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DIVERSITY AND POPULATION DYNAMICS OF FRESHWATER CLADOCERA (CRUSTACEA: BRANCHIOPODA) IN MANMADE PONDS AT BOYE WETLAND, JIMMA ZONE, SOUTHWESTERN ETHIOPIA

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LIST OF ABBREVIATION

DHM: Diel Horizontal Migration

DO: Dissolved oxygen

DVM: Diurnal Vertical Migration

EC: Electrical Conductivity

ITCZ: Inter-Tropical Convergence Zone

WHO: World Health Organization

TAXONOMICAL TERMINOLOGY

Antennules: a pair of first antenna in Cladocera which has sensory in function.

Antenna: the main swimming organ in Cladocera.

Carapace: chitinus body covering of Cladocera.

Fornix: a long and pointed lateral process on the side of the head.

Labrum: a plate seen on the ventral part of the head mainly in Chydoridae species.

Post abdomen: Posterior part of the animal with anus and a pair of claws.

Spinules: small and sharp spines

ABSTRACT

A study was carried out on the diversity and population dynamics of the freshwater Cladocera from March, 2013 to August, 2013 in three manmade ponds in Boye wetland. Samples were taken fortnightly with concurrent measure of influencing variables like air and water temperature, pH, dissolved oxygen (DO), electric conductivity (EC) and transparency were measured. Except for EC no significant differences were recorded for water temperature, pH, DO and transparency among these three ponds but there were significant differences in water temperature and transparency between months. During this study a total of 7 species of Cladocera belongs to 7 genera and 5 families were recorded. Among the five families the Daphnidae and Chydoridae were represented with 2 species each, while Moinidae, Macrothricidae and Sididae represented with 1 species each. The Cladocera species identified during this study include Moina micrura, Diaphanosoma excisum, Alona rectangula, Ceriodaphnia cornuta, Daphnia lumholtzi, Chydoruss sphericus and Macrothrix laticornis. The Moina micrura, Diaphanosoma excisum were the dominant specie, while Daphnia lumholtzi, was the least abundant Cladocera species. The number of species was not too different among the three ponds, however, average Cladocera abundance, was significantly higher (P<0.05) at the pond I and III than pond II. Peak in average abundance of Cladocera species was observed during May and August (139 and 125 ind/L) respectively and the lowest abundance were 102 and 116ind/L observed in March and July. In general, the greatest species richness of Cladocera at the order level was recorded at pond I and III. The diversity (H') and evenness (J') indices were higher at pond III. As present study was a preliminary attempt to know the taxonomy, abundance and periodicity of cladocerans, more studies will be required to make a complete list of available Cladocera species as well as their impact on water quality in the manmade ponds at Boye wetland.

Key words: Cladocera, Diversity, Manmade ponds, Population dynamics

1. INTRODUCTION

1.1. Background

Ethiopia is endowed with a variety of water bodies (lakes, rivers and reservoirs) which have a great scientific interest and economic importance. These freshwaters are very productive at the primary, secondary and tertiary levels and are consequently used as habitats for a variety of organisms (Ebisa, 2010). Therefore, studies on species diversity; evenness and dominance of these biological systems are essential to understand the changes in these aquatic habitats (Perumal *et al*., 2009).

According to Sharma *et al*. (2012) the freshwater zooplankton or secondary producers consist of mainly four major groups i.e. Protozoa, Rotifera, and two orders of Crustaceans (Cladocera and Copepoda). Cladocera is an ancient group of aquatic crustaceans which originated in Palaeozoic period(Forró *et al*., 2008) and they are the integral part of micro-zooplankton (Dodson and Frey, 1991). Cladocerans are a crucial group among freshwater zooplankton and form the most useful and nutritive group in the aquatic food chain. They are taxonomically placed within phylum Arthropoda, subphylum Crustacea, Class Branchiopoda, which is divided to 4 suborders; these are Anomopoda, Ctenopoda, Onychopoda and Haplopoda, 11 families and 80 genera (Dumont and Negerea, 2002). Cladocera is commonly known as the “water fleas” due to its jerky movements in water. Most of the species are freshwater but eight species belonging to the three genera i.e., Penilia, Evadne and Podon are known to be truly marine (Sharma *et al.*, 2011).

Aquatic microcrustaceans usually inhabit every type of habitats in the littoral, limnetic or benthic zones of freshwater lakes and ponds (Forro *et al*., 2008). However, they are to be generally intolerant to high salt concentration in the medium, though there are species that frequently occur in brackish water habitat. Most species are transparent, especially those which inhabit the open waters, while others found among the weed beds of the littoral and benthic zones are darkly pigmented with shades of yellow, brown or red (Witty, 2004). Most species show sexual dimorphism with males generally being smaller than females. The females are two kinds, asexual or parthenogenetic and sexual or gamogenetic (Michael and Sharma, 1987).

Cladocerans are suitable live food sources for aquaculture practice due to their abundance, tolerance to environmental variations, high nutritional quality, easy of handling and suitable size (0.2-5mm) except one lacustrine species *Letodora kindtti*; which has more than 18mm in size. Due to its parthenogenetic reproduction, short generation time, richness with digestive enzymes and high caloric values, Cladocera is considered to be an ideal candidate for ornamental and commercial fishery (Kumar *et al.*, 2005). The first information on Cladocera was reported in 17th century (Korovchinsky, 1997; Dumont and Negrea, 2002). So far, only 620 species are reported from all over the world (Kotov and Stifter, 2006) of this, only about 45-50% of the species may be considered to be more or less well described and valid and many of them having cryptic complexes (Forro *et al.*, 2008). They are important organism in both basic and applied research, due to their easy culturing, short generation time and colonial reproduction. Some species like *Daphnia* have been widely used in ecological and evolutionary assessment studies (Forro *et al.*, 2008).

Cladocerans usually reproduce by cyclical parthenogenesis and gamogenesis; populations are mostly dominated by females (Michael and Sharma, 1987). Sexual dimorphism is normally rather distinct. Sexually produced resting eggs are resistant to desiccation, drought and other unfavorable conditions and even survive passage through the digestive tract of birds (Fguerola and Green, 2002) thus; they are important propagules for passive dispersal.

Cladocerans have high seasonal variability due to the alternation of parthenogenetic and gamogenetic reproduction modes (Egloff *et al*., 1997; Rivier, 1998). Increase in density is accelerated by parthenogenesis, namely, the development of parthenogenetic eggs beginning in the brood chambers of female without fertilization by male and release the young one like an immature adult (Egloff *et al*., 1997). Generally cladocerans reproduce parthenogenetically when the environment is favorable. This ability makes them especially adapted to opportunistic utilization of seasonally changing resources (Brandl, 2002), enabling them to achieve seasonally very high abundances and play significant roles in the diet of various planktivorous fishes and invertebrate predators at high densities (Flinkman *et al*., 1998).

Among crustaceans, cladocerans may be the best indicator for biodiversity assessment in ponds and small lakes because they are easy to identify, play a key role in food webs, and respond to environmental gradients (Jeppesen *et al.,* 2000). Cladocerans can respond both to bottom-up factors, such as changes in water quality and nutrients, algal resources, and aquatic vegetation (Walseng *et al.,* 2006; Ge´linas and Pinel-Alloul, 2008; Peretyatko *et al.,* 2009), and top-down factors induced by fish and macro invertebrate predators (Boven and Brendonck, 2009; Drenner *et al.,* 2009). They have a wide range of phenotypes that allow them to colonize, survive, and develop differently in temporary and permanent ponds (Boven and Brendonck, 2009; Drenner *et al.,* 2009). They are also able to rapidly re-colonize ponds as a result of efficient recruitment from the dormant cyst bank and the ability to reproduce parthenogenetically (Brendonck and De Meester, 2003). Cladocerans are also key species for pond restoration because large-bodied daphnids are efficient grazers on algae and may enhance water transparency in shallow lakes and ponds (Peretyatko *et al.,* 2009).

To the best of our knowledge no research has been done so far in Boye area particularly from these manmade ponds in order to know diversity and dynamics of Cladocera. In view of this, the present investigation will generate substantial information regarding the richness of cladoceran species, diversity and its dynamics from Boye wetland area.

1.2. Statement of the problem

Studying on how the interactions of the various components of a water body and community change at different temporal scales has high significance for a better understanding of the functioning of the ecosystem (Dagne, 2010). Although small lakes and ponds represent important freshwater systems at a global scale, they were, until recently, a neglected component of research in limnology (Downing, 2010). Among the various freshwater bodies ponds are often constitute biodiversity ‘‘hot spots’’ (Williams *et al.*, 2004; Scheffer *et al.*, 2006), because they can harbor high local species richness (alpha diversity) or rare and endemic species not commonly found in lakes and rivers. They also contribute to regional diversity (beta and gamma diversity) due to high variation in community composition through time and space. Pond ecosystem studies are suitable for understanding the impacts of human development on aquatic ecosystems and detecting the influence of residential land use and water body environments on aquatic communities and biodiversity.

In Ethiopia, most limnological studies had been focused on large lakes and reservoirs but knowledge on pond ecology is limited. Some information is available on the Cladocera diversity and population dynamics from Ethiopia but detailed information are still far from complete especially from manmade ponds. Limnological studies have been done regarding on zooplankton seasonal changes, Dejen *et al.* (2004), in Lake Tana, Morgan *et al*.(1980), In Lake Langano and Abijata, Wodajo and Belay (1984), in Lake Awasa, Mengistou and Fernando (1991), in Lake Zeway, Beneberu (2005) and Delelegne (2006) in Lake Beseka. Lemma *et al*. (2001) has studied the interaction among cladocerans and their response to fish predation in Lake Kuriftu. Dejenie *et al*. (2012) also studied the cladocerans community composition in tropical semi-arid highland reservoirs in Tigray (Northern Ethiopia).

Furthermore, Desta and Mengistou (2009) studied that the water quality parameters and macro-invertebrates index of biotic integrity of the Jimma wetlands, Southwestern Ethiopia. But, no study has been done on the diversity and population dynamics of zooplankton mainly on Cladocerans from manmade ponds. Therefore, understanding the diversity and population dynamics of freshwater Cladocerans along with the physico-chemical factors which are controlling their composition and abundance is deserving paramount importance in managing the water bodies and the resources (e.g. enhancing fishery production and mitigating water quality problems through stocking or harvesting zooplanktivorous fishes).

1.3. Significance of the study

This investigation was aimed to study the diversity and population dynamics of freshwater Cladocera which is the integral part of micro-zooplankton and environmental indicators as well. So far, no study has been under taken from this area. The result of this study will be expected as having the following significances:

It provides information about species richness and its dynamics.

It also helps to assess the water quality for sustainable human use and fishery management.

Eventually, it will give baseline information for future researchers in the area of limnology and fishery.

1.4. Objectives

1.4.1. General Objective

- To study the diversity and population dynamics of freshwater cladocerans in manmade ponds at Boye wetland in Jimma zone, Southwest Ethiopia.

1.4.2. Specific Objectives

- To investigate the taxonomic composition of freshwater Cladocera.
- To asses changes in the physico-chemical factors of the ponds water which are influencing the dynamics of zooplankton particularly on Cladocera.
- To compare the abundance and temporal variations of Cladocera in the ponds

1.5. Research Questions

To achieve the above objectives, the following questions were designed

1. How many species of cladocerans are there?
2. Is there any variation in species composition and abundance of cladocerans in different months and ponds?
3. Which species of Cladocera is more abundant in the ponds?
4. Does the abundance and species composition of the Cladocera change with the change in physico-chemical factors?

2. LITERATURE REVIEW

2.1. Taxonomy of Cladocera

Cladoceran taxonomy has undergone intense changes during the last decade, and continues to do so, with a significant number of morphological and molecular revisions appearing (Forro *et al.*, 2008). Because, taxonomical limitations in the Cladocera form an important bottleneck, the cryptic diversity in cladocerans may continue to hamper future investigations. There is a high probability that currently valid species are actual species complexes containing several cryptic species, each with different ecological requirements (Nevalainen *et al*., 2013). It is apparent that cladocerologists working solely with the fossil or intact specimens, whether on taxonomical or ecological topics, should keep up with taxonomical changes by building bridges (Sayer *et al.*, 2010).

Still now the diversity of many invertebrate groups in freshwater ecosystems are poorly understood. The Cladocera (Crustacea: Branchiopoda) are a group of benthic and planktonic microcrustaceans that occupy key roles in freshwater ecosystems world-wide (Dodson and Frey, 1991). Despite an intensive study, it is clear that the number of cladoceran taxa unknown for science exceeds the number of described species (Forro *et al.,* 2008). In addition to that the taxonomy and nomenclature of several species groups within *Daphnia* remain unresolved (Benzie, 2005).

Current estimates for the diversity of the Cladocera (Crustacea: Branchiopoda) are probably too low by 2- to 4-fold (Adamowicz and Purvis, 2005; Forro´ *et al.,* 2008). The currently accepted number of cladoceran species based on existing descriptions is around 620 (Kotov and Stifter, 2006).The described taxonomic diversity of Cladocera, however, underestimates the reality and even higher-ranked taxa are still being discovered, e.g., a new family, Dumontiidae (Santos-Flores and Dodson, 2003). Only about 45–50% of the species may be considered to be more or less well described and valid, while the status of other species is vague, and many of them likely represent cryptic complexes (Korovchinsky, 1997). The families Chydoridae, Daphniidae, Ilyocryptidae, and Sididae have been studied comparatively better. The largest number of valid species is known from Europe, North America, Australia, and South America, and the smallest number from Africa and Southern Asia (Forro *et al.,* 2008). Adamowicz and Purvis (2005) estimated three correction factors to extrapolate global branchiopod diversity from the diversity of described species, and predicted that there are about 2.1 times more branchiopod species in nature than currently known.

According to Kotov and Taylor (2010) Africa is among the most poorly studied regions, with even the best-known cladoceran genus, Daphnia (Anomopoda: Daphniidae), requiring extensive revision. In most of the world high mountain localities are a recent focus of cladoceran taxonomy because they often appear to contain endemics (Smirnov *et al.*, 2006). However, several species of the cladocerans endemic to the high mountains of Africa and South America remain undescribed (Adamowicz *et al.*, 2009). Large cladocerans especially the genus Daphnia, are rare or absent in the tropics. Yet, Daphnia species have been reported to be relatively common in Eastern Africa (Mergeay *et al*., 2006). The abundance of Daphnia in the Ethiopian highlands has remained unnoticed is due to the absence of a regional and national inventory of zooplankton (Dejenie *et al*., 2012).

2.2. Biology of Cladocera

2.2.1. Morphology

Cladocera, commonly known as "water fleas," have a distinct head, a single compound eye, and a large mandible for grinding food particles (Ahmed, 2010). The trunk limbs move rhythmically back and forth and cause food particles to drift towards the mouth. The head is covered by a chitinous head shield and it ends in the rostrum. The mouth is situated between the carapace and head shield and consists of mandibles and a labrum. The first antennae, antennules, mainly act as sensory organs and the second antennae as swimming organs. The body ends have a post abdomen and two post abdominal claws (Nevalainen, 2008). Physical characteristics include jointed appendages and a segmented body, but this noticeable segmentation has been lost in the cladocerans (Wetzel, 1983).

The trunk and appendages of most cladocerans (Anomopoda and Ctenopoda) are enclosed in a bivalved carapace. Tagmosis of the body is obscure (except in *Leptodora kindtii*, the single representative of Haplopoda) and a single eye and ocellus are usually present. Antennules are uniramous, while antennae are biramous (except in females of Holopedium), natatory with 2–4 segments per branch. Four to six pairs of trunk limbs are either mostly similar in shape (Ctenopoda, Onychopoda and Haplopoda) or modified individually for various functions (Anomopoda) (Forro *et al.,* 2008).

2. 2.2. Reproduction

Cladoceran life cycle consists of one active parthenogetic phase and independent gamotogenetic. They reproduce cyclically by alternating two reproduction modes: asexual (parthenogenesis) and sexual (gamogenesis) (Dodson and Frey 1991; Campbell *et al.,* 1999)**.** When conditions become unfavorable, for example due to overcrowding or reduced photoperiod, most cladocerans can switch to sexual reproduction (Korhola and Rautio, 2001). In sexual reproduction, some eggs develop into males, which mate with ephippial females that produce haploid eggs. The fertilized eggs then develop in a specialized brood pouch in the carapace called an ephippium, which is then shed by the female. This specialized structure becomes a resting stage, since it is resistant to desiccation, and can survive even in harsh conditions for up to several decades (Brendonck and De Meester, 2003). The production of ephippia allows Cladocera to quickly recolonize when conditions become more favorable, including recolonization in the spring following winter (Gyllström, 2004), or recolonization following recovery from an environmental perturbation (Binks *et al*., 2005).

2.2.3. Feeding

Generally, cladocerans are filter feeders and feed on algae, small rotifers and copepod nauplii (Dodson *et al.,* 2010). This is the reason why generalist's cladocerans species are able to develop in a high number of environments, like species of the Bosminidae family (Ricardo *et al.,* 2009). Some large cladocerans (Sididae and Daphniidae families) have preference on the food item ingested and they became more selective when there is food limitation (Ferrão *et al*., 2003).

Food selection is determined by particle size but generally includes phytoplankton, bacteria, rotifers, algae, ciliates, cyanobacteria and copepod larvae (Dodson and Frey, 1991). Most of the species are filter feeders and feeding on algae and organic maters.While, some species which belong to the order Onychopoda and Haplopoda are predators (Forro *et al.,* 2008). Some species of the Sididae (e.g. Sida crystallina) and Daphniidae (e.g. *Simocephalus spp*.) attach themselves to vegetation or other substrates while they feed (Yarwood, 2005).

The metabolic rate in cladoceran is variable with temperature and death can occur above the required optimal temperature (Dodson *et al.,* 2010). Under food limiting conditions, a smaller body size is favored (Dodson *et al.,* 2010). For example, *Bosmina* may be able to out-compete a larger species because it could grow faster when food is limited (Sommer *et al*., 1986). Additionally, cladocerans that have a larger body size seem to be scarce when fish are present as fish are visual predators (Sommer *et al.,* 1986).Cladoceran populations expand in conjunction with algael bloom (Abrantes *et al.,* 2006). *Daphnia*, to a lesser extent, *Bosmina* can effectively graze on large abundances of algae and therefore, contribute to improving water quality, which is dependent on algae dynamics (Dodson *et al.,* 2010).

2.3. Characteristics of Cladocera and its population dynamics

Microcrustacean assemblages are noted for their marked annual fluctuations in abundance and species composition. Cladocerans are characterized by annual hundred-fold variations in population size (Dodson and Frey, 1991) and copepods can double their numbers every one to two weeks (Williamson, 1991).

2.3.1. Seasonal patterns

Seasonality is an important driving force in the structure and functioning of freshwater ecosystems (Osam, 2008). The effect of changing seasons is reflected in the timing of biological events that ultimately determine the structure and function of biological communities (Krebs, 1994). Seasonality in the tropics is characterized by two major periods of alternating dry and wet seasons, controlled by an atmospheric boundary; the Inter-Tropical Convergence Zone (ITCZ). The migratory dynamics of the ITCZ determines seasonal precipitation and wind patterns resulting in a “hydrologically controlled tropical seasonality” (Talling and Lemoalle, 1998). This difference in the timing, scale and periodicity of population abundance are known to exist and replication patterns of annual variations are muted by seasonal fluctuations in population size (Osam, 2008). Yarwood (2005) stated that cladocerans show marked seasonal fluctuations in abundance, with patterns varying between species, for example, some (e.g. *Daphnia* spp., *Ceriodaphnia* spp. and *Moina* spp.) typically peak in wet season.

2.3.2. Dispersal and colonization

Dispersal of an individual refers to the ability of the zooplankton to move by their own means or be transported by other agents including physical, animal or human carriers (Mahar *et al*., 2008). The rapid population growth and dispersal ability of cladocerans enables them to swiftly colonize newly formed bodies of water. According to Fryer (1985) in ponds and lakes, the cladoceran *Daphnia magna* became established first, quickly followed by, in order, *Daphnia curvirostris*, *Chydorus sphaericus*, *Daphnia longispina*. Within a few months, varied communities had normally developed in new ponds and increased to abundance levels typical of more established water bodies.

The distribution of cladocerans is controlled by their capability to disperse, as well as their ability to tolerate physical, chemical and biological pressures in new environments (Smol *et al*., 2001). The dispersal and colonization of zooplankton is affected by such agents as water flow, wind, birds, fishes and anthropogenic activities (Havel and Shurin, 2004). This results lead into cosmopolitant distribution of many species of freshwater zooplankton (Mahar *et al*., 2008).

According to Kirsten and Gophen (1999) cladoceran zooplanktons possess most of the predicted traits of a successful colonizer. Adults and ephippia of cladocerans can be introduced by bait bucket releases, by intentional transfers of water or fish and by natural passive transport of the ephippia by wind, birds, mammals and fish (Thorp and Covich, 1991). `Hitchhiking' with human movement allows probability that a colonization event would occur more than once and reduces the probability of extinction after colonization (Kirsten and Gophen, 1999).

