26^0 C in three months April, May and August and in rest of the months it was 25^0 C.

4.4.2. Hydrogen Ion Concentration

The pond water was recorded nearly neutral throughout the study period. The pH of pond was recorded highest in the month of June (7.2) and lowest in the month of March (6.9) and August. The value fluctuates between 6.9 into 7.2 in rest of the month during the study period.

4.4.3. Dissolved Oxygen

The content of Dissolved oxygen of pond water was found to below the level of 5 mg/l throughout the study period. The oxygen content of pond water 2.95 mg/l was recorded minimum in the month of March (pre monsoon) and it increased up to 4.86 mg/l was recorded as maximum in the month of August (monsoon).

4.4.4. Alkalinity

The alkalinity content of water 95 mg/l was recorded minimum in the month of March and it fluctuates throughout the study period. The maximum level 135 mg/l was recorded in the month of June.

4.5. Correlation of Insect Diversity with the Physical Parameters

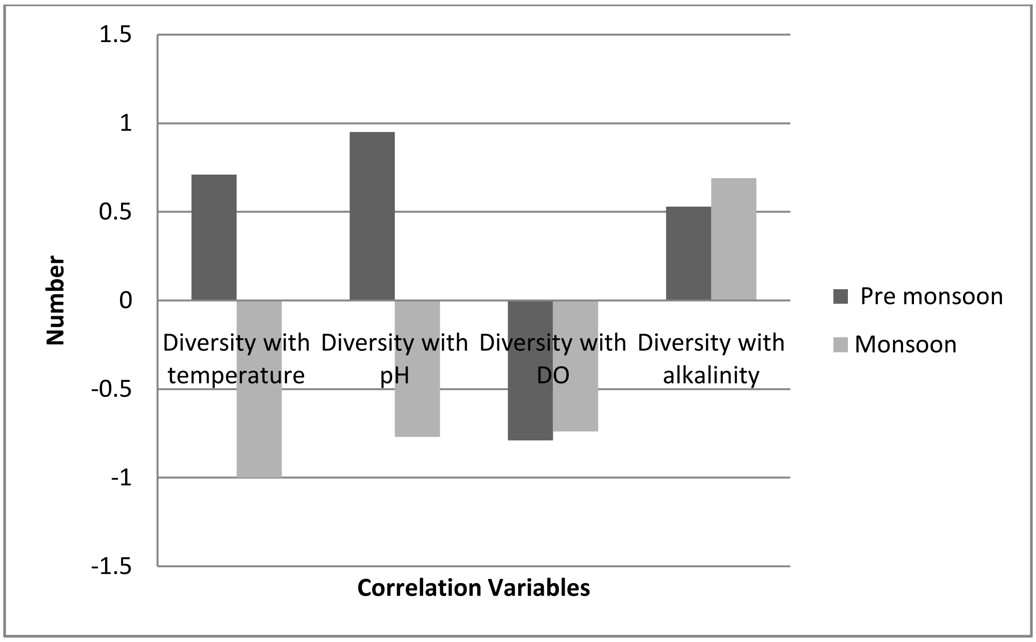


Figure 4.7 Correlations between Diversity Index and Physical Parameters

The relation between the diversity and the physical parameters was varied in pre and post monsoon period. There was a positive relation between diversity and temperature during pre monsoon and strongly negative correlation in monsoon. Similarly, the relation between pH and the diversity was positive in pre monsoon and negative in monsoon. Furthermore, the DO and the diversity were negatively correlated and positive correlation was observed between alkalinity and diversity in both seasons. The positive relation between the parameters and diversity signifies as the parameter increase there is increase in the diversity and vice versa. And the negative correlation signifies that if one of the variable increase then another decreases and vice versa.

5. DISCUSSION

The aim of the study was to explore the aquatic insect fauna, their abundance, diversity and their relation with the physical parameters of the pond. Aquatic insects play a greater role in the pond as some of them are the bio-indicators.

The aquatic insects were collected monthly for six months from March to August (2014) that included pre monsoon and monsoon period. The insects collected belong to three orders, five families and five genera. Among them most diverse order was Hemiptera with three families Notonectidae, Gerridae and Corixidae with single genus each. Both Diptera and Coleoptera had single family Chironomidae and Dysticidae respectively with single genus each. One unidentified species was also reported from the pond. Rajkarnikar (1998) in similar kind of exploration reported four orders of aquatic insects Diptera (four families; Chironomidae, Stratiomyidae, Tipulidae, Culicidae), Coleoptera (four families; Dysticidae, Haliplidae, Ptiliidae and Torridinicolidae), Hemiptera (three families Notonectidae, Gerridae and Corixidae) and Odonata (one family; Coenagrionidae).