2.3.3. Diurnal horizontal and vertical migration

Aggregation of organisms in the edge zone between pelagic and littoral habitats may be the result of a diel horizontal migration (DHM) of cladocerans swimming out (up to a few tens of metres) to open water at night (Cerbin *et al.,* 2003). Cladocerans may need to move to other regions and corresponding increases of cladoceran abundance in open water were observed at night, indicative of diel migrations. This activity is most marked when macrophyte density is high and littoral piscivores are abundant, restricting planktivore distribution (Burks *et al.,* 2002).

Zooplankton actively distributes themselves among various depth habitats in response to varying degrees of alterations in habitat quality (Primicerio, 2000; Lampert, 2005). Changes in vertical distribution can vary hourly, daily, seasonally and annually with respect to its timing and amplitude (Williamson *et al.*, 1996; Primicerio, 2000). Diel vertical migration is the daily upward and downward movement by some zooplankton taxa is evidence of habitat shift by zooplankton when favourable conditions in regular intervals within each 24 hr period and can be considered to be a response to daily changes in habitat conditions with depth (Lampert, 2005). Various factors may operate to drive differences in habitat selection among zooplankton. Differences in competitive ability among competing prey species, often with a strong size-dependent component, result in spatial segregation and influences the pattern of vertical distribution (Primicerio, 2000). Size-dependent predation by vertebrates (principally fish) and invertebrate predators may force prey species into tolerance of suboptimal depths and allow an inferior competitor to occupy the vacated habitat (Primicerio, 2000).

According to Lampert (1989) crustacean zooplankton possess many important adaptations that have led to their success in aquatic habitats. Some taxa exhibit diel vertical migration, moving from dark waters during the day to the warmer surface waters at night to feed, which allows them to avoid visual predators, but comes at an energetic cost (Lee, 2007). Many taxa, especially cladocerans, also have specific inducible morphological and life history strategies to reduce predation, such as helmet (Laforsch *et a*l., 2006) and neck teeth (Black, 1993) formation, earlier reproduction and larger clutch sizes (Riessen, 1999) and stronger carapaces (Laforsch *et al.*, 2004).

2.4. Regulators of Cladocera community structure

Community structure is determined by both biological and physico-chemical drivers that influence species composition and diversity, species interactions and succession. Species diversity, or biodiversity, constitutes a fundamental aspect of zooplankton community structure and is useful for evaluating overall ecosystem attributes and functionality. Local species diversity is shaped by interactions among species and with the physical environment which determine the success of immigrant species (Shurin *et al.,* 2000).

Physico-chemical factors and other biological phenomena are also responsible for structuring zooplankton communities both in space and time. Examples of these forces shaping zooplankton communities are biogeography and dispersal (Shurin *et al.,* 2000; Cottenie *et al*., 2003; Havel and Shurin, 2004), water chemistry (Tessier and Horwitz, 1990), foodweb interactions, competition and predation have also been shown to be the proximal factors controlling community structure (Kerfoot and Lynch, 1987) and they are evolutionary products of adaptive energetic strategies**.**

Life cycle, development and reproduction of cladocerans are influenced by biotic factors such as food availability and predation by fishes and presence of larger invertebrates (Abrantes *et al.*, 2006).The abiotic factors such as pH, temperature and concentration of several important compounds such as oxygen and ammonia in the environment also affecting on its population dynamics (Bini *et al*., 2008). Furthermore, in tropical environments, rain and wind action are the major forces influencing cladocerans population structure, promoting the water column mixing and stimulating nutrient cycling (Sampaio *et al*., 2002). Factors such as pH, dissolved oxygen and nutrients (especially P and N) indirectly affect these organisms, because they strongly influence phytoplankton for their developments (Bonecker *et al*. 2001; Matsumura-Tundisi and Tundisi, 2005). Furthermore, cladocerans populations can oscillate in response to predation by other groups, like insects larvae and fishes (Meschiatti and Arcifa, 2002; Ricardo *et al.*, 2009). Thus, the changes in their abundance, species diversity or community composition can provide potential indications of environmental changes or disturbances (Ngirinshuti, 2011).

As per Norman *et al.*(1998) temperature, reduced DO concentrations, water current velocity, and turbidity have significant impacts on cladoceran and copepod distribution ,physiology,growth, reproduction, filtering rates, genetics, movements, vertical migration and predator-prey interactions. The composition of microcrustacean communities is affected by a range of physicochemical and biotic variables. The most significant of these are pH, temperature, water body size, vegetation, predation and oxygen availability (Yarwood, 2005).

2.4.1. Biological factors

2.4.1.1. Vegetation and habitat structure

The diverse habitats exploited by the Cladocera make them sensitive to ecological changes that might occur in both the vegetated, benthic, and open-water areas, or to shift in the balance between benthic and pelagic productivity (Davidson *et al.*, 2011; Jeppesen *et al.*, 2011).Vegetation and habitat structure are known to be important in determining microcrustacean assemblage composition (Paterson, 1993; Korponai *et al.*, 1997). Aquatic plant beds play an important role in the shaping of zooplankton assemblage structures (Kuczyńska-Kippen and Nagengast, 2006). For this reason, the presence of plankton organisms is closely associated with macrophytes (Balayla and Moss, 2003). Thus macrophytes play an important role in the shaping of the structure of littoral heterogeneity, while species diversity leads to the formation of heterogeneous micro-habitats that support different types of zooplankton assemblages (Balayla and Moss, 2003).These are especially in shallow lakes and ponds, the role of vegetation is also a remarkable factor in determining microcrustacean assemblages (Dodson *et al.*, 2005). Developing macrophyte beds create various microhabitats, which allow the occurrence of more phytophilous species (Ferenc *et al*.,2012).The boundary between littoral macrophyte beds and open waters may also be an important daytime refuge for potentially migrating pelagic cladocerans (Walseng *et al* .,2006*)*.

2.4.1.2. Predation and phytoplankton

Cladocera occupy a strategic, intermediate position in aquatic food webs. They are primary grazers on phytoplankton (although there are predatory cladoceran species), and are also an important food source for planktivorous fish and macroinvertebrates. As a result of their intermediate food web position, Cladocera assemblage and community dynamics are simultaneously influenced by both bottom-up (e.g. phytoplankton) and top-down (predation) effects, making them excellent indicators of changes in trophic interactions. Within the Cladocera, *Daphnia* are commonly referred to as a keystone species (Martin-Creuzburg *et al* .,2005; Sarnelle, 2005), and as a result of their large body size and high surface area of filter-feeding appendages, *Daphnia* are effective for maintaining low algal production in lakes

(Carpenter *et al.,* 1998). Consequently, changes that occur within the Cladocera have the potential to cascade through the aquatic food web, and early observations of cladoceran community change may potentially foreshadow ecosystem-wide shifts in trophic levels (Davidson *et al.,* 2011). Predation has a great role in the community variability of zooplanktons. Because strong predation by fish can lead to large population declines, lead to higher levels of community variability by favouring stochastic over competitive processes in community dynamics (Orrock and Fletcher, 2005).This pattern is common in tropical and subtropical freshwaters, whether in lakes, ponds, reservoirs, rivers or streams (Neves *et al.,* 2003).

2.4.2. Physico-chemical parameters

2.4.2.1. Temperature

In general, water temperature strongly affects developmental strategies, metabolic rates, species distribution and community structure of freshwater organisms (Bronmark and Hansson, 1998). Temperature is an important factor regulating life history traits in Cladocera. Under elevated temperatures, the development of crustaceans accelerates and they achieve maturity at a smaller size (Atkinson, 1994). Reduction of adult body size at higher temperatures has been documented in a wide range of zooplankton species including cladocerans (Weetman and Atkinson, 2004). There are some evidences that small bodied cladocerans dominate in subtropical and tropical fresh waters (Sarma *et al*., 2005).

The dominance of small cladoceran species in warm waters can be accounted for by their competitive superiority over large bodied at higher temperatures (Moore *et al.,* 1996). Better survival of small cladocerans at elevated temperatures can be connected with different energy cost of physiological processes as compared with larger species. Temperature greatly affects the somatic growth rate of crustaceans,egg production, gamete maturation and the duration of juvenile development as well as seasonal timing of reproductive activity (Weetman and Atkinson, 2004). In general, the warmer the temperature of the water, the more rapidly the development occurs, with the optimum temperature observed as being 25°C, although cladocerans are unable to tolerate temperatures above 35°C (Dodson and Frey, 1991).

2.4.2.2. Dissolved oxygen

Oxygen is a key component to geochemical cycling and biological processes, and plays an important role in zooplankton distribution and behavior (Auel and Verheye, 2007; Ulloa and Pantoja, 2009). The effect of dissolved oxygen on the distribution and diversity of zooplankton is therefore an indirect effect that is reflected through their oxygen demand as a result of temperature or other environmental stress factors (Julies and Kaholongo, 2013). Available oxygen for respiration may be considered to be more deficient in small water bodies, such as ponds, compared to larger water bodies, such as lakes (Macan, 1973). This is a result of less wind and wave action in ponds compared to larger water bodies. This turbulence facilitates the diffusion of oxygen into the water, so still water has a slower rate of oxygen uptake. The lower oxygen levels may be helped in decreasing predation, and those species that can survive in hypoxic conditions may be utilizing it as a protection from predators that must avoid hypoxic waters for their own fitness (Larsson and Lampert, 2011).

At higher temperatures, water has lower concentrations of oxygen and bacterial activity, that utilizes oxygen, increases (Macan, 1973). These conditions are complicated by biological production of oxygen which can cause variations in oxygen concentrations, particularly in small water bodies. As such, cladocerans found in ponds may be adapted to live in poorly oxygenated water. Cladoceran species found in lakes, such as *Leptodora kindti* and *Bythotrephes longimanus,* are less tolerant of low oxygen levels than species found in ponds. These cladocerans species found in ponds, from most to least tolerant of low oxygen levels, include *Simocephalus vetulus, Daphnia obtusa, Daphnia magna, Daphnia pulex, Simocephalus exspinosus* and *Daphnia longispina* (Yarwood, 2005).

2.4.2.3. pH

The effect of pH on microcrustacean communities shows notable divisions between species occurring in acid and alkaline waters. Some cladocerans, including *Alona intermedia, Chydorus ovalis, Bosmina longispina* and *Rhynchotalona falcata* are able to tolerate and even demonstrate a preference for acidic water (Fryer, 1993)**.** cladocerans such as the *Daphnia obtusa,* which favours slightly acidic ponds (Fryer, 1985), but, the populations of *Daphnia longispina* declined in acidified lakes (Hamza *et al.*, 1995).Although there has been no single comprehensive study on the effects of pH on all cladoceran species, some studies suggested that, approximately two-thirds of cladocerans favour alkaline waters or are broadly tolerant of a range of conditions while just over one-third prefer acidic waters (Yarwood, 2005).

2.4.2.4. Water transparency

In an aquatic ecosystem water transparency is one of the most important features that control the energy relationship at different trophic levels (Ahmad, 2012). According to Ahmed (2003) the light in water is a factor of profound importance for its role in the photosynthetic processes of all chlorophyll bearing aquatic plants and thus for the primary production. It is often a limiting factor in the distribution of organisms in water particularly the plankton. Water transparency to be extremely low, largely responsible for the very low zooplankton densities because silt held in suspension in turbid water interferes with filter feeding mechanisms of crustaceans and this affects their reproduction success (Dejen *et al.*, 2004). According to Sharma *et al.* (2011) the high value of water transparency is the most valuable parameter that has affected the density of Cladoceran zooplanktion qualitatively and quantitatively. Therefore, this factor usually governs the seasonal growth and distribution of zooplankton communities in fresh water.

2.4.2.5. Salinity

Increasing salinity in freshwater system is a wide phenomenon of environmental concern which expected to become more pronounced in some coastal regions (William *et al*., 2001). Many zooplankton species shows low tolerance to increased conductivity or salinity (Nielsen *et al*., 2003). The ability of zooplankton to tolerate increase in salinity is determined by their ability to regulate in internal osmotic concentration in relation to external environment (Nielsen *et al*., 2003). As salinity increase zooplankton becomes increasingly stressed, resulting in reduced in growth and reproduction and become fatal (Nielsen *et al*., 2003; Claire, 2012).

2.4.2.6. Nutrient loading

Eutrophication of aquatic ecosystem continues to be major concern in freshwater and marine system (Smith and Schindler, 2009). The addition of nutrients to system increase algal biomass as fresh water algal typically phosphors limited. Eutrophication may have many detrimental side effects in aquatic system such as elevated pH, oxygen depletion, increase incidence of fish kill and reduction in diversity (Smith and Schindler, 2009). Nutrient loading also causes environmental degradation or related variables such as hydrogen and oxygen (Jeppensen *et al*., 2000). When nutrient loading is not high enough to cause environmental degradation most species are tolerant of nutrients increase, although species composition may shift (Sternetr, 1994). Dodson *et al., (*2000) and Declerrk *et al*. (2007) suggested that nutrient loading often leads to increase in *Daphnia* species large bodied species with high grazing rates on phytoplankton.

2.4.2.7. Electric conductivity

Electrical conductivity (EC) is a useful indicator of total dissolved solids (TDS) because the conduction of current in an electrolyte solution is primarily dependent on the concentration of ionic species (Hayashi, 2004). Electrical conductivity (EC) is widely used for monitoring the mixing of fresh water and saline water, separating stream hydrographs, and geophysical mapping of contaminated groundwater (Hayashi, 2004). Conductivity is a surrogate for salinity, which influences the osmotic environment of organisms. According to Green *et al*. (2005) water with very low and high conductivities tend to support few species of zooplankton than those exhibiting moderate conductivities. Reproductive and/or survival rates of cladocerans are generally reduced at higher conductivities (Galat and Robinson 1983).

2.4.3. Morphometry

2.4.3.1. Surface area of water body

The surface area of the water body is significant in determining Cladocera species composition. A water body with a larger surface area and greater depth often supports more species of micro-crustaceans (Rautio, 1998). But the relationship between micro-crustacean assemblages and the size of the water body they inhabit is a complex one, particularly when considering individual species. While the frequency of occurrence of some micro-crustacean species progressively increases from small to large water bodies, the reverse pattern is observed for others (Fryer, 1985).

2.4.3.2. Water body permanence (water residence time)

Organisms inhabiting water bodies that are not permanent throughout the year have to show physiological tolerance to the dry phase of the pond or a life history modification which enables them to survive in these habitats (Cerny and Herbert, 1993). Micro-crustaceans are able to sustain their populations in this challenging environment through their reproductive strategies (Fitter and Manuel, 1986) and their resilient eggs which can withstand desiccation. Because of this, micro-crustaceans are often amongst the most abundant animals in temporary ponds. In temporary ponds, the normal summer peaks of micro-crustacean assemblages (when these ponds are dry) are transposed to winter (Fresner and Sampl, 1995; Serrano and Toja, 1995). Fresner and Sampl (1995) found that, in permanent water bodies, the zooplankton had consistently high numbers of copepods but few cladocerans. According to Fresner and Sampl (1995) and Serrano and Toja (1995) permanent water bodies have higher species richness than temporary pond.

3. MATERIAL AND METHODS

3.1. Descriptions of the study site

The study was conducted from March 2013 to August 2013(except June) in a manmade ponds at Boye wetland; 4 km from Jimma town (Figure 1). Boye wetland is located at 07 ^{0} 40' N and 36^{0} 60' E, with an altitude of 1703 m above the sea level, Oromiya Regional State, in southwestern Ethiopia. Jimma town is the capital and administrative center of the zone, located 353 km away from the capital of Ethiopia, Addis Ababa. There were six ponds constructed in 2010 by Jimma University for sewage treatment and bio-gas production but now they are abandoned. The ponds have almost rectangular shape and a surface area of approximately 90m×50m. The distance between any two ponds (raised bed) is about 4 m wide. Some of the ponds having wetland plants such as *Nymphaea odorata* and emergent macrophytes such as Typha grasses (*Typha latifolia*).

Boye wetland is one of the potential habitats for diverse bird species. Tariku and Abebayehu (2011) have identified a total of 36 wetland bird species from Boye wetland. Among these, two species; *Poicephalus flavifrons* and *Macronyx flavicollis* are endemic to Ethiopia.The local residents of this area utilizes the ponds water for washing clothes, livestock , bathing, used as recreational activities(e.g. swimming), for making bricks and different types of pottery materials.

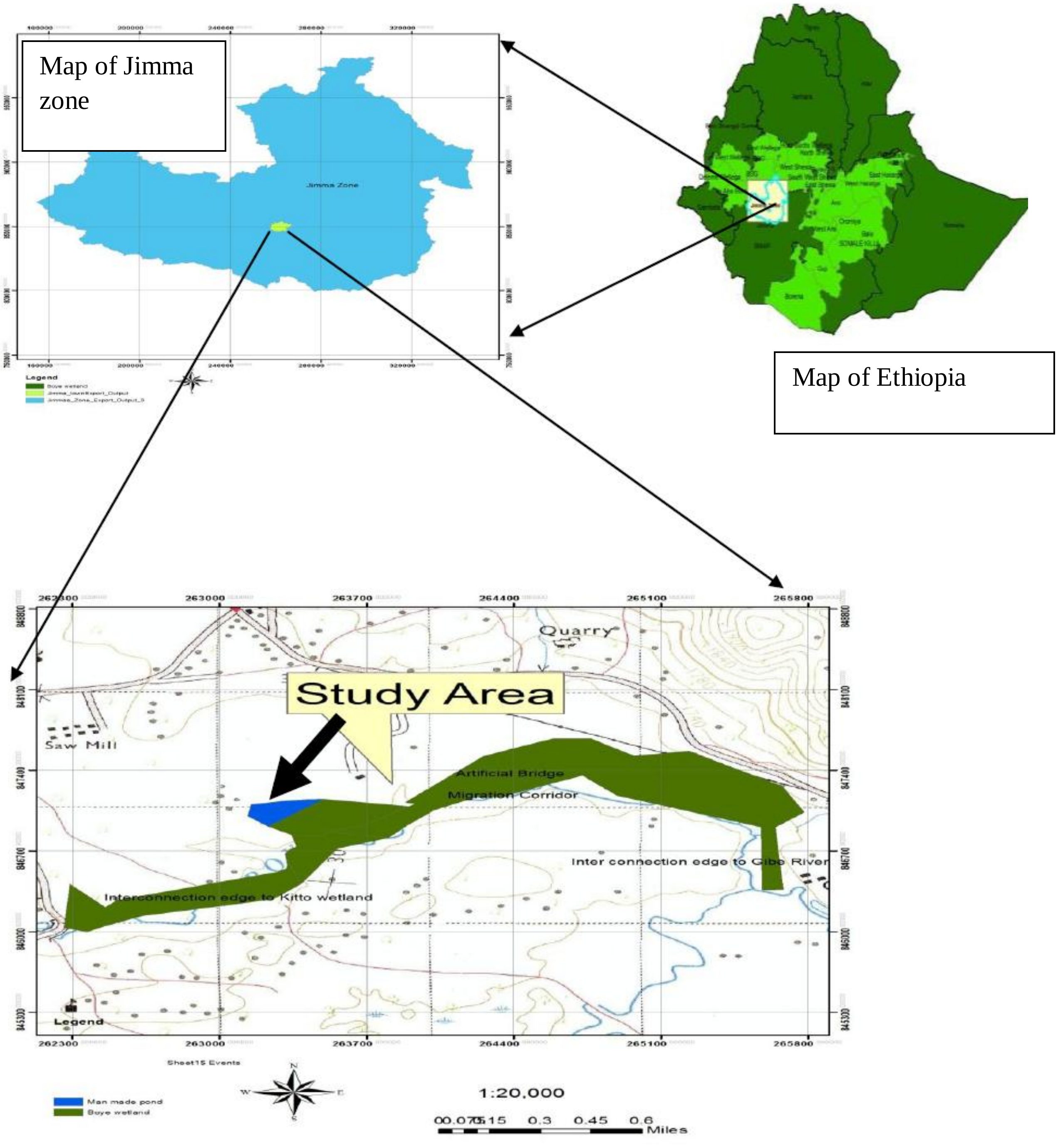


Figure 1. Map of the study site.

According to the national meteorological agency of Jimma branch (2012), the study area receives a rainfall between 1443 and 1588 mm per annum with an average annual rainfall of 1560 mm having the heaviest concentration from June to September and the average maximum and minimum temperature is 28.5 and 11.38^{0}C respectively with a mean daily temperature of 19.79^{0}C. However, significant variations in amount of precipitation have been registered in different months (Figure 2).

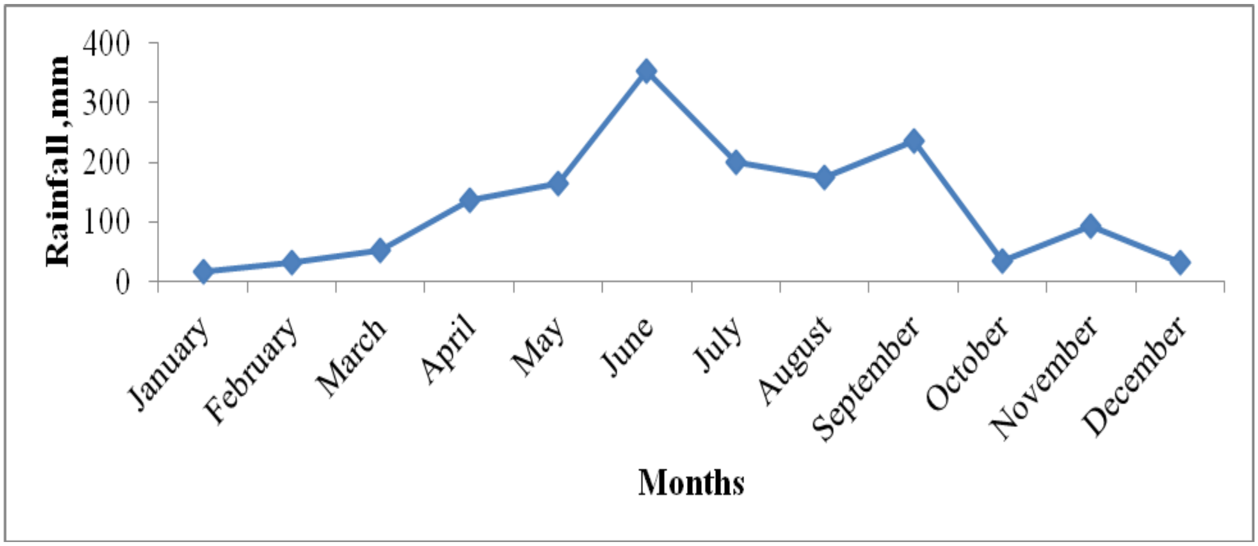


Figure 2. Monthly average rainfall in Jimma for the year 2010 to 2012

(Source: National meteorological agency, 2010, 2011, 2012)

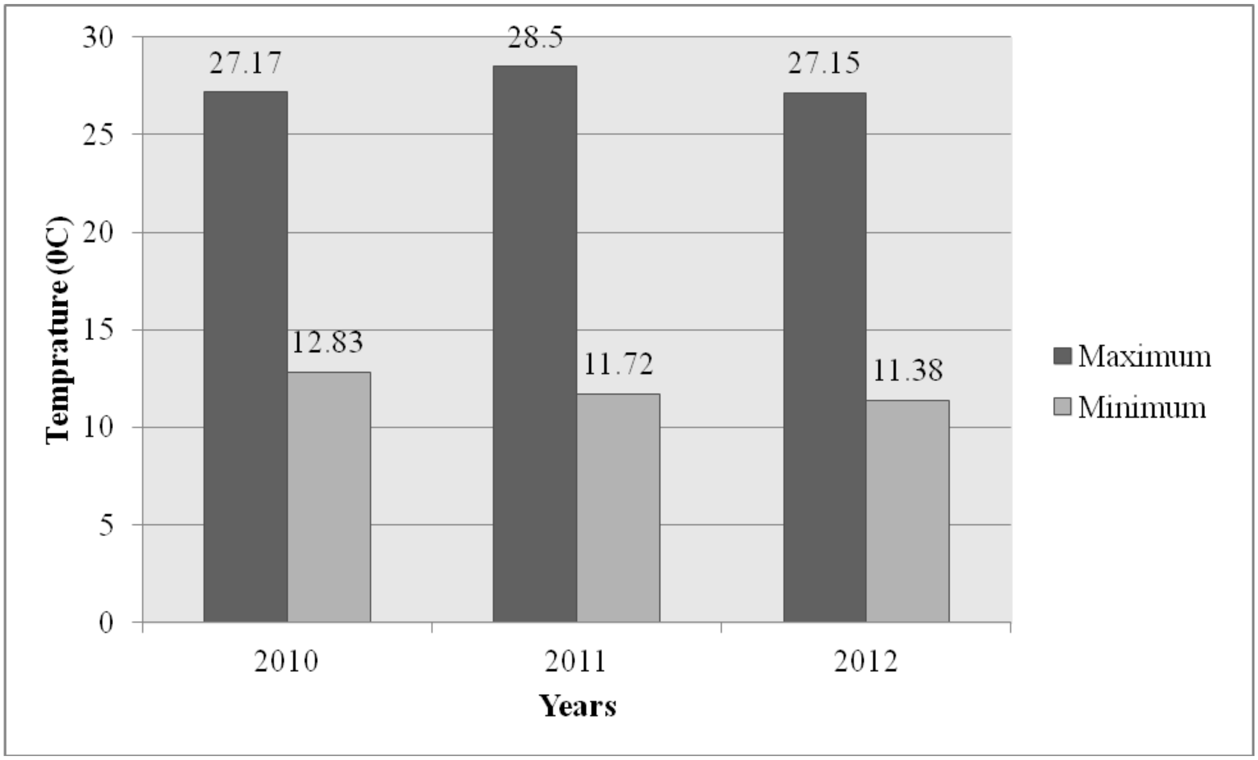


Figure 3. Annual average temperature (^{0}C) in Jimma for the year 2010 to 2012

Source: (National meteorological agency, 2010, 2011, 2012)

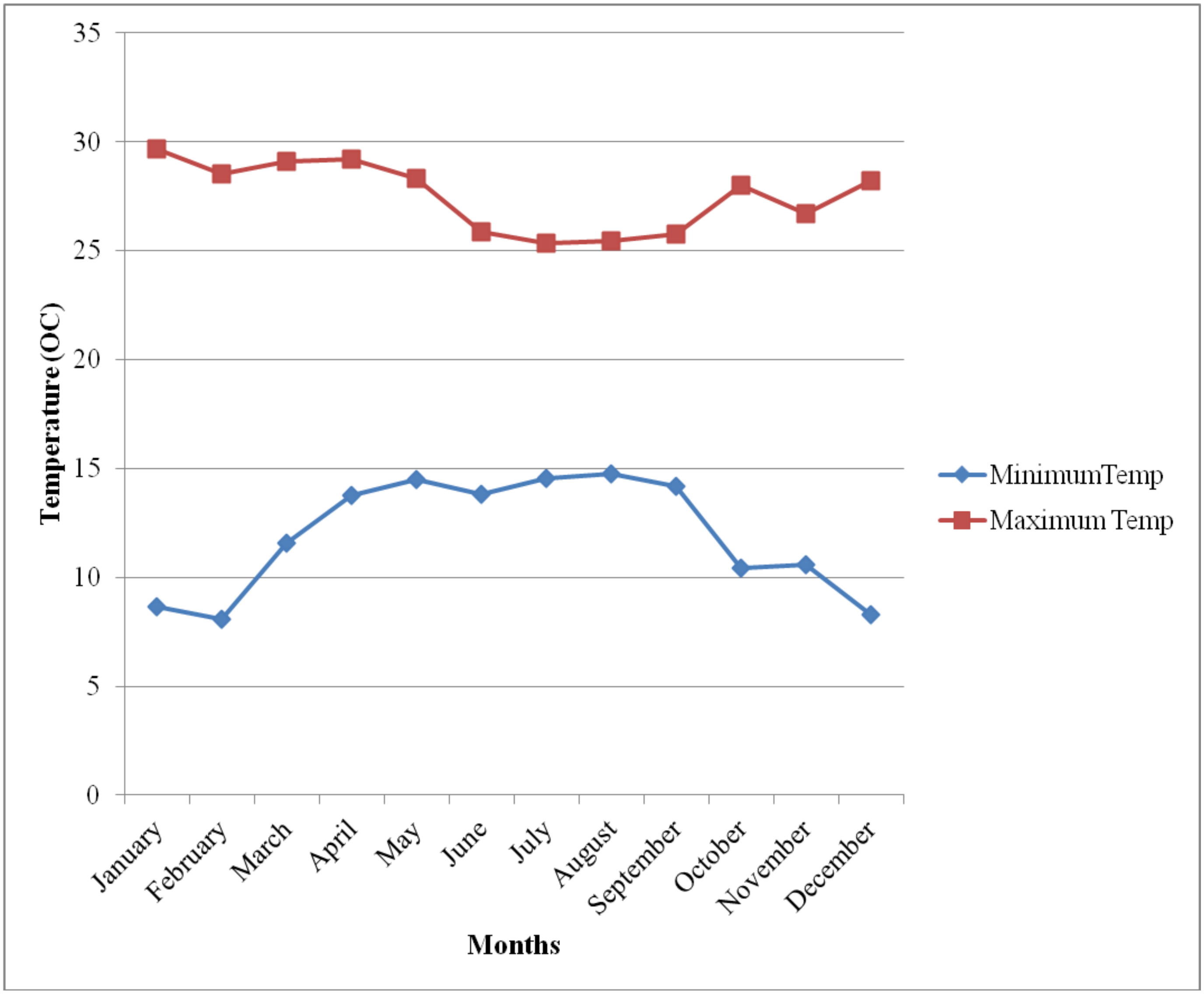


Figure 4. Monthly average temperature (^{0}C) in Jimma for the year 2010 to 2012

(Source: National meteorological agency, 2010, 2011, 2012)

3.2. Sampling protocol

Three ponds were selected based on easy access, presence of macrophytes and anthropogenic activities. The first pond has good macrophytic growth (*Typha latifolia*) and other short grasses and medium anthropogenic effect. The second pond has sparse growth of macrophytes (emergent short grasses) and high anthropogenic activity. The third has profuse growth of macrophytes

(*Typha latifolia* and *Nymphaea odorata*) and other aquatic grasses and least anthropogenic effect as per the standard procedure (Sharma *et al.,* 2011). Fortnightly samples were collected from these ponds. In the month of June, due to some technical reasons periodic zooplankton collection was not performed. A Plankton net (scoop net) with mesh size of 70µm was employed for collection. The horizontal and vertical haul was made to get homogeneous representation of plankton. The sampling time was fixed between 7- 9 am to minimize the vertical migration of zooplankton and fluctuation of dissolved gases mainly O_2 (Onyema and Ojo, 2008).

3.2.1. Sampling from the ponds

Samples were taken by throwing the plankton net to the open waters of the central area with defined length (5meter) and dragged the net slowly. The total volume of filtered water was calculated by using the equation $V= \pi r^2h$, here "r" is the radius of the mouth of the net (12.5 cm) and "h" is the total dragged distance. According to this formula, a total of 245.31 liters of water was filtered by each drag. All samples were taken in triplicate to minimize the sampling error. To avoid dispersal of zooplankton organisms among water bodies, the plankton net was carefully washed and rinsed. The samples also were taken by filtering subsurface pond water through plankton net with 70 µm mesh size; mouth diameter 25 cm for qualitative analysis. After the proper filtration of these samples, the samples were fixed with 5% formalin solution as proposed by Haney and Hall (1973) to avoid damaging animal tissues by bacterial actions and autolysis. The sampling bottle was then labeled with information of sampling pond and date. Finally the samples were transported to Jimma University, Biology department Postgraduate laboratory for further analysis.

3.3. Determination of physical and chemical parameters of water

The physico-chemical factors of the water were assessed. The parameters that were examined included; air and water temperature (^{0}C), pH, Dissolved oxygen (DO) (mg/L), electric conductivity (µS/cm) and transparency (cm). Dissolved oxygen, electric conductivity, pH and water temperature were measured in the field using a multi-probe meter (HQ40d Single-Input Multi-Parameter Digital Meter). Air temperature was measured by mercury thermometer. The apparatus used for transparency measurement was Secchi disc having a diameter of 20 cm.

3.4. Analysis and treatment of the samples

Zooplankton samples brought from the field were allowed to settle at least overnight. Before talking a subsample, each sample was first homogenized by inverting the containers few times to achieve a random distribution of organisms and placed in a beaker and subsamples of 4ml (total volume 125 ml) were taken using a 4 mm mouthed pipette and placed on to a counting chamber which is 50mm long, 20mm wide and 1mm deep and examined under a dissecting microscope where identification and counting were done. The process was repeated three times for each sample and the average was taken. All individuals present in the subsample were identified and counted. For the taxonomical analysis, the specimens were dissected under the low power dissection microscope by using two entomological needles and the taxonomical important parts were mounted on glass slides with glycerin for very close and detailed examinations. Then cladocerans were identified using standard identification monographs and literature keys with stereo and compound microscopes, utilizing taxonomic keys provided by Edmondson(1992), Fernando(2002); Elmoor-Loureiro(2007); Sharma and Sharma (2008) and Van Dame *et al.*, (2010). Figures of the available cladocerans were taken with hand held digital camera and measurements were taken with calibrated ocular micrometer.

3.4.1. Determination of zooplankton abundance

The supernatant plankton's free water was removed and the settled zooplanktons were enumerated by plankton counting chamber. The counting was done by using stereo-microscope. The number of individuals was counted and abundance was expressed as number of individuals per litter based on volume sampled. The volume of water filtered during the sampling time was calculated by the following formula.

$V = \pi r^2 h$

Here, V is the volume of the water filtered, "r" is the radius of the net, and h is the length of the course of the net through the water. The number of each species of Cladocera or genus was calculated by the classical formula (Welch, 1952) and then total Cladocera species were accounted on monthly basis:

$$\frac{Organism}{L} = \frac{Organism / ml}{Concentration \quad factor(C.F)}$$

$$C.F = \frac{Volume\,of \quad water \quad filtered}{Volume\,of \quad concentrate}$$

Then density of cladocerans was expressed as number individuals per litter.

3.5. Biological Indices

Diversity (the number of species in the area), and evenness (equitability, a measure of how evenly individuals are distributed among the species) calculations were carried out on the identified cladocerans to describe the abundance of species and individuals within the three ponds. To describe species diversity in natural communities, ecologists have made widespread use of ecological indices.

1. Shannon Weiner diversity index (H') was calculated according to the expression of Shannon-Weiener, (1949):

$$H' = -\sum_{i=1}^{s}\left(\frac{ni}{N}\right)\times\ln\left(\frac{ni}{N}\right)$$

where: Where H' = index of species diversity, *ni* is the number of individuals in a species in the sample *S* is the total number of species, also called species richness, *N* is the total number of individuals in the sample

2. Evenness index (J') was calculated following the equation of Pielou (1966):

$$J' = \frac{H'}{\ln S}$$

where: H = Shannon Weiner diversity index and S = Number of species

3. Richness index (D) was calculated by the equation of Margalef (1968):

$$D = \frac{S-1}{\ln N}$$

Where: D = Richness index,S = Total number of species and N = Total number of individuals

4. Relative abundance index (Ra) was calculated according the formula in Omori and Ikeda (1984):

$$Ra = \frac{N\chi 100}{Ns}$$

Where: N = Number of species in the sample, Ns = Total number of individuals in the sample

3.6. Statistical Analyses

Descriptive statistics like standard deviation and coefficient of variation were used to describe the variance around means of physic-chemical parametrs. One-way ANOVA was applied to check the variation in physic-chemical parameters among the ponds and sampling dates. To check the presence of variation in Cladocera density between months and ponds students T-test was applied. To assess which physico- chemical variables were the most important determinants of cladoceran community structure, Pearson Correlation Coefficients (r) for non-zero estimates of Cladocera abundance with selected variables were checked. All these statistical analyses were performed by using SPSS version 16 computer software in order to setup mean, standard deviation and range. All the graphs were drawn by using Microsoft offices excel 2007 computer soft ware.

4. RESULT

4.1. Physico-chemical characteristics of the ponds

4.1.1. Temperature

The atmospheric temperature depicted a definite temporal trend during the entire period of study and changed with the change in the months. The maximum value of air temperature (29.8^{0}C) was recorded in the month of April against minimum of 21.1 ^{0}C in the month of July (Table 1). During this study, fluctuation in water temperature showed no variation among the three ponds. Water temperature was positively related to the air temperature(r = 0. 679, p<0.05), transparency (r = 0.515, p = 0.004) and conductivity(r = 0.33, p =0.068) but negatively related to pH (r = -0.014, p = 0.943) and DO (r = -0.094, p = 0.623). Spatial (between the ponds) there was no significant difference (F=0.153, P = 0.86) but temporal variations (months) significance difference in water temperature was observed (F=14.56, P < 0.05). Generally an average water temperature in the ponds was 23.28±1.87 ^{0}C, 23.05±2.23 ^{0}C and 22.79±1.82 ^{0}C in pond I, II and III respectively (Table 1.).The maximum and minimum water temperature was recorded in 28th April and 14th July respectively (Figure 5.).

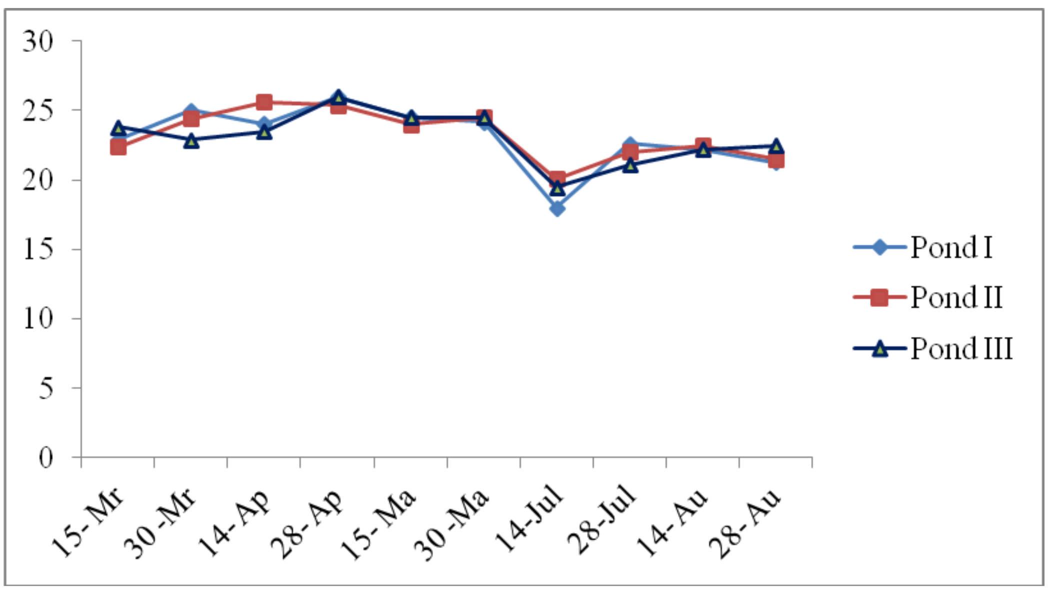


Figure 5.Spatial and temporal variation of water temprature in the ponds

4.1.2. Conductivity

Conductivity was little higher in ponds number I and II (Between 300-400 μScm^{-1}) during the period from March-May and there was a sudden fall in July while in pond number III showing almost uniform conductivity between 100-150 μScm^{-1} (Figure 6). In the present investigation, there was a significant ($F = 81.611$, $P<0.05$) difference in conductivity between ponds but there was no significant difference between months ($F = 0.73$, $P = 0.582$). The maximum (378 μScm^{-1}) and minimum (104.5μScm^{-1}) value of EC was observed in pond I and III respectively. The variation observed in EC in the sense that pond III had almost one third of the readings EC of pond I. The highest and lowest value of EC was recorded during 15th March and 14th July respectively (Figure 6).

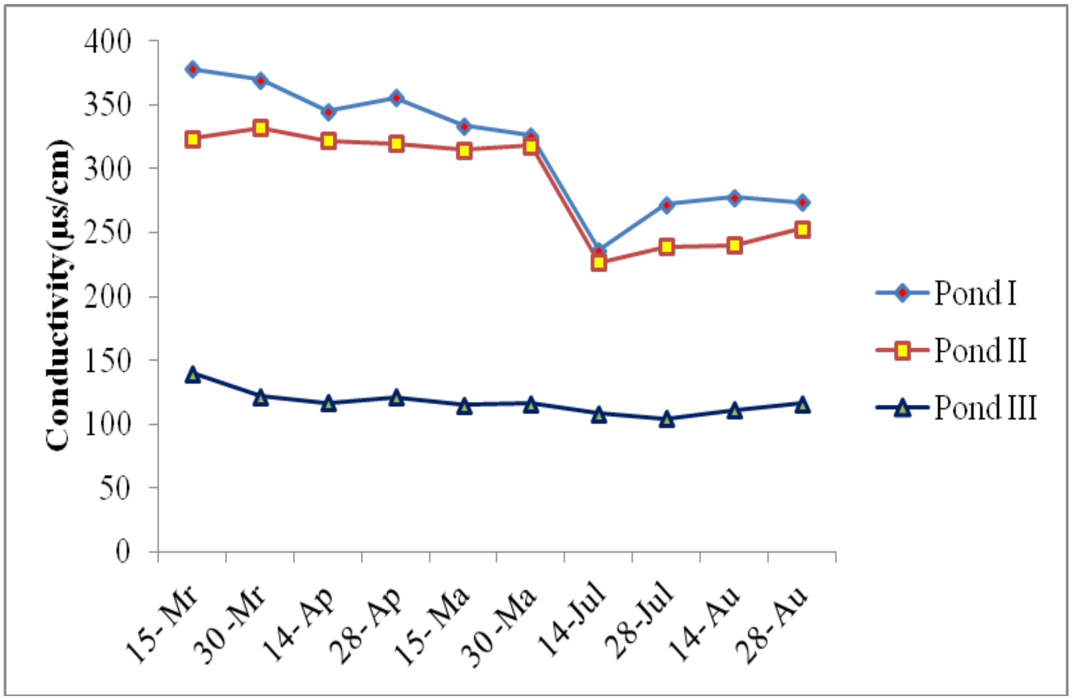


Figure 6. Spatial and temporal variation of conductivity in three ponds

4.1.3. Transparency

The transparency (Secchi depth) of the water in the three ponds fluctuated both spatially and temporally. The ponds were nearly turbid throughout the study period with a single peak during the rainy months. Significant variation in water transparency was not observed between the ponds (F = 1.612, P = 0.218) but between months there was highly significant (F = 16.12, P<0.05) difference in water transparency. Monthly variation in water transparency was registered with maximum value of 43 cm in 28th April at pond II and minimum of 12 cm in 28th July at pond I respectively (Figure 7.).