A total of 4,181 insects were collected during the study period of six months. The total number of Diptera, Hemiptera, Unidentified species and Coleoptera were 2670, 1171, 275 and 65 respectively. The abundance of Diptera in pre monsoon was higher with the presence of single genus *Chironomus* sp. in comparison to monsoon which are typical for many fresh water systems (Heatherly and Whiles 2005). Shah *et al*. (2011) described the abundance of Chironomidae higher in pre monsoon than post monsoon. Pinder (1986) also described the family Chironomidae as the most abundant group in freshwater communities in Thailand. Purkayastha and Gupta (2015) observed higher abundance of Hemiptera in pre monsoon and Coleoptera in monsoon from the pond. In this study the order Coleoptera with genus *Dysticus* sp. was abundant in pre monsoon. The alternating period of rainfall and drought could affect the Dysticid populations (Nakanwe, 2009). The order Hemiptera with genus *Notonecta* sp., *Corixa* sp. and *Gerris* sp. was abundant in monsoon. Hossain *et al*. (2015) recorded higher abundance of Hemiptera in monsoon from the rivers of Bangladesh. According to Ohiokhioya *et al*. (2009) community composition varied seasonally, with a trend toward a declining proportion during the rainy season and increasing proportion during the dry season.

The fluctuation in diversity index, species richness and evenness of the insect species was observed during each study month. The highest value of diversity index, species richness and evenness was observed in two months; June and July of monsoon period with the values 1.56, 7 and 0.8 respectively. The lowest values of both diversity index and evenness was recorded in the month of August 0.79 and 0.49 respectively while lowest species richness in the month of March. The mean diversity index value was 1.11 in pre monsoon and 1.33 in monsoon is an indication of the disturbance in the environmental conditions (Wilhm and Dorris, 1968). Shah *et al*. (2011) mentioned high diversity index in post monsoon and comparatively low in pre monsoon from Jagdishpur reservoir. The diversity values for real communities are often found to fall between 1.0 and 6.0 (Stiling, 1996), this means that diversity in all the sampling month were relatively low since none had an H’ value higher than 1.56. In addition, other anthropogenic utilization (Wetzel, 1990) might also be influencing the insect diversity of the pond.

The physicochemical parameters are useful in detecting the effect of pollution on the water quality, but changes in trophic conditions of water are reflected in the biological community structure including species pattern, distribution and diversity (Ishas and Khan, 2013). Low dissolved oxygen, high nitrate or phosphorous concentrations and low pH can cause reduced water quality. A desirable habitat quality is generally characterized by a heterogeneous habitat with both slow and fast moving water, woody debris, substrate variety, and well-vegetated, stable banks (Galuppo *et al*., 2007). Impairment of habitat and water chemistry can lead to the reduced diversity of aquatic macro-invertebrates (Hepp *et al*., 2013)

The most common physical assessment of water quality is the measurement of temperature. Temperature impacts both the chemical and biological characteristics of surface water. The maximum temperature recorded was 26^0C in April, May and August (both monsoon and pre monsoon). Similar type of finding was listed by Vasantkumar and Roopa (2014) which shows maximum water temperature in May and minimum in June. The difference in water temperature may depend on the climatic condition as well as on time, rate of wind flow and amount of sunlight (Devi *et al*., 2013). In the present study the coefficient of correlation between diversity and temperature was 0.71 showed positive relations in pre monsoon period and -1 showed strongly negative correlation in monsoon period. Water temperature affects the numbers of aquatic insects as each species have particular range of temperature to survive due to different metabolism and respiratory rate (Devi *et al*., 2013).

pH affects the dissolved oxygen level of the water, photosynthesis of aquatic organisms (phytoplankton) and the sensitivity of these organisms to pollution, parasites and diseases (Ngodhe *et al*., 2014). A change in pH also affects aquatic life indirectly by altering other aspects of water chemistry. The pH value was observed highest in monsoon with value 7.2 and low in pre-monsoon (6.9). The increase rate of decomposition of organic matters, source of high water temperature, mixing of domestic sewage caused low pH value (Dubey *et al*., 2006). The coefficient of correlation between pH and the diversity was 0.95 showed positive in pre monsoon and -0.77 in monsoon showing negative relation.

The concentration of dissolved oxygen (DO) is one of the most important parameter to indicate water purity and to determine the distribution of various aquatic insect groups (Wahizatul *et al*., 2011). The highest value of DO was recorded in the month of August in the monsoon and lowest in pre monsoon period (March). In this study the coefficient of correlation between DO and the diversity shows negative relation in both the pre monsoon and monsoon period (r= -0.79 and -0.74 respectively). Paaijmans *et al*. (2008) noted that suspended particles in the water absorb heat thus they could increase water temperatures. This, in turn, could reduce the oxygen content of the water since warm water holds less dissolved oxygen than cold (Mandal, 2014).