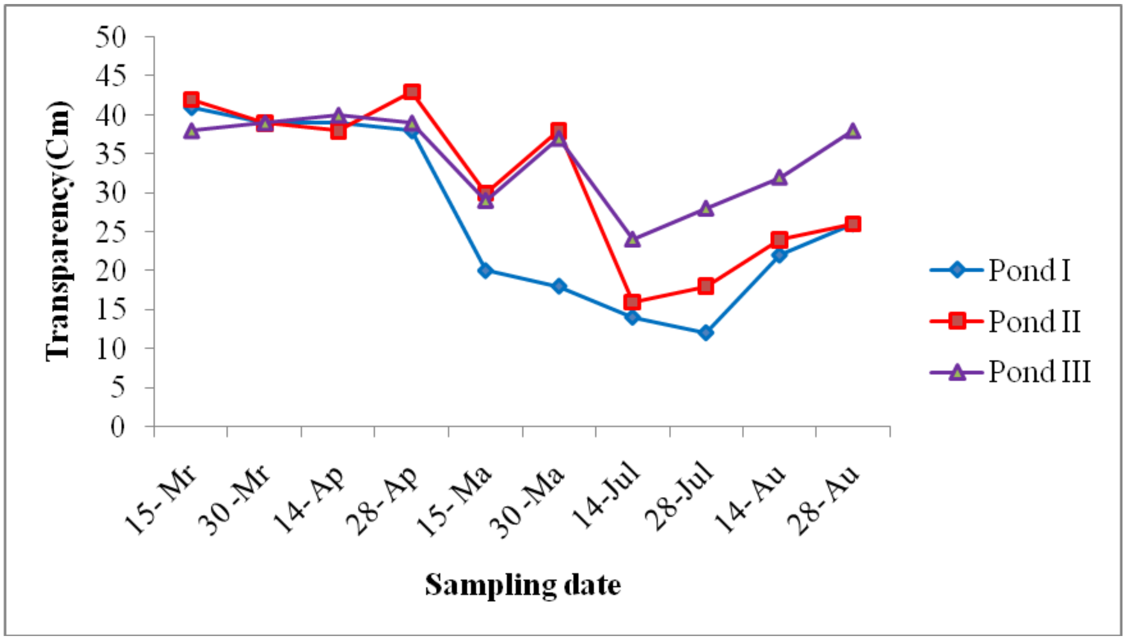


Figure 7. Spatial and temporal variation of water transparency in the ponds

4.1.4. pH

In the present study, the pH of the ponds varied from 6.52 to 8.45 at pond I, 6.58 to 8.35 at pond II and 7.33 to 8.6 at ponds III in the months of March and August respectively (Figure 8 and Table 1).Statistically analysis for pH showed that there was no significant difference between the ponds and months in terms of pH (F = 0.732, P = 0.490, F = 2.425, P = 0.075).

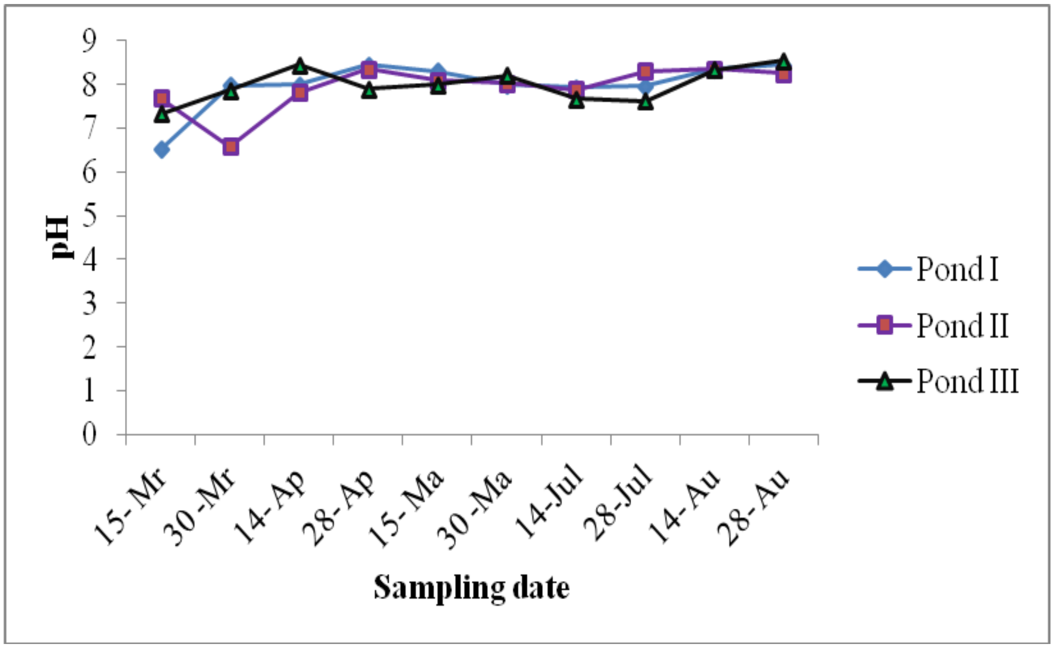


Figure 8.Spatial and temporal variation in pH in three ponds

4.1.5. Dissolved oxygen

The monthly dissolved oxygen concentrations revealed variations from a minimum of 4.33 mg/L in pond II in March, followed by the maximum values were attained in August (7.79 mg/L) in pond I (Figure 9). The average dissolved oxygen in the ponds were not statistically significantly different ($F = 0.532$, $P = 0.593$) and ($F = 2.587$, $P = 0.61$) both spatial and temporal respectively. The dissolved oxygen in the ponds ranged from an average of 5.46±0.79 in pond III, 5.49±1.02 mg /L in pond I to 5.84±0.93 mg/L in pond II (Table 1).

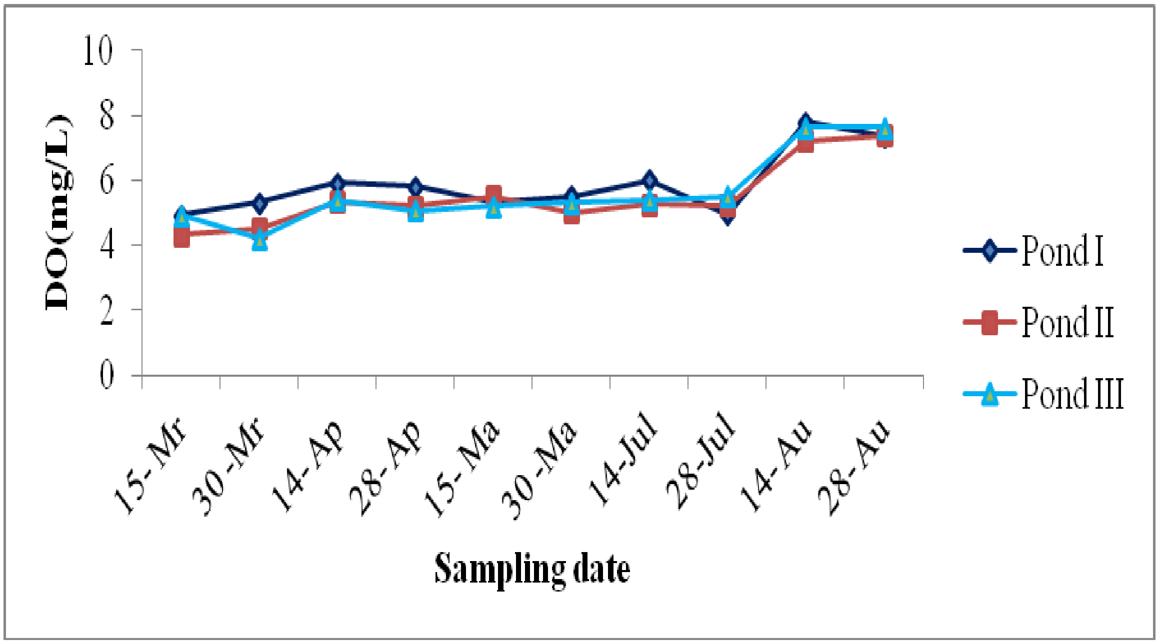


Figure 9. Spatial and temporal variation in dissolved oxygen in the three ponds

Table 1 .Summary of physico-chemical parameters in the manmade ponds. Values are mean± SD. The minimum and maximum values are indicated in parentheses

Parameter	Pond I	Pond II	Pond III	Significance
Air temperature (^{0}C)	25.81±3.16(21.1-29.8)	25.83±2.81(22-29.8)	26.25±2.77(21.5-29.8)	P>0.05
Water temp(^{0}C)	23.05±2.23(18-25.6)	23.28±1.8(20-26)	22.79±18(19.5-26)	P>0.05
Transparency (cm)	26.9±11.33(12-41)	31.40±9.96(16-43)	34.40±5.68(24-40)	P>0.05
Conductivity (µScm$^{-1)}$	316.9±4.49(236-378)	289±43.05(227-332)	117.09±9.67(104.6-140)	P<0.05
pH	8.12±0.29(6.5- 8.45)	8.05±0.44(6.58 - 8.35)	7.91±0.44(7.33-8.60)	P>0.05
D.O (mgl^{-1})	5.49±1.02(4.33-7.37)	5.84±0.93(4.92-7.79)	5.46±0.79(4.80-7.62)	P>0.05

4.2. Species composition of Cladocera

During the present investigation a total of 7 species of Cladocera belonging to 7 Genera and 5 Families were recorded from the three ponds. Among these two belonged into family Daphnidae one Monidae, Sididae, Macrothrixidae and Two Chydoridae. Apart from these Cladocerans there were some co-occurring species like 6 rotifers and 3 copepods and 1 ostracoda species were recorded (Table 2.) The recorded species of Cladocrans include: *Moina micrura*, *Diaphanosoma excisum*, *Alona rectangula*. *Ceriodaphnia cornuta*, *Daphnia lumholtzi*, *Chydrous sphericus* and *Macrothrix laticornis* from the ponds. In this study *Moina micrura* and *Diaphanosoma excisum* were the dominant Cladocera species, recorded in all the ponds with percentage contribution of 39.60 % and 39.92 %, in pond I 37.89 % and 37.76% in pond II and 25.57 % and 40.78 % in pond III.

Table 2. List of Cladocera species and other co-occurring zooplankton from ponds.

Cladocera	**Copopeda**	**Rotifera**	**Ostracoda**
Alona rectangula	*Eudiaptomus gracilis*	*Brachionus falcatus*	*Hemicypris fossulata*
Ceriodaphnia cornuta	*Mesocyclops aequatorialis*	*Brachionus forficula*	
Chydrous sphericus	*Thermocyclops hyalinus*	*Brachionus quadridentatus*	
Diaphanosoma excisum		*Keratella tropica*	
Daphnia lumholtzi		*Filinia* sp.	
Macrothrix laticornis		*Asplanchna* sp.	
Moina micurura			

Family Daphnidae and Chydoridae were numerically the dominant families represented with 2 species each, while Moinidae, Macrothricidae and Sididae represented with 1 species each and thus contributing 29%, 29%, 14%, 14% and 14% respectively to the Cladoceran fauna of these water bodies (Figure. 10).

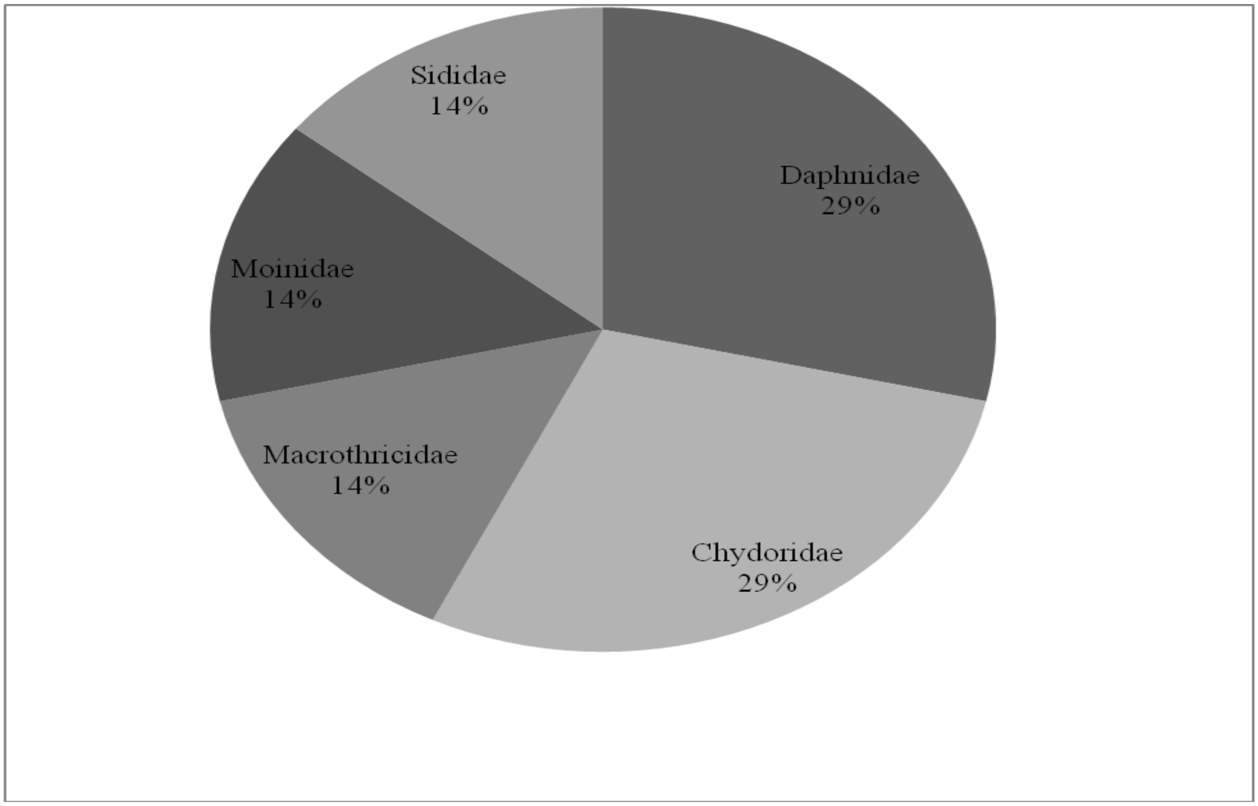


Figure 10. Percentage composition of different families of Cladocera from three ponds

4.3. Taxonomical description of recorded Cladocera

1. *Diaphanosoma excisum* Sars, 1885

Female (Plate1 fig: c)

Size: Mean length: 0.79, SD = 0.052, Mean Width: 0.27,SD = 0.053 (n = 5)

Carapace almost oblong in outline, posterior end abruptly truncate. Posterodorsal corner of the valves almost ending in a right angle. Posteroventral corner with variable number of dentecles followed by delicate cilia. Number of denticles sometimes differing even on the two valves. Duplicature joining ventral shell margin at nearly right angle. Head large oblong quadrate and truncate. Postabdomen narrow with fine setules. Claw with 3 basal spines decreasing in size proximately.

Male: Not observed

Distribution: India, Africa, Europe

2. *Macrothrix laticornis* Jurine, 1820

Female: (Plate1, fig: d)

Size: Mean length: 0.39, SD± 0.048, Mean width: 0.23, SD± 0.024 (n = 5)

Body almost oval in outline with maximum width slightly before the middle. Dorsal margin almost evenly arched, ventral margin arched ateriorly and ascending posteriorly. Shell markings reticulate and cause minute serrations on dorsal margin of the head and body. Ventral margin of the shell with a few long setae and serration between setae became inconspicuous. Head sub-triangular and almost evenly arched. Antennules broadened distally with a row of bristles at distal end and anterior margin with 6 notches. Ocellus small and situated nearer to the base of the antennules than eye. Post abdomen small with sharp teeth like bristles. Claw with setae on concave margin.

Male: Not observed

Distribution: Africa, India and Madagascar

3. *Ceriodaphnia cornuta* Sars, 1862

Female: (Plate1, fig: b)

Size: Mean length: 0.34, SD ± 0.033, Mean width: 0.21, SD ± 0.020 (n = 5)

Carapace of the female rather tumid, broadly oval in outline, produced posteriorly in to a short projection, lying slightly above the longitudinal axis. Valves distinctly reticulate with large polygonal or hexagonal ornamentations. Free edge of the valve smooth. Head small, depressed and separated from body by a distinct ocular depression with rounded frontal part and produced in front of antennules into a very acute short and deflexed rostrum. Head also with a short spine or horn over eye on anterior margin. Eye large, ocellus small and punctiform not extending to the tip of the rostrum. Post abdomen moderately broad with 5-6 anal spines. Claw short, stout and finally setulated.

Male: Not observed

Distribution: India, Africa, Thailand and Sri Lanka

4. *Daphnia lumholtzi* Sars, 1885

Female: (Plate1, fig: g)

Size: Mean length: 0.66, SD ± 0.016, Mean width: 0.29, SD±0.030 (n = 5)

Carapace broadly oval in outline narrowed posteriorly and continued into a considerably long posterior spine. Dorsal surface of valves moderately arched and armed with elongated and distinct spinules which continue to posterior spines, spinules extending till behind the middle region of ventral surface of the valve. Head with distinct dorsal depression above the heart, produced anteriorly in the form of a helmet of variable length rostrum somewhat variable in shape. Antennules well developed situated close to the rostrum. Eye large, ocellus small. Fornics extremely well developed, produced into a spine. First abdominal process nearly twice in length of second. Postabdomen tapering distally, its dorsal surface weakly spinulated with 10-13 anal spines and groups of lateral setae. Claws short, curved with 3 setae having 10-12 spinules.

Male: Not observed

Distribution: Europe, Africa, India, Canada, Sri Lanka.

5. *Moina micrura* Kurz,1874

Female: (Plate1, fig: a)

Size: Mean length: 0.61, SD ± 0.048, Mean width: 0.39, SD± 0.047 (n = 5)

Carapace almost rounded in shape. Head globular with an ocular depression. Ocellus is absent. Antennules cigar shaped with sensory setae on its middle. Valve plan without any reticulation and its margin have 64-80 small spinules on its margin. Post abdomen tapering in shape with 10-12 anal denticles. Calw large and curved and no spinules on its concave margin.

Male: Not observed

Distribution: Cosmopolitan

6. *Alona rectangula* Sars, 1862

Female: (Plate1, fig:e)

Size: Mean length: 0.403, SD ± 0.023, Mean width: 0.251, SD ± 0.013(n = 5)

Animal slightly brownish in colour. Psterodorsal and posteroventral corners of the valve rounded; valves with longitudinal lines with tubercles. Head shield with rounded posterior margin. Three main connected head pores. Spines present on the proximal segments of the antenna. Plate of the labrum with convex ventral margin. Ocellus almost as large as eye. Postabdomen wide with rounded distal margin; 7-9 anal spines. Anal margin slightly concave and with lateral row of setae. Claw with row of setae in proximal 3/4th of the concave margin.

Male: Not observed

Distribution: India, Africa, Russia.

7. *Chydorus sphericus* O.F Muller, 1776

Female: (Plate1, fig: f)

Size: Mean length: 0.278, SD ± 0.030, Mean width: 0.216, SD ± 0.023(n = 5)

Body almost spherical in outline, length slightly more than widith. Posterodorsal corner of the valves distinct. Posteroventral corner rounded without denticles. Valves usually reticulated with pentagonal or hexagonal cells. Rostrum pointed and emarginated. Posterior margin of the head shield rounded, head pores two in number. Antennules with sensory setae near middle of the anterior margin. Plate of the labrum with smooth convex anterior margin and with produced pointed apex. Ocellus nearer to the eye than apex of the rostrum. Postabdomen short with 7-8 anal deticles. Pre- anal corner projecting. Lateral setae in several groups and arranged in single row. Claw with two basal spines and setae on the concave margin.

Male: Not observed

Distribution: Cosmopolitan

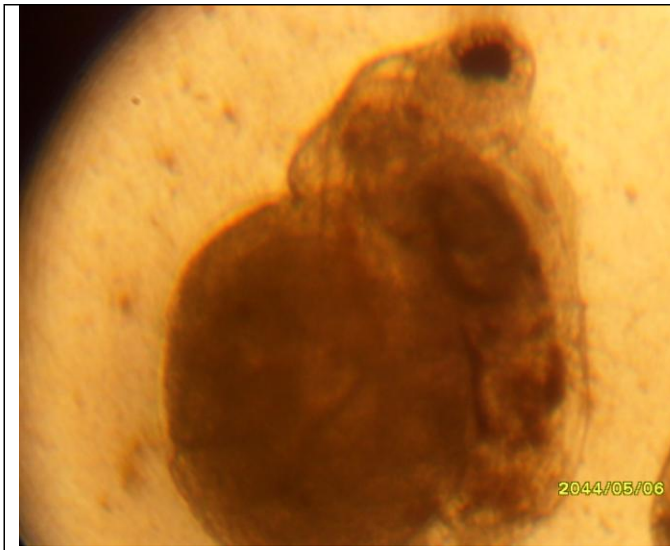


Fig .a : *Moina micurura* Kurz

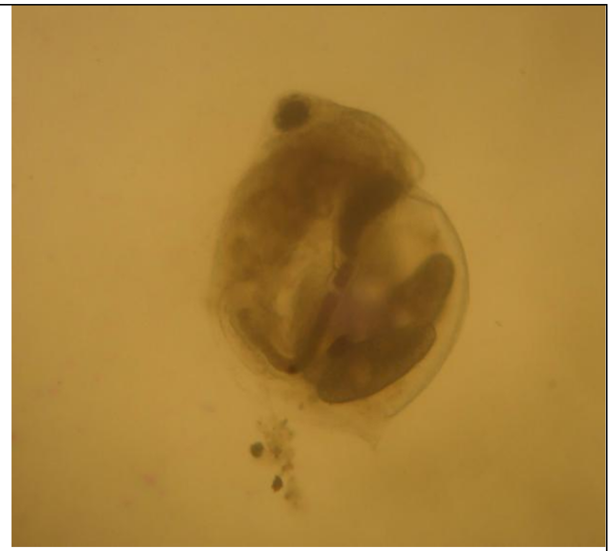


Fig. b : *Ceriodaphnia cornuta* Sars

Fig .c : *Diaphanosoma excisum* Sars

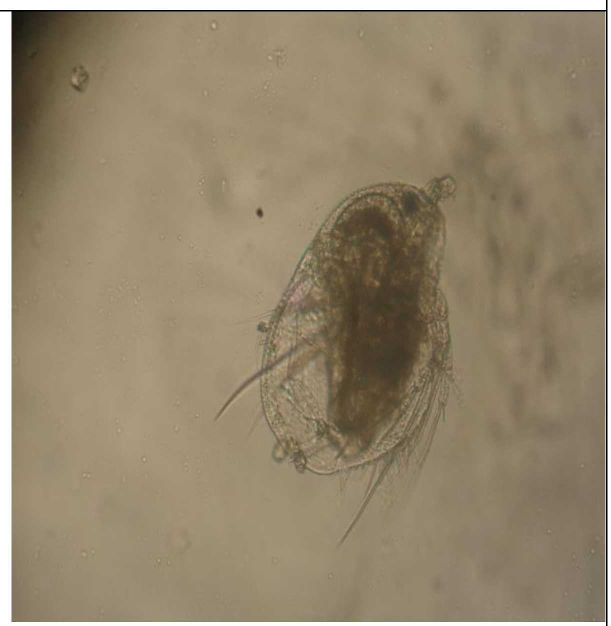


Fig .d: *Macrothrix laticornis* Jurine

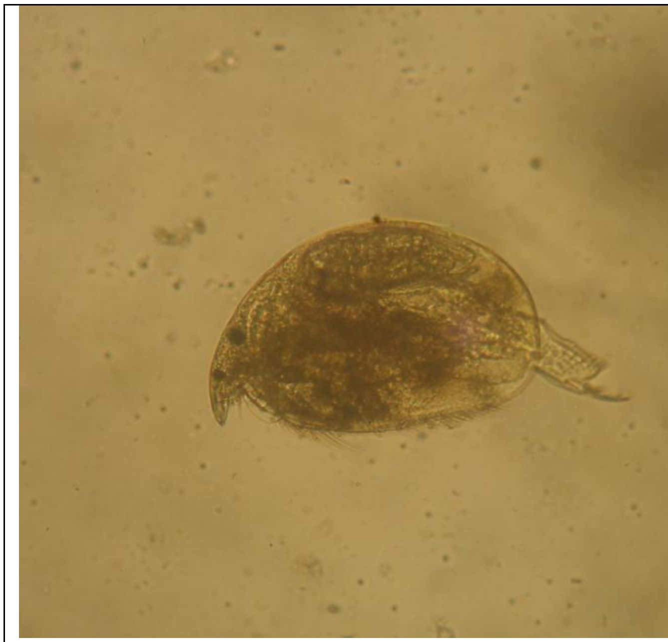


Fig. e: *Alona rectangula* Sars

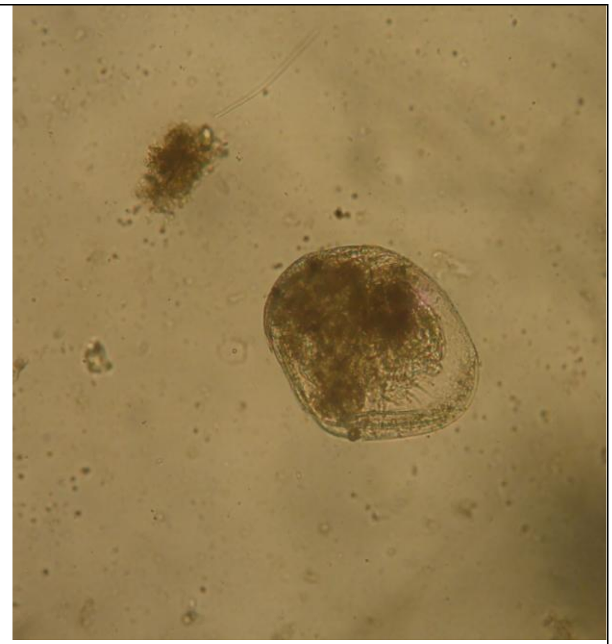


Fig. f : *Chydrous sphericus* O.F.Muller

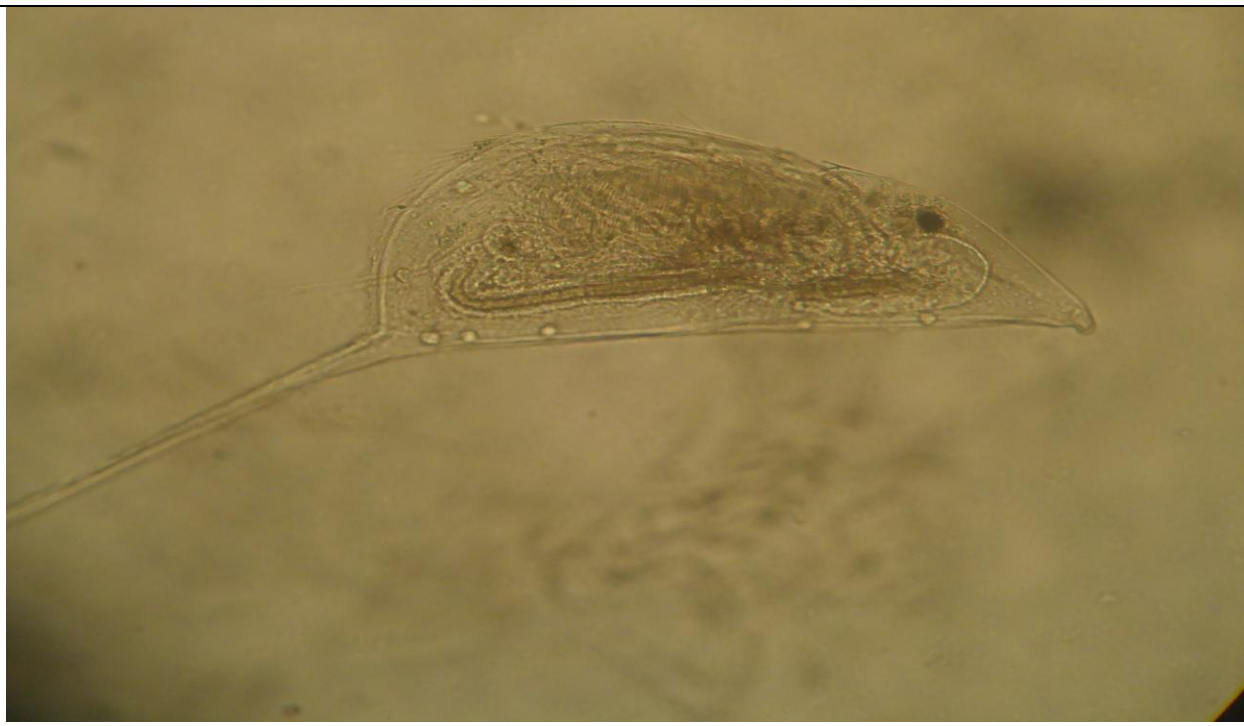


Fig. g : *Daphnia lumholtzi* Sars

Plate 1: Figures of Cladocera species recorded from the manmade ponds in Boye wet land

4.4. Spatial variation in Cladocera species and its abundance.

Seven species of Cladocera were identified from the ponds during the study period. Spatially there was a significant (T-test, $p = 0.02$) difference in species composition between the ponds. The highest number of Cladocera species was 7 registered at pond III, followed by 6 and 5 respectively from pond I and II respectively. Among these, *Moina micrura*, *Diaphanosoma excisum*, *Alona rectangula*, *Ceriodaphnia cornuta*, and *Macrothrix laticornis* were recorded from the three ponds and contributed for more than 91% of the total cladoceran density in all ponds. The Cladoceran, species which showed restricted occurrence were *Chydrous sphericus* at pond I and III while, *Daphnia lumholtzi* was the least abundant and restricted only to pond III (Table 3.).

Table 3. Distribution pattern of Cladocera species in the three ponds

Cladocera	Sites		
	Pond I	Pond II	Pond III
Sub-order Anomopoda			
Family Chydoridae			
Alona rectangula	+	+	+
Chydrous sphericus	+	-	+
Family Daphniidae			
Ceriodaphnia cornuta	+	+	+
Daphnia lumholtzi	-	-	+
Family Macrothricidae			
Macrothrix laticornis	+	+	+
Family Moinidae			
Moina micurura	+	+	+
Sub-order Ctenopoda			
Family Sididae			
Diaphanosoma excisum	+	+	+
Total	**6**	**5**	**7**

Where **+** denote the species present and **-** denote the species absent

In the present investigations, the total Cladocera abundance, was significant (T-test, p = 0.005) difference between the ponds. From the three ponds a total of 1200 Cladocera populations or organisms/L of water was counted. Out of this, 382 org/L from pond I, 359 org/L and 459 org/L were counted from pond II and III respectively. In general, highest densities of cladocerans were recorded in the pond III and lowest densities in the pond II (Figure. 11)

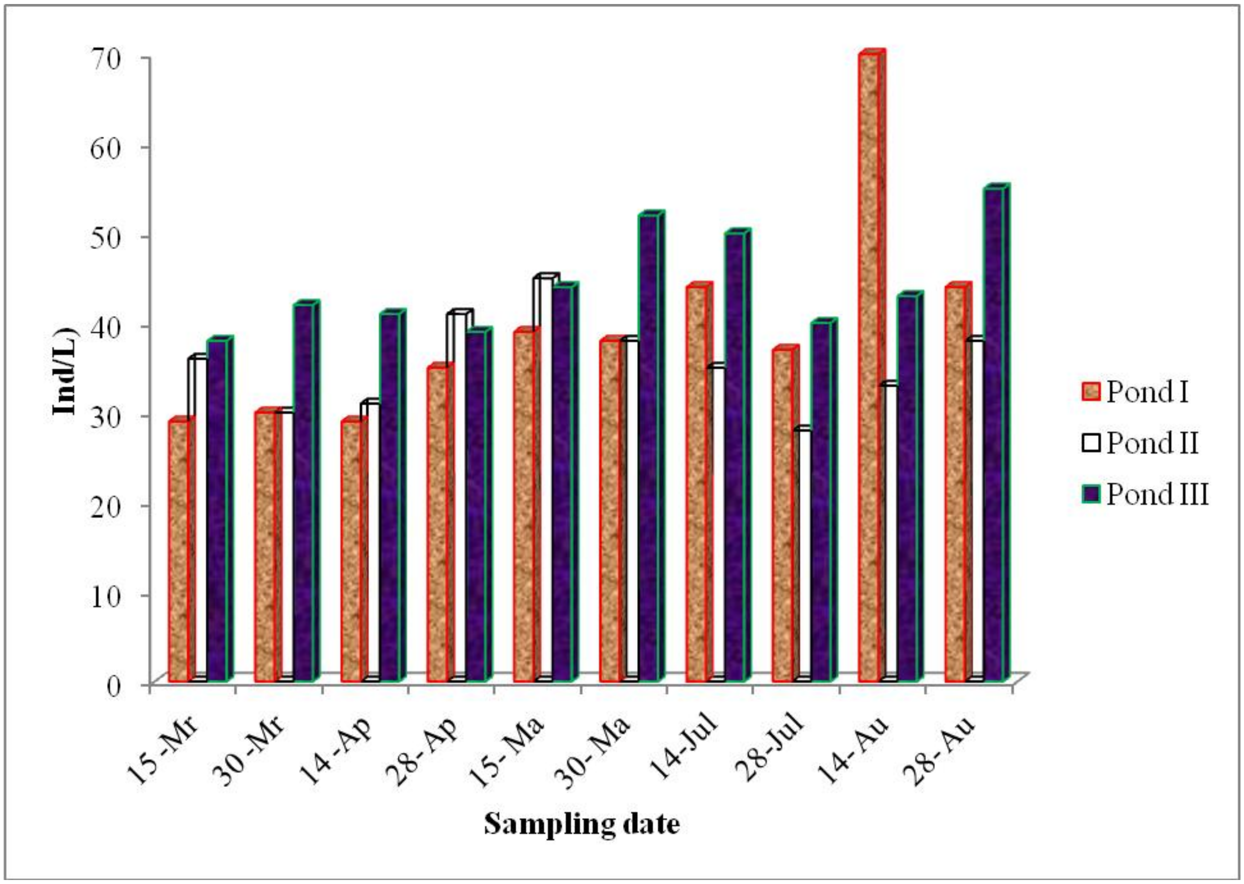
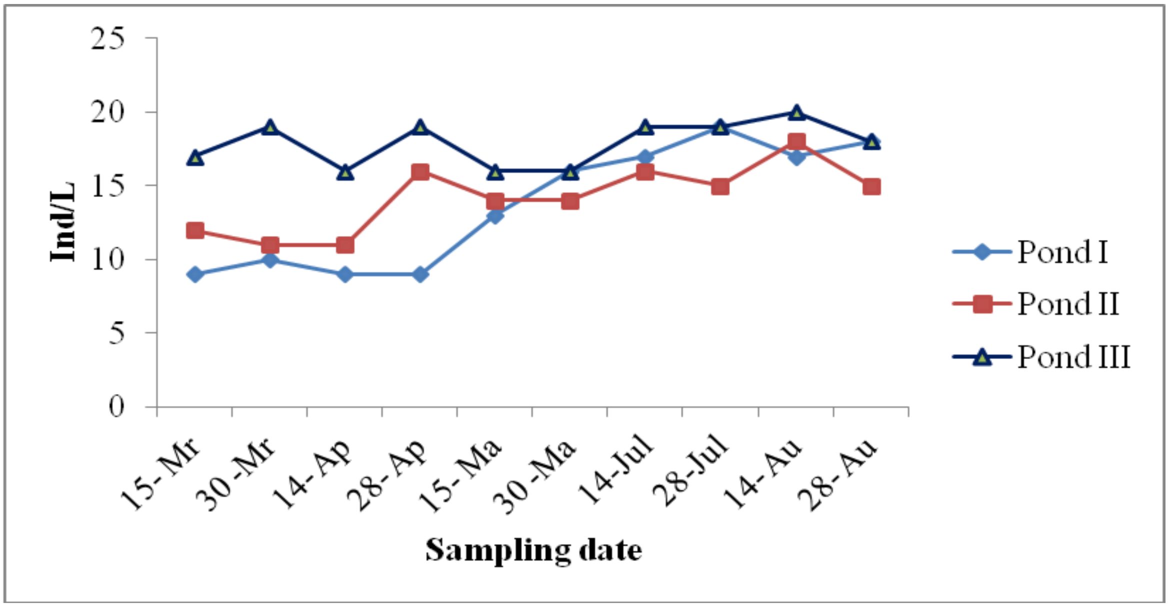
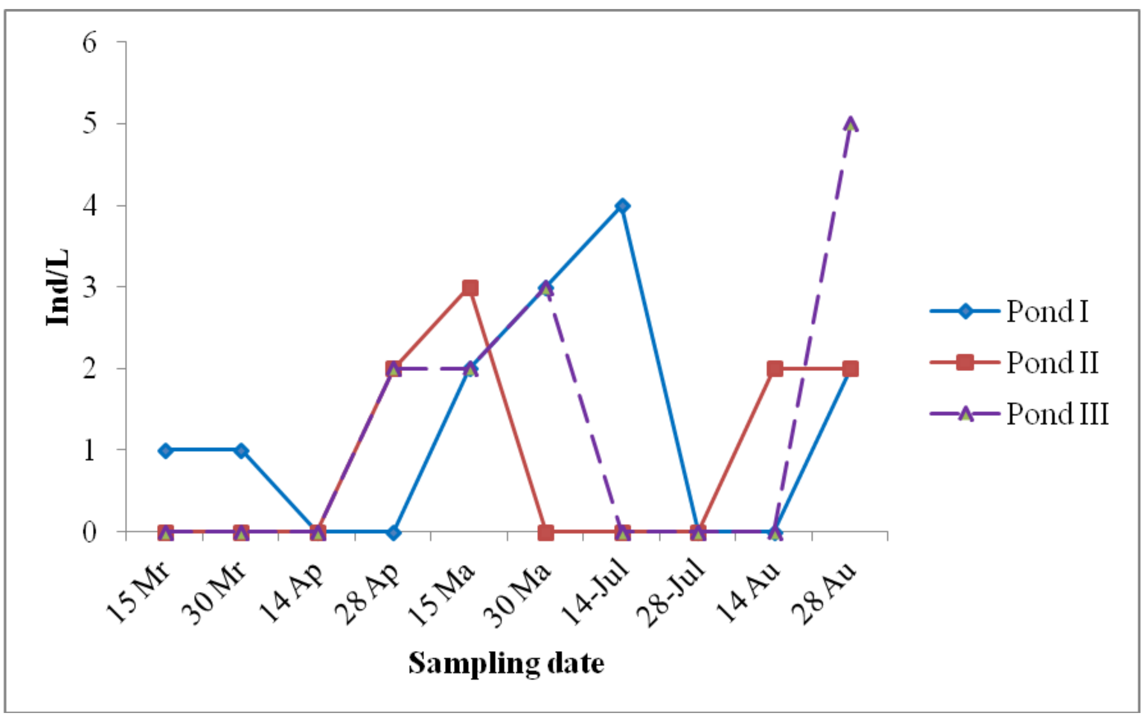


Figure 11. Spatio-temporal distribution of total cladoceran species abundance during the study period

Most Cladocera species did not show spatial variation in their distribution. From the seven cladocera species counted, four species (*Diaphanosoma excisum*, *Alona rectangula* ,*Ceriodaphnia cornuta* and *Chydorous sphericus*) showed higher proportions as well as their maximum peaks in pond III (Figure 12a. and b.) while, *Moina micrura and Macrothrix laticornis* showed higher proportions in pond I (Figure 12c.).