Alkalinity indicates that water was contaminated with ions, carbonate, bicarbonate and hydroxide which are accumulated in water from rain and soil including phosphate and silicate (Devi *et al*., 2013). Alkalinity values of 20-200 mg/L are common in fresh water ecosystems. Alkalinity below 10 mg/L indicates poorly buffered water system (Biggs, 1995). The present study showed alkalinity and diversity were positively correlated in both pre monsoon and monsoon period (0.53 and 0.69 respectively).

The positive relation between the parameters and diversity signifies as the parameter increase there is increase in the diversity and vice versa. And the negative correlation signifies that if one of the variable increase then another decreases and vice versa.

In present study the diversity of the aquatic insects was observed highest in June and July in monsoon. This may be due to rainfall as it influences the water depth and as well as water quality to the diversity in extreme conditions (Mohd Rasdi *et al*., 2012). Low dissolved oxygen, and low pH can cause reduced water quality. Impairment of habitat and water chemistry can lead to reduce the diversity of aquatic macro invertebrates (Resh and Betts, 2007). Pearson correlation was carried out to investigate the effects of environmental parameters and water parameters towards orders of aquatic insect's density. The test also carried out to know the relationship of the aquatic insects such as Diptera larvae with environmental and water parameters.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the results throughout this study period, a total of five families representing three orders with one unidentified order were recorded. The order Diptera was represented by *Chironomus* sp., Coleoptera by *Dysticus* sp. and Hemiptera by *Gerris* sp., *Notonecta* sp. and *Corixa* sp.

The diversity index was recorded high in June and July (1.56). The species richness and evenness was also recorded high in June and July in the monsoon period. The order Diptera was present in overall study period in both pre monsoon and monsoon but high number of individual were recorded in March. Larva, pupa, adult and exuviae stages of *Chironomus* species were observed throughout the study period. The order Coleoptera with *Dysticus* species (both adult and juvenile) was abundant in May (pre-monsoon). Hemiptera was recorded high in August in the monsoon while very less number in April. The adult and juvenile forms of *Notonecta* and *Gerris* species were recorded and *Corixa* species was represented only by adult form. The unidentified species was null in pre monsoon but recorded in monsoon (July and August).

The diversity of species was positively related with temperature, pH and alkalinity but negatively related with DO in pre monsoon. In monsoon, diversity shows positive correlation with alkalinity but negative with temperature, pH and DO.

6.2 Recommendations

Based on this research, following are the important recommendations:

- More research work related to aquatic insects should be encouraged.
- Anthropogenic activities such as bathing, washing and cleaning in the pond must be controlled for minimizing habitat disturbance.
- Study of predator species and their control should be done to enhance the population of the insects.
- The pollution must be controlled to increase the diversity and maintenance of pond ecosystem.

7. REFERENCES

Abhijna, U. G., Ratheesh, R. and Kumar, A. B. 2013. Distribution and Diversity of Aquatic Insects of Vellayani Lake in Kerala. J. Environ. Biol. **34**(3): 605-611.

Atkinson, E.T. 1980. Fauna of the Himalayas, Containing Species of Kumaon, Garhwal, Nepal and Tibet. Cosme Publications, Delhi, India.

Behar, S. 1997. Testing the Waters; Chemical and Physical vital signs of a River. Montpelier, VT: River Watch Network. 211p.

Biggs, B. J. F. 1995. Relationship between Benthic Biota and Hydrological indices in New Zealand streams. Freshwater Biology **38**(2): 327-342.

Biggs, J., Williams, P., Whitfield. M., Nicolet, P. and Weatherby, A. 2005. 15 years of Pond Assessment in Britain: Results and Lessons learned from the work of Pond Conservation. Aquatic Conservation, Marine and Freshwater Ecosystem **15**(6): 693-714.

Borror, D. J., DeLong, D. M. and Triplehorn, C. A. 1981. An Introduction to the Study of Insects. 5th ed. Saunders College Publishing, Philadelphia, 827p.

Choudhary, D. and Gupta, S. 2015. Aquatic Insect Community of Deepor beel (Ramsar site), Assam, India. Journal of Entomology and Zoology Studies, **3**(1): 182-192.

Collinson, N. H., Biggs, J., Corfield, A., Hodson, M. J., Walker, D., Whitfield, M. and Williams, P. J. 1995. Temporary and Permanent ponds: An Assessment of the Effects of drying out on the Conservation value of Aquatic Macro-invertebrate Communities. Biological Conservation. **74**(2): 125-134.

Dalal, A. and Gupta, S. 2014. Aquatic Insect Diversity in two Temple ponds of Silchar, Assam, N.E. India and their Conservation values. Knowledge and Management of Aquatic Ecosystems, 415:09.

Davies, B. R. 2005. Developing a Strategic Approach to the Protection of Aquatic Biodiversity. PhD, Oxford Brookes University, Oxford, UK.

Devi, M. B., Devi, O. S. and Singh, S. D. 2013. Preliminary Study of Aquatic Insect Diversity and Water Quality of Loktak Lake, Manipur. International Journal of Integrative sciences, Innovation and Technology; Sec. C **2**(3):33-37.

DiFranco, J. L. 2014. Protocols for Sampling Aquatic Macroinvertebrates in Freshwater Wetlands, Department of Environmental Protection, Maine.

DOAD. 1992. National Fisheries Development Plan, 1992/93. Fisheries Development Division, Department of Agriculture Development, HMGN, Kathmandu, Nepal.

Dubey, K. K., Girri, A. K. and Lagarkha, R. 2006. Seasonal changes of Water quality parameters of Yamuna River at Kalpi, Distt –Jalaun. Nat. J. of Life Sci. 2 (supp.) 32408.

Galuppo, N., Maci, S., Pinna, M. and Basset, A. 2007. Habitat types and Distribution of Benthic Macro-invertebrates in a transitional Water Ecosystem: Alimini Grande (Puglia, Italy). Transitional Waters Bulletin **4**: 9-19.

Grant, I. F. and Tingle, C. C .D. 2002. Ecological Monitoring Methods: For the Assessment of Pesticide Impact in the Tropics. Natural Resources Institute, UK. 183-193.

Gupta, S. and Barman, B. 2015. Aquatic Insects as Bio-indicator of Water Quality- A study on Bakuamari stream, Chakras Hila Wildlife Sanctuary, Assam, North East India. Journal of Entomology and Zoology Studies **3**(3): 178-186.

Gupta, S. and Purkayastha, P. 2013. Estimating ecosystem health of shallow water pond in lower Irongmara, Barak Valley, Assam, India using ASPT, SPI and BWMP Score. International Research Journal of Biological Sciences **2**(8): 1-4.

Gupta, S., Purkayastha, P. and Dey, S. 2013. Use of Aquatic Insects in Water quality assessment of Ponds around two Cement Factories of Assam, India. Internatinonal Research. Journal of Environment Sciences **2**(7).

Heatherly II, T. and Whiles, M. R. 2005. Diversity and Community Structure of Littoral Zone Macro-invertebrates in Southern Illionis Reclaimed Surface Mines Lakes. The American Midland Naturalist Journal **154**: 67-77.

Hepp, L. U., Restello, R. M. and Milesi, S. V. 2013. Distribution of Aquatic Insects in Urban Headwater Streams. Acta Limnologica Brasiliensia **25**(1): 1-9.

Hershey, A. E., Lamberti, G. A., Chaloner, D. T. and Northington, R. M. 2010. Ecology and Classification of North America Freshwater Invertebrates. 3rd edition, 659-694pp

Hossain, S., Aslam, Abu F. M., Saha, B. and Howlader, A. J. 2015. Abundance of Aquatic Insects in Relation to Physico-Chemical parameters of two Highly Polluted Rivers Sitalakkhya And The Buriganga. Bangladesh J. Zool. **43**(1): 63-72.

Illies and Botosanenu 1963. Aquatic Insect Ecology, I. Biology and Habitat. John Wiley and sons. 151 pp.

Imms, A. D., Richards, O. W. and Davies, R. G. 1977. Imms' General Textbook of Entomology, vol. 2, 1st ed., Springer Netherlands, 388p.

Ishas, F. and Khan, A. 2013. Aquatic biodiversity as an ecological indicators for water quality criteria of River Yamuna in Doon Valley, Uttarakhand, India. World Journal of Fish and Marine Sciences **5**(3): 322-334.

IUCN-Nepal. 1996. An Inventory of Nepal's Wetlands. IUCN-Nepal, Kathmandu.

Jana, S., Pahari, P. R., Dutta, T. K. and Bhattacharya, T. 2009. Diversity and Community Structure of Aquatic Insects in a Pond in Midnapore town, West Bengal, India. J. Environ. Biol. **30**(2): 283-287.

Leelahakriengkrai, P. 2013. Diversity of freshwater benthos in the Ecotourism area at Chiang Dao District in Chiang Mai Province, Thailand. Biodiversity Journal, **4**(3):399-406.

Majumder, J., Das, R. K., Majumder, P., Ghosh, D. and Agarwala, B. K. 2013. Aquatic Insect Fauna and Diversity in Urban Fresh Water Lakes of Tripura, Northeast India. Middle-East Journal of Scientific Research **13**(1): 25-32.

Malla, Y. K., Kapoor, V. C., Tamrakar, A. S. and Vaidhya, K. 1978. On a Collection of Aquatic Insects of Kathmandu Valley. J. Nat. His. Mus. **2**(1): 1-19.