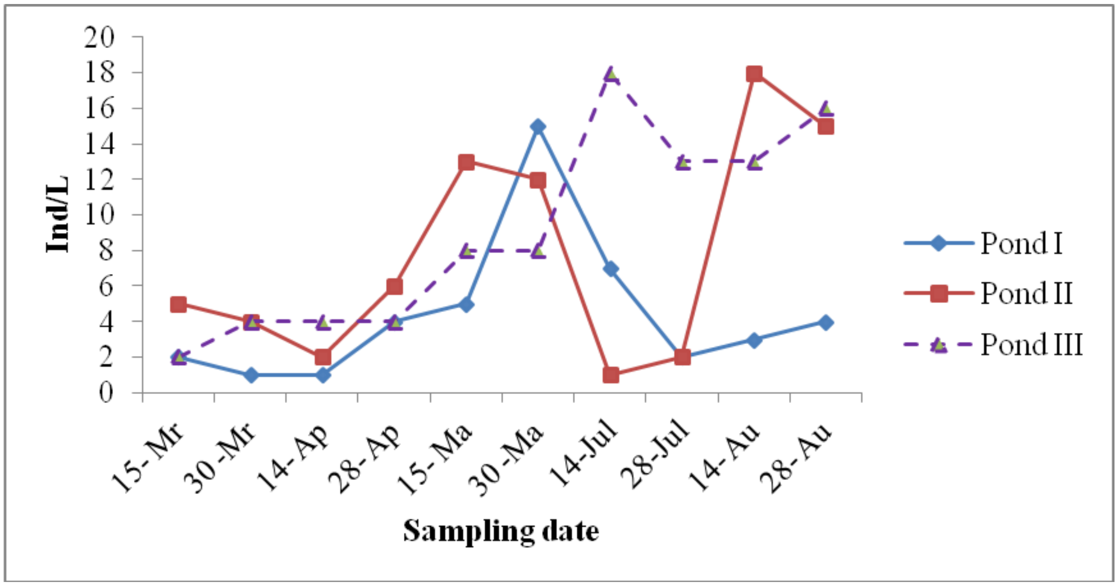


a

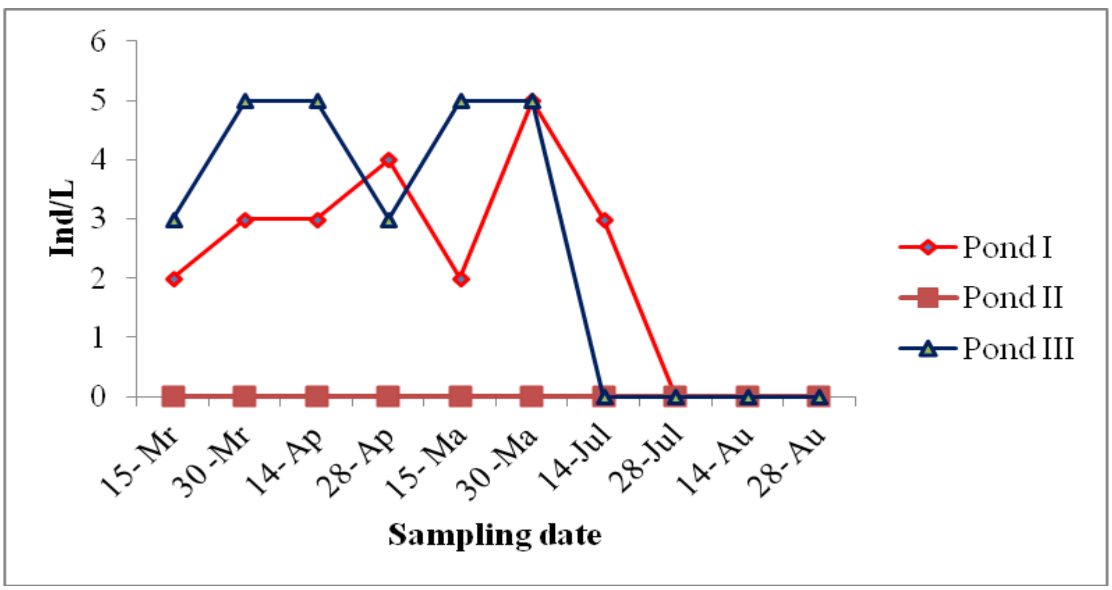


b

Figure 12 a. Spatio-temporal distribution of *Diaphanosoma excisum* (a) *Alona rectangula* (b)

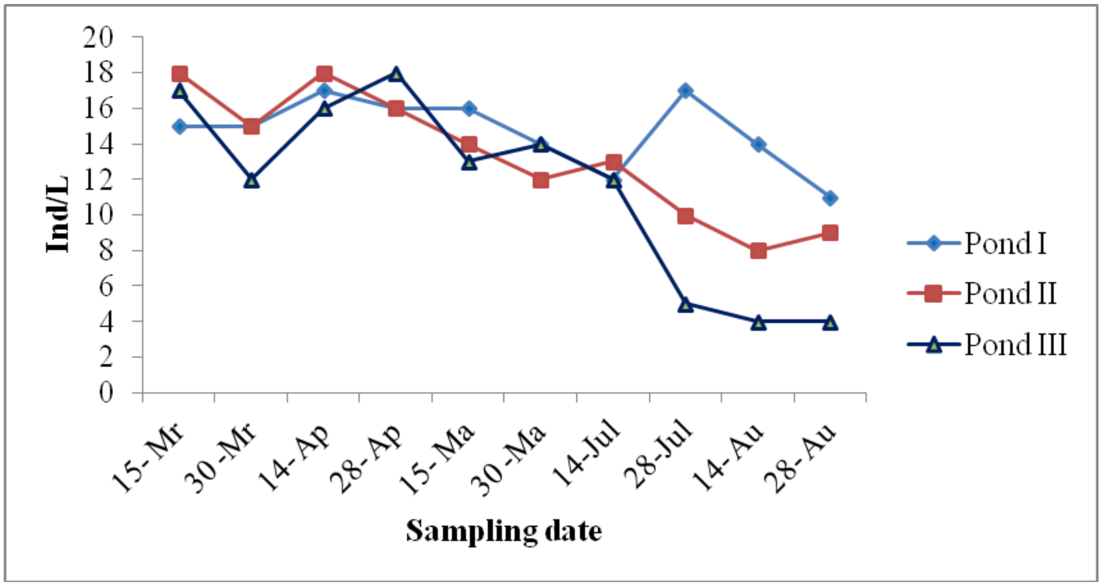


c



d

Figure 12b. Spatio-temporal distribution of *Ceriodaphnia cornuta (*c) and *Chydorous sphericus* (d)



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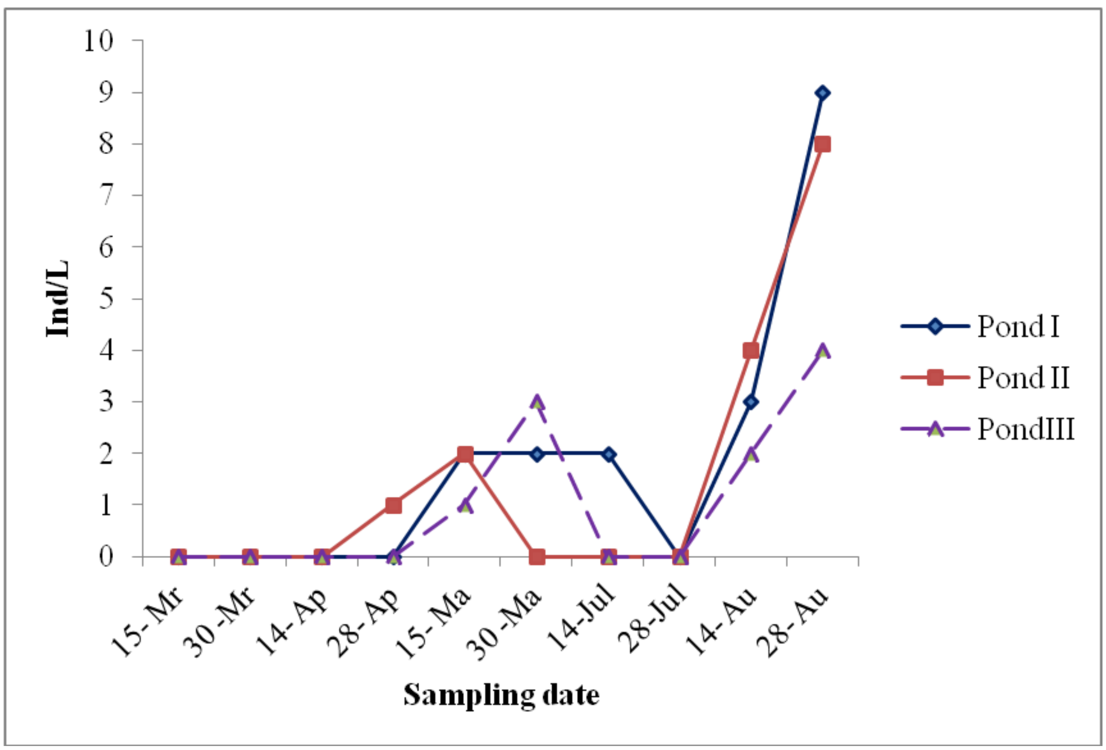


f

Figure 12c.Spatio-temporal distribution of *Moina micrura* (e) and *Macrothrix laticornis* (f)

4.5. Temporal variation in Cladocera species and its abundance

In a temporal pattern, a significant difference in cladoceran species (T- test, $p = 0.005$) and abundance was observed along the studied months (T- test, $p < 0.05$). Highest number of species (7) was recorded in July, while lowest number of species (3) was recorded in March. In pond I the total species of Cladocera recorded from this pond were 6. The highest numbers of species were 5 which were recorded in all the months except in April the number was 4 and recorded (absence of *Macrotrix laticornis* and *Alona rectangula*). The total number of Cladocera ranged between 29 individual/L during 15th March and 70 individual/L during 14thAugust**.** In pond II the total species of Cladocera recorded was 5 species, the highest number of species were 5 which were recorded in August. Whereas the lowest number of species were 3 and recorded in March and July (absence of *Alona rectangula* and *Macrothrix laticornis*). The total number of Cladocera ranged between 28 individual/L during 28th July and 46 individual/L during 15th May. In pond III the total numbers of Cladocera species recorded from this pond was 7, the highest number of species was 6, recorded in August and the lowest number was 4 in the month of March and July respectively (Figure. 13). The total number of Cladocera ranged between 38 individual/L during 15th March and 54 individual/L during 28th August.

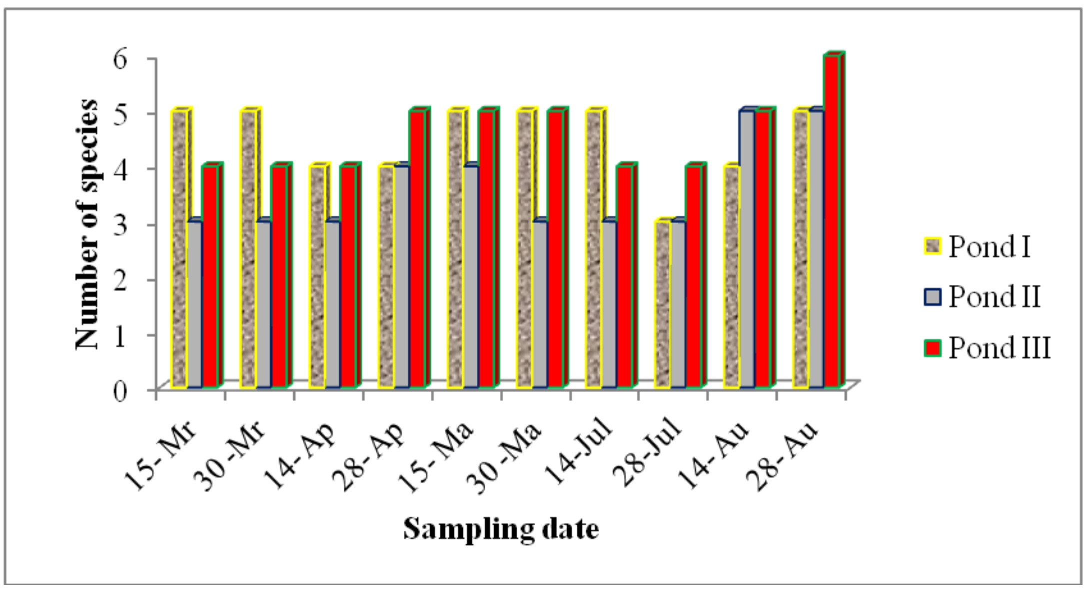


Figure 13.Temporal variation in species composition in the three ponds

The population of *Moina micurura, Diaphnosoma excisum* and *Ceriodaphnia cornuta* were encountered throughout the study period. The population *of Moina micrura* was comparatively higher with a peak during 28th April and but it declined from May to August (Figure. 14). Low population of *Diaphanosoma excisum* was recorded in 14th April, while it was increased from May to August. High population of *Ceriodaphnia cornuta* was recorded in 30th May, and lowest in 14th April. Maximum population of *Chydrous sphericus* was recorded in 30th May (Figure. 14). Its population was apparently absent from 28th July to August. The population of *Alona rectangula* remained low during most of months, but a minor peak value was observed in 28th August. Low population of *Macrothrix laticornis* was observed from March to May, but its population reaches peak during August. The population of *Daphnia lumholtzi* was observed in the month of July and population number was slightly increased towards August (Figure.15). Generally in the temporal pattern, the population of cladocerans showed maximum density (May and August), while low density was found in the March and July.

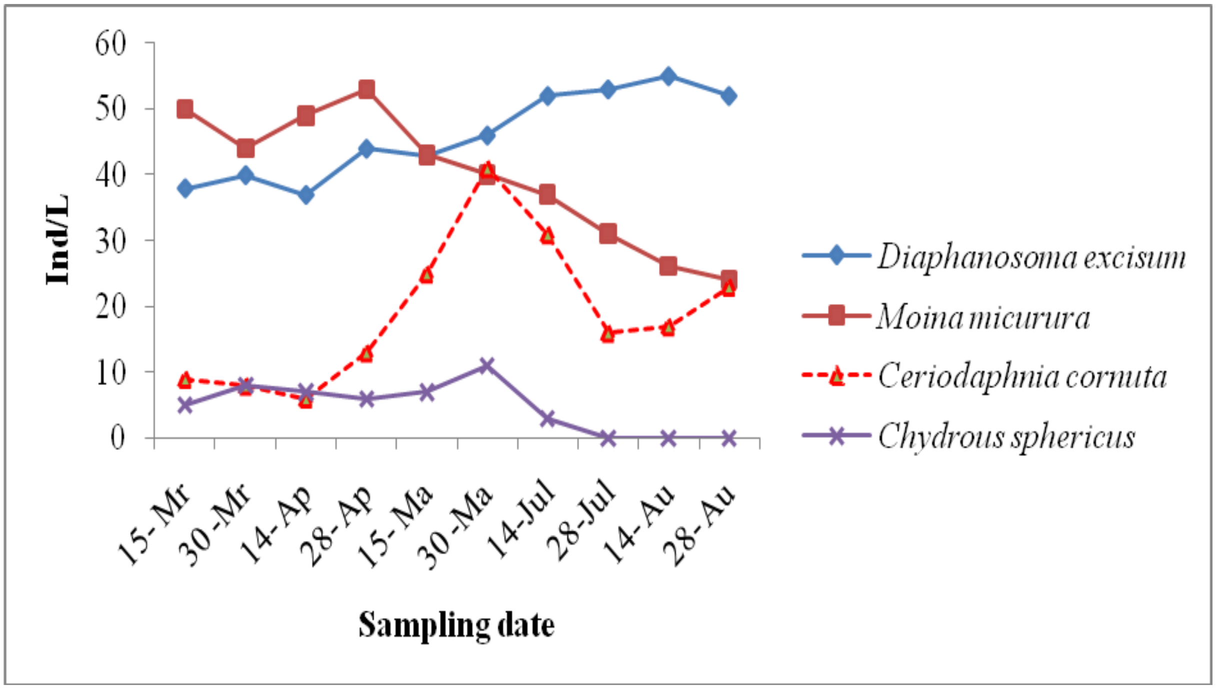


Figure 14.Temporal patterns in the abundance of *Diaphanosoma excisum, Moina micurura, Ceriodaphnia cornuta* and *Chydrous sphericus* (individual / L) during study period.

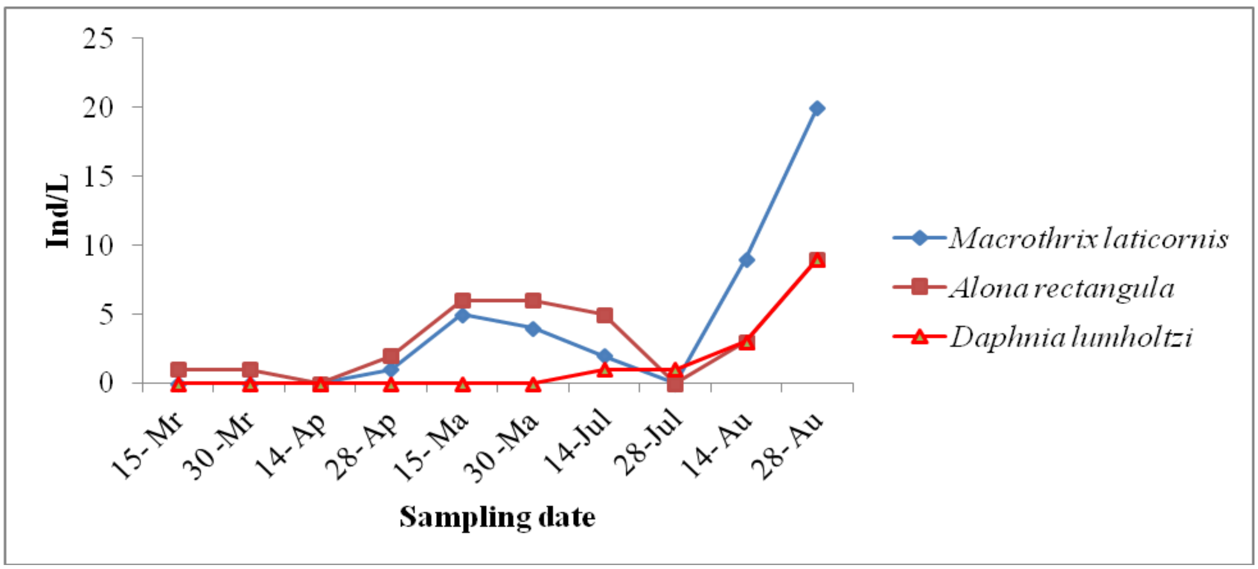


Figure 15. Temporal patterns in the abundance of *Macrothrix laticornis, Alona rectangula* and *Daphnia lumholtzi* (individual / L) during study period

4 .6. Diversity indices

4.6.1. Diversity, Evenness and Richness Analysis

Diversity index is commonly used as bio-criteria for the interpretation of the environmental status, as well as to measure the average degree of uncertainty within the community. Cladoceran community analysis was done by calculating species diversity (Shannon- wiener index), species richness (Margalef's index) and evenness (Pielou's index) in all the ponds whose values are shown in (Table. 4). Species richness relies only on cladoceran abundance and the number of taxa. Pond III reflected highest values for species diversity (H'= 1.5) and species richness (D' = 0.98). Pond II showed least values for species richness (D' = 0.68) as shown in (Table. 4). As far as evenness index is concerned comparatively nearly similar values were found between pond I and III, indicating that these two sites have much even distribution as compared to remaining pond II (Table 4).

Table. 4. Over all diversity, evenness and species richness index of Cladocera in the three ponds.

Ponds	S	N	D'	**J'**	H'
Pond I	6	382	0.84	0.78	1.4
Pond II	5	359	0.68	0.75	1.2
Pond III	7	459	0.98	0.77	1.5

Where (S) = number of species, (N) = Average number of individuals/L, (D') = Margalef richness, (J') = Evenness and (H') = Shannon diversity for each pond averaged over all sampling dates.

4.6.2. Relative abundance index (Ra)

Moina micrura was the most abundant species at pond I and *Daiphanosoma excisum* was abundant at pond III and *Alona rectangula was* least abundant in pond II (Table.5).

Table 5. Relative abundance index (Ra) of Cladocera species reported at the three ponds during the study period.