Mandal, H .K. 2014. Assessment of Waste water Temperature and its Relationship with Turbidity. Recent Research in Science and Technology **6**(1): 258-262.

Maneechan, W. and Prommi, T. O. 2015. Diversity and Distribution of Aquatic Insects in Streams of the Mae Klong Watershed, Western Thailand. Psyche: A Journal of Entomology 2015.

McAbendroth, L., Foggo, A., Rundle, S. D. and Bilton, D. T. 2005. Unravelling Nestedness and Spatial pattern in Pond Assemblages. Journal Animal Ecology. **74**: 41-49.

McDonald, J. 1976. A preliminary survey of Aquatic Insects in the Southern Himalayas, Recharch Park, Salt Lake City, Utah

Medona, M. R., Nirmala, T. and Delphin Rose, M. R. 2015. Diversity and Distribution of Aquatic Insects in Sothuparai Reservoir, at Periyakulam, Theni District, Tamilnadu, India. Int. J. Bur. Res. Rev. **7**(9): 10-15.

Mishra, P.N. 1975. Fauna of Nepal, Paper presented at the Natural Science Seminar. Inst. Sci., T.U., Kathmandu.

Mohd Rasdi, Z., Fauziah, I., Che Salmah, M. R. 2012. Diversity of Aquatic Insects in Keniam River, National Park, Pahang, Malaysia. Asian Economic and Social Society **2**(3): 312-328.

Mool, P., Bajracharya, S. R. and Joshi, S. P. 2001. Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Floods: Monitoring and Early Warning Systems in the Hindu Kush-Himalayan Region – Nepal. Kathmandu: ICIMOD.

Nakanwe, S. N. 2009. Developing a Monitoring Framework for the Aquatic Flora and Fauna of the Ishana Sub-basin in the Cuvelai Basin. Internal Report file no 20/12/2/8/4, Water Environment Division, Department of Water Affairs and Forestry, Ministry of Agriculture, Water and Rural Development,Windhoek.

Nasiruddin, M. Azadi, Md. A. and Reza, Md. S. 2014. Abundance and Diversity of Aquatic Insects in Two Water Bodies of Chittagong University Campus. Bangladesh J. Zool. **42**(1):19-33.

Ngodhe, S. O., Raburu, P. O. and Achieng, A. 2014. The Impact of Water Quality on Species Diversity and Richness of Macro-invertebrates in small water bodies in Lake Victoria Basin, Kenya. Journal of Ecology and the Natural Environment **6**(1): 32-41.

Niroula, B., Singh, K. L. B., Thapa, G.B., and Pal, J. 2010. Seasonal Variations in Physico-Chemical Properites and Biodiversity in Betana Pond, Eastern Nepal. Our Nature, **8**:212-218.

Oertli, B., Joye, D. A., Castella, E., Juge, R., Cambin, D. and Lachavanne, J. B. 2002. Does size matter? The Relationship between Pond area and Biodiversity. Biological Conservation **104**: 59-70.

Ohiokhioya, T., Imboobe, T. and Ohiozebae, E. 2009. Pollution Status of a Tropical Forest River using Aquatic Insects as Indicators. African J. Ecol. **48**(1): 232-238.

Paaijmans, K. P., Takken, W., Githeko, A. K. and Jacobs, A.F. 2008. The Effect of Water Turbidity on the near-surface Water Temperature of larval habitats of the Malaria mosquito *Anopheles gambiae*. International Journal of Biometeorology **52**(8): 747-753.

Pinder, L.C.V. 1986. Biology of Freshwater Chironomidae. Annual Review of Entomology. **31**: 1-23.

Prommi, T. and Payakka, A. 2015. Aquatic Insect Biodiversity and Water Quality Parameters of Streams in Northern Thailand. Sains Malaysiana **44**(5):707-717.

Purkayastha, P. and Gupta, S. 2012. Insect Diversity and Water Quality Parameters of Two Ponds of Chatla Wetland, Barak Valley, Assam. Current World Evironment **7**(2): 243-250.

Purkayastha, P. and Gupta, S. 2015. Ecology of Monabeel; A Floodplain Ecosystem of Cachar, Assam with special reference to Aquatic Insect Community. Tropical Ecology **56**(2): 245-255.

Rajkarnikar, S. M. 1998. A study on Abiotic and Biotic Components of the Pond "Jagmaru Pukhu" Lalitpur District, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Rana, A. and Chhetri, J. 2015. Assessment of River Water Quality using Macro-invertebrates as Indicators: A case study of Bhalu Khola tributary, Budhigandaki River, Gorkha, Nepal. International Journal of Environment, **4**(3): 55-68.

Resh, V. and Betts, E. 2007. "Bioindicators of Strawberry Creek", Department of Integrative Biology, University of California.

Samweel, N. and Nazir, T. 2014. Diversity of Aquatic Insects and Function of Fluvial Ecosystem of Song River of Rajaji National Park, India. Global Journal of Science Frontier Research (H), **14**(1).

Santhosh, S., Krishna Mohan, C., Dhanesh, N. R., Sobha, V. and Akolker, P. 2014. Biomonitoring status and Contribution to the knowledge of Benthic Macro-invertebrates for river Meenachil, Southern Kerala, India: A First case approach. International Journal of Advanced Research in Biological Sciences **1**(6): 218-225.

Scheffer, M., Van Geest, G. J., Zimmer, K., Jeppsen, E., Sondergaard, M., Butler, M. G., Hanson, M. A., Declerck, S. and De Meester, L. 2006. Small habitat size and Isolation can promote Species richness: Second-order effects on Biodiversity in shallow Lakes and Ponds. Oikos **112**(1): 227-231.

Shah, D. N., Shah, R. D. T. and Pradhan, B.K. 2011. Diversity and Community Assemblage of Littoral Zone Benthic Macroinvertebrates in Jagadishpur Reservoir. Nepal Journal of Science and Technology **12**: 211-220.

Shannon, C. E. and Weaver, W. 1949. The Mathematical Theory of Communication. The University of Illinois Press, Urbana, 117pp.

Sharma, C. M., Sharma, S., Borgstrom, R., and Bryceson, I. 2005. Impacts of a small dam on Macroinvertebrates: A case study in the Tinau River, Nepal. Aquatic Ecosystem Health and Management, **8**(3): 267-275.

Sharma, R. K. and Agrawal, N. 2012. Faunal Diversity of Aquatic Insects in Surha Tal of District - Ballia (U. P.), India. Journal of Applied and Natural Science. **4**(1): 60-64.

Shrestha, R. 2006. Diversity and Evenness of Aquatic Insects as a Tool for Biological Assessment of Godawari Rivulets. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Smith, R. L. 1974. Ecology and field biology 2nd ed. Harper and Row Publishers, New York.

Stiling, P. D. 1996. Ecology: Theories and Applications. 2nd ed. New Jersey: Prentice Hall 538pp.

Subramanian, K. A. and Sivaramakrishnan, K. G. 2007. Aquatic Insects for Bio-monitoring Fresh water Ecosystems- A Methodology Manual. Asoka Trust for Research in Ecology and Environment (ATREE), Bangalore, India.

Suren, A. M. 1994. Macro-invertebrate communities of Streams in Western Nepal: Effects of Altitude and Land use. Freshwater Biology, **32**, 323-336.

Swarup, H., Pathak, S. C. and Arora, S. 1981. Laboratoy Techniques in Modern Biology. Lucky Press, 374pp.

Takigawadyl, Y. and Namikawa, D. A. I. 1952-53. Fauna and flora Of Nepal Himalaya; Scientific results of the Japanese expeditions to Nepal Himalaya. H. Kiahara, **1**: 251.

Vasantkumar, B. and Roopa, S. V. 2014. Physico-chemical and Aquatic Insect Diversity of Pond ecosystem in Karwar, India. Int. J. of Life Sciences **2**(2): 148-154.

Voshell, Jr. and Reese, J. 2002. A Guide to Freshwater Invertebrates of North America. McDonald and Woodward Publsihing Co. Blacksburg, VA.

Wahizatul, A. A., Long, S. H. and Ahmad, A. 2011. Composition and Distribution of Aquatic Iinsect communities in relation to Water quality in two Freshwater streams of Hulu Terengganu, Terengganu. Journal of Sustainability Science and Management **6**(1): 148-155.

Wetzel, R. G. 1990. Reservoir Ecosystems: Conclusions and Speculations. In: Reservoir Limnology: Ecological Perspectives (Eds K.W. Thornton, B.L. Kimmel & F.E. Payne). Wiley, New York, 27-38pp.

Wilhm, J. L. and Dorris, T. C. 1968. Biological Parameters for Water Quality Criteria. Bioscience **18**: 477-481.

Williams, P., Whitfield, M., Biggs, J., Bray, S., Fox, G., Nicolet, P. and Sear, D. 2004. Comparative Biodiversity of Rivers, Streams, Ditches and Ponds in an Agricultural Landscape in Souther England. Biological Conservation. **115**(2): 329-341.

Yadav, L. P. 1996. The Effects of Physico-Chemical Parameters on the Distributuion and Abundance of Zooplankton in Taudaha Lake. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Yadav, R. P. 2006. Aquatic Insects of Palung Khola, Makwanpur District, Nepal. Our Nature, **4**:104-106.

Yadav, U. K. R. 1994. Water Quality and Benthic Fauna of Feeding River, Palung and Streams of the Kulekhani Reservoir. IInd National Conference on Science and Technology, June 8-11, Katmandu, Nepal.