Species	Relative abundance (%)		
	pond I	pond II	pond III
Alona rectangula	2.6	2.31	2.98
Chydorous sphericus	5.12	0	5.82
Ceriodaphnia cornuta	7.96	17.84	20.32
Macrothrix laticornis	4.8	4.2	2.15
Moina micrura	39.60	37.89	25.57
Daiphanosoma excisum	39.92	37.76	40.78
Daphnia lumholtzi	0	0	2.38
Total	100%	100%	100%

4.7. Relationships between environmental parameters with Cladocera species abundance

To evaluate the relationship of cladocerans density with selected physico-chemical factors, correlation analysis was applied. The species considered in the correlation analyses for the three ponds were those Cladocera species which were found at all the three ponds during the study period. These were *Moina micurura, Diaphanosoma excisum.Ceriodaphnia cornuta,Macrothrix laticornis* and *Alona rectangula.* The density of the cladocera species was inversely related to water transparency except (*Moina micurura)* had a significance correlation ($p<0.05$) with *Moina micurura* and *Diaphanosoma excisum.* The water temperature showed inversely related with the most of the cladoceran species abundance (except for *Moina micurura*, $p = 0.034$*)* (Table 6). The pH of the water also showed no significant correlation with density of cladocerans (except for *Macrothrix laticornis*, $p = 0.012$*).*The density of *Diaphanosoma excisum,Macrothrix laticornis* and *Alona rectangula* showed positive correlation with pH, while the density of

Moina micurura and Ceriodaphnia cornuta showed inverse relationship with pH. The total densities of *Moina micurura* was directly related to water transparency, electrical conductivity and dissolved oxygen and significantly correlated at (p = 0.029 and 0.02) with water transparency and electrical conductivity respectively, but not significant correlated with dissolved oxygen (p = 0.87). Electrical conductivity and Dissolved oxygen showed inverse correlating to the abundance of *Diaphanosoma excisum.Ceriodaphnia cornuta, Macrothrix laticornis* and *Alona rectangula* and it has a significant correlation (p<0.05) with *Diaphanosoma excisum and Ceriodaphnia cornuta* but had not a significant correlation (p>0.05) with *Macrothrix laticornis* and *Alona rectangula.*

Table 6. Summary of Pearson Correlation Coefficients(r) between five cladocera species abundance and physico-chemical parameters. At a significance levels of (P<0.05)

Parameters	**Species**				
	M.micurua	*D.excisum*	*C.cornuta*	*M.laticornis*	*A.rectangula*
Transparency	r = 0.379	r = -0.338	r = -0.102	r = -0.180	r = -0.127
	p = 0.039*	p = 0.034*	p = 0.592	p = 0.342	p = 0.505
pH	r = - 0.104	r = 0.077	r = -0.175	r = 0.453	r = 0.232
	p = 0.586	p = 0.688	p = 0.354	p = 0.012*	p = 0.218
DO	r = 0.317	r = -0.367	r = -0.022	r = -0.429	r = -0.143
	p = 0.87	p = 0.046	p = 0.908	p = 0.018*	p = 0.450
Conductivity	r = 0.423	r = -0.723	r = -0.399	r = -0.034	r = -0.122
	p = 0.02*	p = 0.000*	p = 0.029*	p = 0.858	p = 0.521
Water temperature	r = 0.388 p = 0.034*	r = -0.457 p = 0.011*	r = -0.08 p = 0.968	r = -0.151 p = 0.427	r = -0.055 p = 0.775

* = significant at p <0.05

5. DISCUSSION

5.1. Physico–chemical Characteristics of water

According to Ahmad (2012) the temperature of a water body plays an important role in the regulation and distribution pattern of biotic communities. Temperature alters the physico-chemical condition of the water like pH, conductivity; saturation level of gases and various forms of alkalinity. A rise in temperature of the water leads to the speeding up of the chemical reactions in water and reduces the solubility of gases.

During the present study, the fluctuation of water temperature was very narrow among the three ponds. This might be due to the ponds are located in the same altitude and topography. Surface water temperature has positively correlated with air temperature. Water temperature, was in line with air temperature fluctuated between a maximum value of air temperature (29.8^0C) and water temperature (26^0C) was recorded in the month of April against minimum air temperature (21.1 ^{0}C) and water temperature (18 ^{0}C) in the month of July. The high water temperature might be due to high solar radiation and atmospheric temperature, whereas low water temperature in July might be due to low atmospheric temperature due to cloud cover and solar radiation. A similar pattern of temperature fluctuations has been reported by Majagi and Vijaykumar (2009) stated temperature fluctuations in water were influenced considerably by air temperature, humidity and solar radiation. Ahmed (2003) stated increase in solar radiation due to comparatively longer day length may explain gradual increase in both air and water temperature from April to August. Water temperature ranging between 13.5 and 32^oC is reported to be suitable for the development of the planktonic organisms (Gaikwad *et al*., 2008).

In this study, the water temperature ranged between 18 and 26°C and this range of temperature is more favorable for enhancing growth of primary producer algae which promote the production of zooplankton (Michael and Sharma, 1987). Therefore water temperature in the ponds is suitable for planktonic organism both phytoplankton and zooplankton.

Electrical conductivity (EC) is a useful indicator of total dissolved solids (TDS) and ions because the conduction of current in an electrolyte solution is primarily dependent on the concentration of ionic particles (Hayashi, 2004). The rises and or falls of electrical conductivity are attributed to the dissolved solids in water (Bauder *et al.*, 2003).

High value of EC was observed in pond I, it might be due to the presence of a big rock underlying the bottom of the pond, which is believed to be weathering with temperature and therefore release of ions that raise the EC. Progressive decrease in the conductivity was observed from March to July but slight increase in August. The high conductivity during March could be explained by more evaporative concentration of ions due to high temperature at less solubility and high degradation of organic substances. As per, Wetzel (2001) electrical conductivity can vary with temperature, mainly due to the effect of temperature on the viscosity of water related to ionic mobility. This explanation is also supported by Story (2008) seasonal variability in conductivity may be related to evaporation and dilution. Gaikwad *et al.,* (2008) also stated that the dilution of solid substance in turn reduces the EC value alkalinity and zooplankton production.The electrical conductivity of the ponds ranged from a minimum value of 104.8 µS cm-1 in July in pond III to 378 µS cm-1 in March in pond I. The maximum conductivity value of the ponds (except pond III) is outside the range that drinking water should have (25-250 µScm-1(WHO, 1996).

In natural waters, pH shows diurnal and seasonal changes due to variation in photosynthetic activity where in pH increases due to utilization of carbon dioxide in the process. During this study high pH value was recorded in August. This might due increase photosynthetic activities by phytoplanktons. This is in close agreement with report of Shiddamallayya and Pratima (2008) the high pH value during August (summer) might be due to the high photosynthesis of micro-macro organism resulting in high production of free carbon dioxide during the equilibrium towards alkaline side. High photosynthetic activity due to increased production of phytoplankton may support an increase in pH (Ahmed, 2003). According to Kurbatova (2005) and Tanner *et al.* (2005) the pH range between 6.0 and 8.5 indicates medium productive nature of a reservoir; more than 8.5 highly productive and less than 6.0 low productive nature of a reservoir.

Dissolved oxygen is an important aquatic parameter which is a vital in the context of culture of any aquatic animal as oxygen plays a crucial role in their life processes. It measures the amount of free oxygen available in the water; hence sufficient dissolved O_2 is essential for good water quality. The oxygen supply in water mainly comes from atmospheric diffusion and photosynthetic activity of plants. High dissolved oxygen is an indication of healthy aquatic ecosystem (Chattopadhyay and Banerjee, 2007). The dissolved oxygen evaluated the degree of freshness of an aquatic ecosystem (Agbaire and Obi, 2009). The maximum dissolved oxygen was observed in August. This might be associated with decreasing in water temperature. The inverse relationship of dissolved oxygen with water temperature is documented by Basu *et al*. (2010). Similar type of result was also observed in the present study. This is also in line with WHO (1998) which stated that, variations in dissolved oxygen can occur due to temperature fluctuations (colder water can hold more oxygen) and photosynthetic activities. Low dissolved oxygen retaining capacity of water due to increased organism respiratory demand at high temperature may also cause low values of dissolved oxygen (Rao, 1986).

According to U.S. Environmental Agency, DO > 5 mgL-1 is considered favorable for growth and activity of most aquatic organisms; DO < 3 mgL-1 is stressful to most aquatic organisms, while DO < 2 mgL-1 does not support fish life. Thus, when the mean concentration of DO measured at the three ponds is compared according to the standard set above, the concentrations at pond I, II and III (5.49, 5.84 and 5.46 mgL-1 respectively) are considered to be favorable for aquatic life.

In an aquatic ecosystem water transparency is one of the most important features that control the energy relationship at different trophic levels. A low value of water transparency in the ponds was observed during July. This is in line with Cano (1980) the decrease in water transparency during August coincided with a high concentration of suspended solids in the water, probably due to the re-suspension of bottom sediments. Low transparency values during the summer season may be due to sedimentation of suspended soil particles and low suspended organic matter with poor planktonic growth (Sinha *et al.*, 2002).

5.2. Species composition of Cladocera

During this study seven species of cladocerans were identified, they were *Moina micrura*, *Diaphanosoma excisum*, *Alona rectangula*. *Ceriodaphnia cornuta*, *Daphnia lumholtzi*, *Chydrous sphericus* and *Macrothrix laticornis*. This assemblage is in agreement with those typical of northern shallow lakes and ponds (Louette *et al.,* 2008; Drenner *et al.,* 2009). Baloch *et al.* (2010) also stated that the cladoceran genera like *Alona, Chydorus, Macrothrix* and *Moina* are generally considered as shallow pond water species. Their common occurrence in shallow ponds along with aquatic weeds also recorded by various workers (Michael and Sharma, 1987; Korovchinsky and Smirnov, 1996).Cladoceran species recorded in the present study were also recorded from most lakes in Ethiopia (Dejen *et al.*,2004; Imoobe and Akoma,2008 ; Dagne, 2010; Dejenie *et al*., 2012; Tamire and Mengistou,2013).

5.3. Spatio-temporal distribution and abundances of Cladocera

Pond III showed rich macrophytic growth and represented by maximum number of cladoceran species and abundance. This showed the effects of aquatic vegetation, in association with increasing nutrient and created conducive condition for cladoceran community structure. Other studies have already stated that, the presence of macrophytes in permanent lakes and wetlands created the conditions for more diverse cladoceran communities as reported by Peretyatko *et al.* (2009) and Sorf and Devetter (2011). The highest diversity values of cladoceran community was found for the sites situated among submerged vegetation which create a favorable anti-predation refuge against a number of predators, both invertebrate and vertebrates (Kuczyńska-Kippen and Nagengast, 2006). These ecological types of macrophytes also often serve as a nutritional source for their inhabiting organisms (Jones *et al*., 2000). Dejen *et al. (*2004) also reported that in Lake Tana, the cladocerans were most abundant in the sub littoral zone of the lake where the aquatic weeds are high.

The low diversity and abundance of Cladocera species was recorded from pond II, this might be related to the presence of few vegetation and anthropogenic activities such washing and swimming. Similar result is reported by Solomon *et al*. (2009) recognized various anthropogenic stress affecting the abundance and diversity of the Cladocera population. The species diversity tends to be low in stressed and polluted ecosystem (Bass and Harrel, 1981). In contrast Siokou-Frangou and Papathanassiou (1991) reported the cladocerans abundance is generally high in disturbed areas in which perturbations of zooplankton causes domination of small number of species.

Chydorous sphericus was absent in pond II, this might be the habitat nature and feeding behavior of the species. This is in agreement with Cerbin, *et al. (*2003) some cladocerans will occur amongst submerged vegetation out of necessity for their mode of feeding, such as periphyton scrapers (e.g. Chydorids) which live in close association with plant surfaces. Kotov (2006) also reported predominantly the member of the families Macrothricidae and Chydoridae which have specializations that allow them to the use the resources in the littoral zone, including appendices specialized in scraping and handling food; the chydorids also present great mobility of the post-abdomen.

The restricted occurrences of *Daphnia lumholtzi* to pond III might be due to the presence of dense aquatic vegetation in pond III used as a refuge to protect from planktivorous fishes predation. The presence of fish was observed based on actual capture of juvenile fish during sampling of zooplankton by visual observations, and information gained from the society around the ponds and sometimes humans were observed actively fishing on these ponds. This is also supported by Lemma *et al*. (2001) stated that the presence of *Daphnia spp.* in Lake Kuriftu could be assisted by the availability of refuge such as high turbidity, in spite of the presence of planktivory in the lake.

5.4. Temporal variation in cladoceran species and abundance

Cladocerans are constantly exposed to a great variety of environmental factors, whose fluctuations constrain the size, reproduction and survival of populations. According to Rajagopal *et al*. (2010) the composition and relative abundance of species in the aquatic communities is influenced by the variation in tropic state and seasonal changes of physicochemical variables of water body. In the present study, the Cladocera population fluctuates monthly shows bimodal peaks and its population was maximum during May followed by August and least during March. This might be associated with increased availability of food or nutrients (phytoplankton and bacterioplankton).This is in agreement with Yarwood (2005) seasonal variation in Cladocera populations suggests that the most favorable period for growth is from May to August, which may be attributed to the increase of phytoplankton population during this period.

According to Ricardo *et al.* (2009) the great amplitude variation of species richness in the rainy season can be related to two factors. First, the spatial heterogeneity of cladocerans, which explore the environment in different ways searching for adequate conditions for their development, for example, when an increase in volume of the reservoir raises food availability and alter the phytoplankton community. Second, rain effect is noticeable because it causes the transport of autochthonous (from littoral zone) and allochtonous materials to water bodies. Mergeay *et al*. (2006) also stated low water temperature and other environmental conditions are prerequisites to the hatching of resting eggs of various cladocerans during rain season. This factor may explain the dominance of the cladocerans during the rainy season and also leads to hatching of resting zooplankton eggs deposited in previously dry area. Dejen *et al*. (2004) attributed the dominance of cladocerans in Lake Tana to the rapid hatching of resting egg in rain season. The dominance of cladocerans during the rainy season may be ascribed to multiple factors that include low water temperature, high nutrient condition, food availability and hatching of resting eggs (Okogwu, 2010).

Various cladoceran species show their higher population at different times of the study period.The population of *Diaphanosoma excisum* and *Moina micurura dominated* throughout the five month sampled, even though their peak was different in different time. The population of *Moina micurura* progressively decreased towards August while the population of *Diaphanosoma excisum* was increased. This might be associated with acidiophilic nature of the *Moina micrura* persistent during the dry season and *Diaphanosoma excisum* was the most protracted summer occupant species (Hart, 2000). Crosetti and Margaritora (1987) also reported the main planktonic species is *Moina micrura* that appeared when other cladocerans diminished in stressful conditions during the drying period.

The population of *Ceriodaphnia cornuta* and *Chydorous sphericus* progressively increased from March to May but their populations declined in July. This might be due the effect of turbidity diminished the population of these species. This is in agreement with Dagne (2010) the difference in the response of cladoceran species to an increase in turbidity (e.g. disappearance of *Daphnia barbata* and *Ceriodaphnia cornuta* at low water transparency could be the susceptibility of the species.

The absence of *Daphnia lumholtiz* from March to May might be due to food limitation. Other study reported that Daphnia specie have the potential to out-starve smaller competitors through high per capita filtration rates at high food concentrations (Vanni, 1986) but low food supply might favour small-sized taxa. Starvation is especially harmful to juvenile *Daphnia*, while *Ceriodaphnia* are less sensitive to low food levels (Romanovsky and Feniova, 1985).

Increased in cladocerans population in this study during wet set season is also documented by Dejen, (2004) in Lake Tana, Morgan *et al*. (1980), In Lake Langano and Abijata, Kasahun Wodajo and Amha Belay (1984), Lake Awasa, Mengistu and Fernando (1991), Lake Zeway, Beneberu (2005), Lake Beseka, Delelegne (2006), also reported that there was cldocerans increase during the wet season. But in contrast with the report of Dagne (2010) in Lake Ziway and Dejenie *et al.(*2012) in tropical semi-arid highland reservoirs in Tigray

5.5. Effect of physico-chemical variables on Cladocera aboundance

The abundance and distribution of zooplankton is guided by a variety of ecological factors. The physiochemical parameters such as temperature, light, pH, organic and inorganic constituents and the interrelationship with their organisms play an important role in determining the nature and pattern of fluctuation of population densities of zooplankton. Density and diversity of Cladocera depend on water temperature, DO, turbidity and transparency (Pawar and Pulle, 2005).

The maximum population of most Cladocera species was seen with low water temperature in August. It indicates that low level of water temperature favor for Cladocera species. According to Mergeay *et al*. (2006) low water temperature and other environmental conditions are prerequisites to the hatching of resting cladoceran eggs in natural water. Another reason for the seasonal declines could be due to thermal stress (Havens *et al.*, 2000). Havens *et al*. (2000) found the spring declines in the biomass of cladoceran species generally occur when water temperatures near 30 °C; however, a temperature of 24 °C was considered optimal for growth, supporting that temperature may be a main controlling variable among freshwater cladocera (Havens *et al.*, 2000).

The low density of most cladoceran species was observed during July. The low abundance Cladocera species during this period was most probably due to low light penetration (low transparency). This in agreement with Dagne (2010) stated that the standing stock of cladocerans declined despite an increase in Chlorophyll a concentration following the decline in water transparency. Moreover, the transparency appeared to be extremely low, which might be largely responsible for the very low zooplankton densities recorded during the study period as Dejen *et al*. (2004) had earlier reported that silt held in suspension in turbid water interferes with filter feeding mechanisms of crustaceans and this affects their reproduction success.

Water transparency was negatively associated with abundances of *Diaphanosoma exisum* and positively associated with the abundances of *Moina micrura.* The difference in the response of cladoceran species to an increase in turbidity (e.g. disappearance of *Daphnia barbata* and *Ceriodaphnia cornuta* at low water transparency but an increase of *Moina micrura* and *Diaphanosoma excisum*) could reveal differences in the susceptibility of the species (Thrilled, 1986). Sharma *et al.* (2011) also reported the high value of transparency was the most valuable parameter that has affected the density of *Cladoceran* zooplanktion qualitatively and quantitatively. Therefore this factor usually governs the seasonal growth and distribution of zooplankton communities in fresh water.

The abundance of cladocerans population was high at low concentration of conductivities i.e. pond III and during August. Generally the densities of cladocerans decreased with increased conductivity this might be conductivity could affect reproduction and physiological activities of Cladocera species. This result is supported by Dejenie *et al*. (2012) in the dry season Cladocera community variation was related to conductivity and chlorophyll a. Reproductive and/or survival rates of cladocerans are generally reduced at higher conductivities (Galat and Robinson ,1983).

During this study most of the cladoceran species their population was increased with increased in pH from 7.68-8.55. This might be associated with alkaliphilic nature of the species. Jhingran (1982) reported that the reduction in the number of genera or species may be due to the variation in pH of water associated with the genera (species) composition of Zooplankton inhibiting among them.

6. CONCLUSION AND RECOMMENDATION

In this study, the diversity and population dynamics of freshwater Cladocera were studied in connection with the physico-chemical variables of the water. The physico-chemical parameters and the Cladocera species abundance has showed some interrelationships and these relationships are helpful to understand the temporal and spatial variation of Cladocera population in this aquatic ecosystem. From the present study it is clear that, the Cladocera species composition and abundance varied temporally. Cladocera species abundance was maximum and minimum in the month of May and March respectively. It is because of the variation in physico-chemical factors and other intrinsic factors. In the present study a total of 7 cladoceran species were identified from the study ponds. Among the recorded Cladocera species, *Moina micrura* and *Diaphanosom excisum* were numericaly dominant and *Daphnia lumholtzi* is the least dominant species. Variation in percentage composition of cladoceran communities was observed in all the three ponds.

With respect to conservation measures, these findings stress the importance of maintaining ponds of different nature as they can support different species of cladoceran despite the fact of being located in the same topographic region. Based on the results which are obtained during the study period, the following recommendations are made.

- ✓ Present study is a preliminary attempt to know the taxonomy, abundance and dynamics of freshwater cladocerans. However, more studies will be required to make a complete list of available Cladocera species and other co-occuring species of zooplankton as well as their impact on water quality in these manmade ponds.

- ✓ Since there is considerable dependence of many commercial fish species on the invertebrate fauna as food resource, there is a need to investigate further the biology and ecology of this zooplankton which in turn will give an idea for the suitability good fish farming in this area.

- ✓ Close monitoring of the physico-chemical factors are essential to avoid the contamination with toxic substance since these ponds do not have outlets and inlets.

- ✓ In future, there is need for extension of time and to establish realistic results that are trustworthy. Thus, the number of Cladocera species may increases if the sampling is done for prolonged periods. So, at least a year round detailed study will be required to ascertain the species composition.
- ✓ A regular limnological study on these ponds are hereby advised in order to understand the quality of water because the people in and around the Boye wetland are depending this water bodies for their day today life activities.
- ✓ As a secondary producer, it would be nice to investigate the functional responses of zooplankton and also to examine in more detailed importance of their abundance, spatial and temporal distribution, and their crucial role in fishery and aquaculture.
- ✓ Limnological studies should be carried out continuously to generate baseline data on physico- chemical parameter such nitrate and phosphate to know the trophic state of the ponds. Hence, the reclamation of these ponds needs serious concern for conservation of the faunal diversity and the water quality.

7. REFERENCE

Abrantes, N., Antunes, S.C., Pereira, M.J. and Goncalves, F. (2006). Seasonal succession of cladocerans and phytoplankton and their interactions in a shallow eutrophic lake (Lake Vela, Portugal). *Acta .Oecol*., **29**:54-64.

Adamowicz, S. J. and Purvis, A. (2005). How many branchiopod crustacean species are there? Quantifying the components of underestimation.*Glob.Ecol. Bioge.,* **14**:455–468.

Adamowicz, S., Petrusek, A. and Colbourne, J. (2009). The scale of divergence: a phylogenetic appraisal of intercontinental allopatric speciation in a passively dispersed freshwater zooplankton genus. *Mol. Phylo. Evol.,* **50**: 423–436.

Agbaire, P.O. and Obi, C.G. (2009). Seasonal variations of some physico-chemical properties of River Ethiope water in Abraka, Nigeria. *J. Appl. Sci. Environ. Manage.,* **13**(1): 55-57.

Ahmad, J. S. (2012). Crustacean community of Wular lake, Kashmir. Ph.D.Dissertation, University of Kashmir, Pp 208.

Ahmed, M.M. (2003). Ecology and taxonomy of plankton of Manchhar Lake (Distt. Dadu), Sindh, Pakistan. Ph.D.Dissertation. University of Sindh, Pakistan, Pp 320.

Ahmed, T. (2010). Zooplankton population dynamics in Clayton County water authority reservoirs, B.Sc. Thesis. Atlanta, Georgia, Pp 28.