Yadav, U. K. R. and Prasad, S. N. 1980. General Composition and Distribution of Zoobenthos in Rajdal Pond (Lagankhel, Lalitpur). J. Inst. Sci. Tech. **3** (1):181pp.

Yadav, U. K. R. and Rajbhandari, B .C. 1982. Studies on the Benthic Macrofauna of Bansbari Khola and Dhobi Khola in Kathmandu Valley. NCST.**5**.

Yadav, U. K. R., Basnet, K. and Mehata, J. 1983. Studies on Benthic Fauna of Four ponds of Godavari Fish Farm, Kathmandu valley. J. Nat. Hist. Mus. **7**(1/4):73-82.

Yadav, U. K. R., Karki, S. B., Karki, T. B., Jha, S. N. and Mehta, J. 1981. Studies on the Macrofauna of Godawari Khola, Kathmandu Valley, Nepal. J. Nat. Hist. Mus. **9**(1/4):23-26.

Yule, C. M. and Yong, H. S. 2004. "Freshwater Invertebrates of the Malaysian Region", Academy of Sciences Malaysia, Kuala Lumpur Malaysia.

ANNEXES

ANNEXES I Photo Plates of Collected species

1. Order: Coleoptera

1.1 Adult (dorsal view)

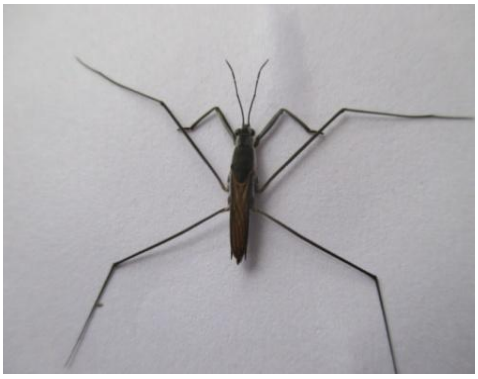
` 1.2 Adult (ventral view)

1.3 Juvenile (dorsal view)

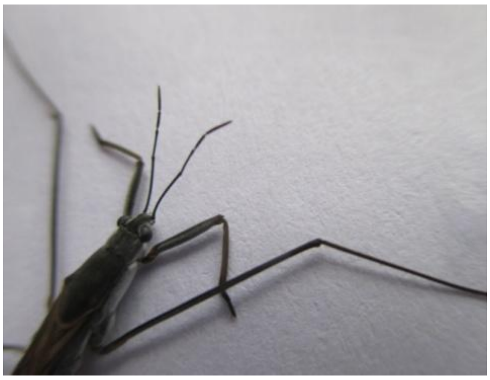
1.4 Juvenile (ventral view)

Fig. *Dysticus* sp.

2. Order: Hemiptera



2.1 Adult



2.2 Adult showing antennae

2.3 Juvenile

Fig. *Gerris* sp.

2.4 Juvenile

2.5 Adult (freshly collected)

2.6 Adult (preserved specimen.)

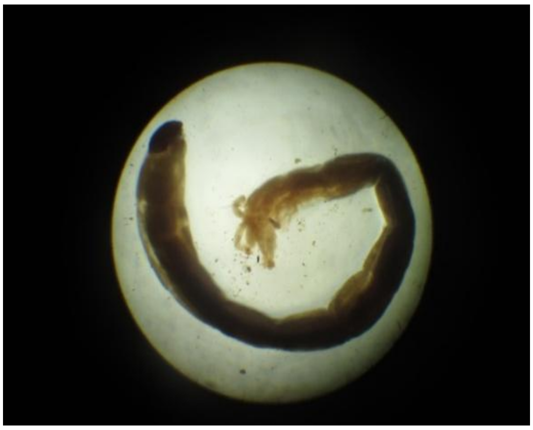
Fig. *Notonecta* sp.

2.7 Adult

Fig. *Corixa* sp.

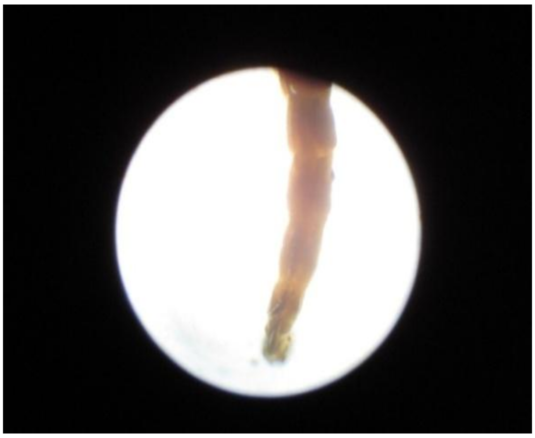
3. Order Diptera

3.1 Larva



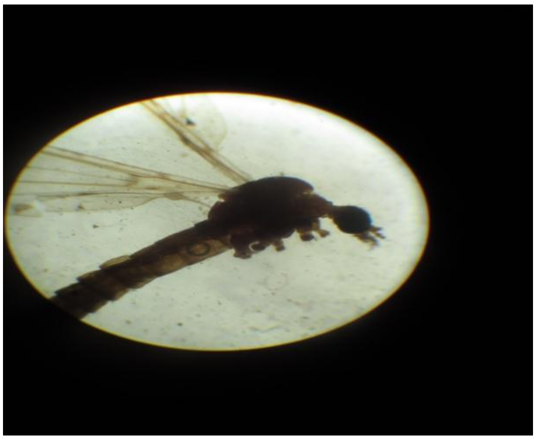
3.2 Larva under microscope

3.3 Pupa (cephalothorax)



3.4 Pupa (abdomen)

Fig. *Chironomus* sp.



3.5Adult (head and thorax)

3.6 Adult (abdomen)

3.7 Exuviae

Fig. *Chironomus* sp.

Fig. Unidentified species (whole specimen)

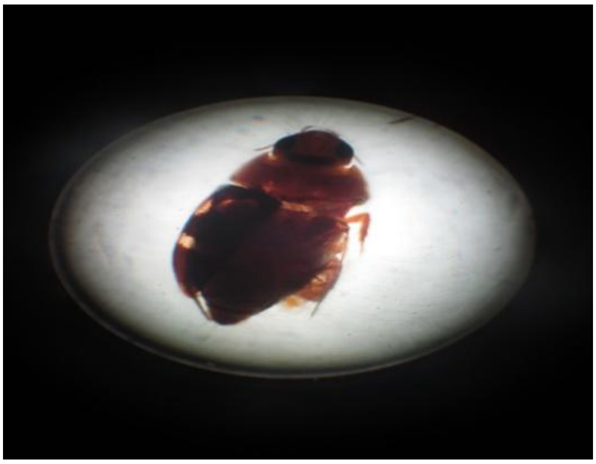


Fig. Unidentified species (pressed)

ANNEXES II Photo plate of study site the 'Na pukhu' pond and sample collection

1. Site A

2. Site B

3. Site C

4. Species collection

5. Water Sample collection

6. Human interference in pond

7. Lab analysis of water sample

8. Preserved species in different vials

9. Observation under microscope

ANNEXES III Data Analysis

Table: 1 Monthly fluctuation of Species Diversity, Species Richness and Species Evenness of the Pond

	Pre Monsoon			Post Monsoon		
	March	April	May	June	July	August
Diversity Index	0.88	1.04	1.41	1.56	1.56	0.79
Species Richness	4	5	6	7	7	5
Species Evenness	0.63	0.65	0.79	0.8	0.8	0.49

Table: 2 Monthly Collections of Aquatic Insects

Species	March	April	May	June	July	August
Dysticus sp.	7	12	35	11		
Gerris sp.		15	30	10		
Corixa sp.				252	115	
Notonecta sp.					276	473
Chironomus sp.	816	691	611	394	129	29
Unidentified species					78	197

Table: 3 Monthly Abundance of the Insects

Order	March	April	May	June	July	August
Diptera	99.15%	96.24%	90.38%	59.07%	21.57%	4.15%
Hemiptera		2.09%	4.44%	39.28%	65.39%	67.67%
Unidentified species					13.04%	28.18%
Coleoptera	0.85%	1.67%	5.18%	1.65%		

Table: 4 Pre monsoon and Monsoon Abundance

	Coleoptera	Hemiptera	Diptera	Unknown
Pre monsoon	2.44%	2.03%	95.33%	0
Monsoon	0.56%	57.33%	28.11%	14%

Table: 5 Variations in Physical Parameters

	Pre monsoon			Post monsoon		
Months → Physical parameters ↓	March	April	May	June	July	August
Air Temperature (^{0}C)	29	30	31	32	28	29
Water Temperature (^{0}C)	25	26	26	25	25	26
p^H	6.9	7	7.05	7.2	7.1	6.9
DO (mg/l)	2.95	3.02	3.64	3.51	4.45	4.86
Alkalinity (mg/l)	95	115	125	135	120	115

Table: 6 Correlations between the Diversity and the Physical Parameters of the Pond

	Pre monsoon	Monsoon
Diversity with temperature	0.71	-1
Diversity with p^H	0.95	-0.77
Diversity with DO	-0.79	-0.74
Diversity with alkalinity	0.53	0.69

ANNEXES IV Field Record Sheet

Month	Site	GPS Location	Sample No.	Name of species	No. of species collected	Air Temperature	Water Temperature	pH