Atkinson, D. (1994). Temperature and organism size a biological law for ectotherms? *Adv. Ecol. Res.*, **25**: 21–58.

Auel, H. and Verheye, H. M. (2007). Hypoxia tolerance in the copepod *Calanoides carinatus* and the effect of an intermediate oxygen minimum layer on copepod vertical distribution in the north Benguela Current upwelling system and the Angola-Benguela Front. *J. Exp. Mar. Biol. Ecol.*, **352:** 234-243.

Balayla, D. J. and Moss, B. (2003). Spatial patterns and population dynamics of plant-associated microcrustacea (Cladocera) in an English shallow lake. *Aqu.Ecol.*,**37**: 417-435.

Baloch, W.A., Tunio, G.R., Noonari, S. and Noonari, I.B. (2010). Occurrence of zooplankton (rotifera and cladocera) in some water bodies near Jamshoro**.** *Sindh .Univ. Res. J.,* **42**(1): 31-34.

Bass, D. and Harrel, R.C. (1981). Water quality of southeast texas stream. *Hydrobiologia*, **76**:69 79.

Basu, M., Roy, N. and Barik, A. (2010). Seasonal abundance of net zooplankton correlated with physico-chemical parameters in a freshwater ecosystem. *Int. J. Lak.Riv.*, **3**(1): 67 77.

Bauder, T.A., Waskom, R.M. and Davis, J. G. (2003). Irrigation Water Quality Criteria. Colorado State university, U.S.A.

Beneberu, G. (2005). Study on littoral dynamics in Lake Ziway.M.Sc. Thesis. Addis Ababa University. Pp 65.

Benzie J. A. H. (2005). Cladocera: the genus *Daphnia* (including *Daphniopsis*). In: Dumont H. J. F. (ed.) *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World*, 21. Kenobi Productions, Ghent and Backhuys Publishers, Leiden.

Bini, L. M., Silva, L. C. F., Velho, L. F., Bonecker, C. C. and Lansac-Tôha, F. A. (2008). Zooplankton assemblages' concordance patterns in Brazilian Reservoirs. *Hydrobiologia*, **598**: 247 – 255.

Binks, A.J., Arnott, S. E. and Sprules, W.G. (2005). Local factors and colonist dispersal influence crustacean zooplankton recovery from cultural acidification. *Ecol. Appl*., **15**: 2025- 2036.

Black, A.R. (1993). Predator induced phenotypic plasticity in *Daphnia pulex* life-history and morphological responses to *Notonecta* and *Chaoborus*. *Limnol. Oceanogr*., **38**: 986-996.

Bonecker, C. C., Lansac-Tôha, F. A., Velho, L. F.M. and Rossa, D. C. (2001). The temporal distribution patterns of copepods in CorumbáReservoir, State of Goiás, Bra. *Hydrobiologia*, **453**: 375-384.

Boven, L. and Brendonck, L. (2009). Impact of hydroperiod on seasonal dynamics in temporary pool cladoceran communities. Fundamental and Applied Limnology- Archiv fur, *Hydrobiologie*, **174**(2): 147–157.

Brandl, Z. (2002). Methodology and general ecology. In Fernando, C. H. (ed.), *A Guide to Tropical Freshwater Zooplankton*. Backhuys Publishers, Leiden, Pp 1–21.

Brendonck, L. and De Meester, L. (2003). Egg banks in freshwater zooplankton: evolutionary and ecological archives in the sediment. *Hydrobiologia*, **491**: 65-84.

Bronmark, C. and Hansson, L. A. (1998). *The biology of lakes and ponds*. Crawley,M.J., Little C., Southwood T. R. E. and Ulfstrand S. (eds.). Oxford University PressInc., New York.

Burks R. L., Lodge, M., Jeppesen, E. and Lauridsen, T. L. (2002). Diel horizontal migration of zooplankton: costs and benefits of inhabiting the littoral. *Freshwat. Biol.*, **47**: 343-365.

Campbell, N.A., Reece, J.B. and Mitchell, L.G. (1999). *Biology*. Addison Wesley Longman, Inc., New York.Pp 1175 .

Cano, E. (1980). Inventario integrado de los recursos naturales de la provincia de La Pampa. Ediciones Instituto Nacional de Tecnología Agropecuaria (INTA), Provincia de La Pampa y UniversidadNacional de La Pampa, Buenos Aires, Pp 493.

Carpenter, S.R., Cole, J.J., Kitchell, J.F. and Pace, M. L. (1998). Impact of dissolved organic carbon, phosphorus, and grazing on phytoplankton biomass and production in experimental lakes. *Limnol. Oceanogr*., **43**: 73-80.

Cerbin, S., Balayla ,D.J. and Van de Bund, W.J. (2003). Small-scale distribution and diel vertical migration of zooplankton in a shallow lake (Lake Naardermeer, the Netherlands). *Hydrobiologia*, **491**: 111-117.

Cerny, M. and Herbert, P.D.N. (1993). Genetic diversity and breeding system variation in *Daphnia pulicaria* from North American lakes. *Heredity*, **71**: 497-507.

Chattopadhyay, C. and Banerjee, T.C. (2007). Temporal changes in environmental characteristics and diversity of netphytoplankton in a freshwater lake. *Turk. J. Bot.*, **31**: 287-296.

Claire, C.S. (2012). Windows of opportunity: the timing of dispersal events influences zooplankton community response to environmental change in subarctic ponds.M.Sc. Thesis, Queen's University, Kingston, Ontario, Canada, Pp 129.

Cottenie, K., Nuytten, N., Michels, E. and De-Meester, L. (2003). Zooplankton metacommunity structure: regional versus local biotic and abiotic processes in a set of interconnected ponds. *Ecology,* **84**: 991-1000.

Crosetti, D. and Margaritora, F. G. (1987). Distribution and life cycles of cladocerans in temporary pools from Central Italy. *Freshwat. Biol.*, **18**: 165-175.

Dagne, A. (2010). Zooplankton community structure, population dynamics and production in relation to abiotic and biotic factors in Lake Ziway, Ethiopia. Ph.D.Dissertation, Vienna University, Austria.Pp 166.

Davidson, T.A., Bennion, H., Jeppesen, E., Clarke, G.H., Sayer, C.D., Morley, D., Odgaard, B.V., Rasmussen, P., Rawcliffe, R., Salgado, J., Simpson, G.L.and Amsinck, A.L. (2011). The role of cladocerans in tracking long-term change in shallow lake trophic status. *Hydrobiologia* ,**676**: 288-315.

Declerck,S.,Vanderstukken,M.,Pals,A.,Muylaert,K.andDeMeester,L.(2007).Planktonbiodiversity along gradient of productivity and its mediation by macrophyets. *Ecology*, **88**:2199-2210.

Dejen, E., Jacoubs, V., Nagelkerk, A.J. and Sibbing, F.A. (2004). Temporal and spatial distribution of micro crustacean zooplankton in relation to turbidity and other environmentalfactors in a large tropical lake (Lake Tana, Ethiopia). *Hydrobiologia*, **513**: 39-49.

Dejenie , T., Steven, A., Declerck,J., Asmelash, T ., Risch,S., Mergeay,J., De Bie, T.and De Meester, L. (2012). Cladoceran community composition in tropical semi-arid highland reservoirs in Tigray (Northern Ethiopia): A metacommunity perspective applied to young Reservoirs.*Limnologica*, **42**:137– 143.

Delelegne, T. (2006). Seasonal and spatial variations of zooplankton in relation to physic chemical variables and phytoplankton production in Lake Beseka (Metehara), Ethiopia M.Sc.Thesis.Addis Ababa University.

Desta.H. Y. and Mengistou, S. (2009). Water quality parameters and Macroinvertebrates index of biotic integrity of the Jimma wetlands, southwestern Ethiopia. *J. Wet. Ecol.,* **3**: 77-93.

Dodson, S. and Frey, D. (1991). *Cladocera and other Brachiopoda*.Thorp J.H. and Covich A.P (ed.). Ecology and Classification of North American freshwater invertebrates, Academic Press Inc, San Diego, California, Pp 92101.

Dodson, S. I., Lillie, R. A. and Will-Wolf, S. (2005). Land use, water chemistry, aquatic vegetation and zooplankton community structure of shallow lakes. *Ecol.Appl.,* **15**: 1191–1198.

Dodson, S., Arnott, S. and Cottingham, K.L. (2000). The relationship in lake communities between primary productivity and species richness. *Ecology*, **81**:2662-2679.

Dodson, S.L., Caceres, C.E. and Rogers, D.C. (2010). *Cladocera and other Branchiopoda*. *In* Thorp J and Covich A, editors. Ecology and Classification of North American Freshwater Invertebrates. Elsevier, New York. Pp 773–827.

Downing, J. A. (2010). Emerging global role of small lakes and ponds: little things mean a lot. *Limnetica*, **29**(1): 9–24.

Drenner, S. M., Dodson, S. I., Drenner ,R. W. andPinde, J. E. (2009). Crustacean zooplankton community structure in temporary and permanent grassland ponds. *Hydrobiologia*, **632**: 25–233.

Dumont, H. J. and Negrea, S. V. (2002). Introduction to the class Branchiopoda. In: Dumont H. J. (ed.), Guides to the Identification of the Microinvertebrates of the Continental Waters of the World. Backhuys Publishers, Leiden, Pp 19.

Ebisa, N. (2010). Water Quality and phytoplankton dynamics in Geffersa reservoir. M.Sc.Thesis. Addis Ababa Univarisity. Addis Ababa, Ethiopia. Pp 66.

Edmondson, W. T. (1992). *Freshwater biology*. Second Eds. John Wiley and Sons. Inc., New York, Pp 1248.

Egloff, D. A., Fofonoff, P. W. and Onbé, T. (1997). Reproductive biology of marine cladocerans. *Adv. Mar. Biol*., **31**:79–168.

Elmoor-Loureiro, L. M. A. (2007). Phytophilous Cladocerans (Crustacea, Anomopoda and Ctenopoda) from Parana˜ River Valley, Goia´s, Brazil. *Rev. Bras. Zool*., **24** (2):344–52.

Ferenc, C. V., Horvath, K. K., Katalin, J.T. and Forró, L. (2012). Seasonal dynamics and composition of cladoceran and copepoda assemblages in ponds of a Hungarian cutaway peat land. *Inter. Rev. Hydrobiol*., **97**: 420–434.

Fernando, C. H. (2002). A *guide to tropical fresh water zooplankton*: Identification ecology and impacts on fisheries. Backhuys, Leiden. Pp 290.

Ferrão-Filho, A. S., Arcifa, M. S. and Fileto, C. (2003). Resource limitation and food quality for cladocerans in a tropical Brazilian lake**.** *Hydrobiologia*, **491**:201-210.

Figuerola, J. and Green, A. J. (2002). Dispersal of aquatic organisms by waterbirds: a review of past research and priorities for future studies. *Freshwat. Biol.*, **47**: 483–494.

Fitter, R. and Manuel, R. (1986). *Field guide to the freshwater life of Britain and North- West Europe*, Collins, Grafton Street, London.

Flinkman, J., Vuorinen, I. and Aro, E. (1998). Planktivorous Baltic herring (*Clupea harengus*) preyselectively on reproducing copepods and cladocerans. *Can. J. Fish. Aquat. Sci.*, **49**: 73–77.

Forro, L., Korovchinsky, N. M., Kotov, A. A. and Petrusek, A. (2008). Global diversity of cladocerans (Cladocera; Crustacea)in freshwater. *Hydrobiologia*, **595**:177–184.

Fresner, R. and Sampl, H. (1995). Population dynamics of plankton organisms in gravel ponds. *Inter. Assoc. Theor. Appl.Limnol.*, **26** (4):1926-1930.

Fryer, G. (1985). Crustacean diversity in relation to the size of water bodies: some facts and problems. *Freshwat.Biol.*, **15**: 347-361.

Fryer, G. (1993). *The freshwater Crustacea of Yorkshire: a faunistic and ecological survey,* Titus Wilson and Son, Kendal.

Gaikwad, S.R., Ingle ,K.N. and Thorat, S.R. (2008). Study of zooplankton patter and resting egg diversity of recently dried waterbodies in north Maharashtra region. *J. Environ. Biol.*, **29**: 353-356

Galat, D.L. and Robinson, R. (1983). Predicted effects of increasing salinity on the crustacean zooplankton community of Pyramid Lake, Nevada. *Hydrobiologia*, **105**:115-131.

Ge´linas, M. and Pinel-Alloul, B. (2008). Relating crustacean zooplankton community structure to residential development and land-cover disturbance near Canadian Shield lakes. *Can. J.Fish. Aqua.Sci.*, **65**: 2689–2702.

Green, A.J., Fuentes, C., Moreno-Ostos, E. and Rodrigues da Silva, S.L. (2005). Factors influencing cladoceran abundance and species richness in brackish lakes in Eastern Spain. *Ann. Limnol. Int. J. Lim.*, **41** (2):73-81.

Gyllström, M. (2004). Induction and termination of diapause in a freshwater zooplankton community. *Arch. Hydrobiol*., **161**: 81–97.

Hamza, W., Bonacina, C. and Canale, C. (1995). Effects of water acidity and recovery on the viability of both *Daphnia longispina* (O.F. Muller) and *Dapnia obtusa* (Kurz) in Lake Orta (N. Italy). *Inter. Assoc.Theor. Appl. Limnol.*, **26** (4): 1936-1941.

Haney, J.F. and Hall, D.J. (1973). Sugar-coated *Daphnia*, Preservation technique for Cladocera. *Limnol. Oceanogr.*, **18**:331–333.

Hart, R. C. (2000). Comparative long-term periodicity of *Diaphanosoma excisum* in adjacent warm-water impoundments, with an evaluation of contributory factors. *Limnologie*, **27**: 1933– 1939.

Havel, J. E. and Shurin, J. B. (2004). Mechanisms, effects and scales of dispersal in freshwater zooplankton. *Limnol. Oceanogr.*, **49**: 1229-1238.

Havens, K. E., Raymond ,S. and Beaver, J. R. (2000). Dynamics of the exotic *Daphnia lumholtzii* and native macro-zooplankton in a subtropical chain-of-lakes in Florida, USA. *Freshwat. Biol.*, **45**:21–32.

Hayashi, M. (2004). Temperature-electrical conductivity relation of water for environmental monitoring and geophysical data inversion. *Envi. Moni. Ass.,**96:** 119–128.*

Imoobe, T. O. T. and Akoma, O. C. (2008). Assessment of Zooplankton Community Structure of the Bahir Dar Gulf of LakeTana, Ethiopia. *Ethio. J. Env. Stu. Mana*., **1**(2): 26-34..

Jeppesen, E., Jensen, M., Sondergaard, T. and Landkildehus, F. (2000). Trophic structure, species richness and biodiversity in Danish lakes: changes along a phosphorus gradient. *Freshwat. Biol.,* **45**: 201–218.

Jeppesen, E., Nõges, P., Davidson, T.A., Haberman, J., Nõges, T., Blank, K., Lauridsen, T.L., Søndergaard, M., Sayer, C., Laugaste, R., Johansson, L.S., Bjerring, R. and Amsinck, S.L. (2011). Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). *Hydrobiologia*, **676**: 279-297.

Jhingran, V. G. (1982). Fish and fisheries of India, New Delhi: Hindustan .Pp 268–269.

Jones, J.I., Moss, B., Eaton, J. and Young, J.O. (2000). Do submerged aquatic plants influence periphyton community composition for the benefit of invertebrate mutualists? *Freshwat. Biol.*, **43**:591-604.

Julies, E.M. and Kaholongo, I. (2013). Relationship between dissolved oxygen and the vertical and longitudinal distribution of zooplankton off the Namibian coast. *Int. Sci. Technol. J. Nam*., **1**(1):78-88.

Kerfoot, W. C. and Lynch, M. (1987). Branchiopod communities: Associations with planktivorous fish in space and time: In: W.C Kerfoot and A. Sih (eds), *Predation: Direct and indirect impacts on aquatic communities*.University Press of New England, Hanover, New Hampshire. Pp 367-378.

Kirsten, A. W. and Gophen, M. (1999). Factors which affect the abundance of an invasive cladoceran, *Daphnia lumholtzi*, in U.S. reservoirs. *Freshwat.Biol.*, **42**: 1-10.

Korhola, A. and Rautio, M. (2001). Cladocera and other brachiopod crustaceans. In: Smol JP, Birks HJB, Last WM (eds) Tracking environmental change using lake sediments 4: zoological indicators. Kluwer, Dordrecht, Pp 5–41.

Korovchinsky, N. and Smirnov, N. (1996). Introduction to the cladocera (Daphniiformes, Polyphemiformes and Leptodoriformes). Universiteit Ghent, Belgium.

Korovchinsky, N. M. (1997). On the history of studies on cladoceran taxonomy and morphology, with emphasis on early work and causes of insufficient knowledge of the diversity of the group. *Hydrobiologia*, **360**: 1–11.

Korponai, J., Matyas, K., Paulovits, G., Tatrai, I. and Kovacs, N. (1997). The effect of different fish communities on the cladoceran plankton assemblages of the Kis-Balaton reservoir Hungary. *Hydrobiologia*, **360**: 211-221.

Kotov, A. A. (2006). Adaptations of Anomopoda Crustaceans (Cladocera) to the benthic mode of life. *Entom.Rev.*, **86**(2): 210‑225.

Kotov, A. A. and Stifter, P. (2006). Ilyocryptidae of the World. In: Dumont H. J. (ed.). Guides to the Identification of the Micro invertebrates of the Continental Waters of the World 22. Kenobi Productions, Ghent and Backhuys Publishers, Leiden.

Kotov, A.A. and Taylor, D. J. (2010). A new African lineage of the *Daphnia obtusa* group (Cladocera: Daphniidae) disrupts continental vicariance patterns. *J. Plan. Rese*.,**32**: 937–949.

Krebs, C. J. (1994). *Ecology: Experimental Analyses of Distribution and Abundance.* (Fourth edition), Harper Collins, New York. Pp 801.

Kuczyńska-Kippen, N. and Nagengast, B. (2006). The influence of the spatial structure of hydro macrophytes and differentiating habitat on the structure of rotifera and cladoceran communities. *Hydrobiologia*, **559**: 203-212.

Kumar, S., Srivastava, A. and Chakrabarti, R. (2005). Study of digestive proteinases and proteinase inhibitors of *Daphnia carinata*. *Aquaculture*, **243**: 367–372.

Kurbatova, S. A. (2005). Response of microcosm zooplankton to acitification.*Izv.Akad. Nauk. Ser. Biol.*, **1**:100-108 .

Laforsch, C., Beccara, L. and Tollrian, R. (2006). Inducible defenses: the relevance of chemical alarm cues in *Daphnia*. *Limnol. Oceanogr.*, **51**: 1466-1472.

Laforsch, C., Ngwa, W., Grill, W. and Tollrian, R. (2004). An acoustic microscopy technique reveals hidden morphological defenses in *Daphnia*. USA. *Natl. Acad. Sci*., **101**: 15911-15914.

Lampert, W. (1989). The adaptive significance of diel vertical migration of zooplankton. *Funct. Ecol*., **3**: 21-27.

Lampert, W. (2005). Vertical distribution of zooplankton: density dependence and evidence for an ideal free distribution with costs. *BMC, Biology*, **3** (10): 1-12.

Larsson, P. and Lampert, W. (2011). Experimental evidence of a low-oxygen refuge for large zooplankton. *Limnol. Oceanogr.*, **56**(5):1682-1688.

Lee, A.S. (2007). Responses of zooplankton community structure and ecosystem function to the invasion of an invertebrate predator *by thotrephes longimanus.* PhD.Thesis, Queen's University, Kingston, Ontario, Canada. Pp 253.

Lemma, B., Benndorf, J. and Koschel, R. (2001). Fish predation pressure on and interactions between Cladocerans: Observations using enclosures in three temperate lakes (Germany) and one tropical lake (Ethiopia). *Limnologica*, **31**: 209-220.

Louette, G., De Meester , L. and Declerck, S. (2008). Assembly of zooplankton communities in newly created ponds. *Freshwat. Biol*.,**53**: 2309–2320.

Macan, T.T. (1973). *Ponds and Lakes,* George Allen and Unwin Ltd, London.

Mahar, S.I., Jafri, H. and Baloch, W.A. (2008). Seasonal variation and species composition of crustacean zooplankton (order: cladocera) in manchhar lake. *Pakis. J. Zool.,* **40**(2): 65-68.

Majagi, S.and Vijaykumar, K. (2009). Ecology and abundance of zooplankton in Karanja reservoir. *Env.Moni.Ass*., **152**:451–458.

Margalef, R. (1968). Perspectives in ecology theory. Univ. Chicago press, Chicago, Pp 111.

Martin-Creuzburg, D., Wacker, A. and von Elert, E. (2005). Life history consequences of sterol availability in the aquatic keystone species *Daphnia*. *Oecologia*, **144**: 362–372.

Matsumura-Tundisi, T. and Tundisi, J. G. (2005). Plankton richness in a eutrophic reservoir (Barra Bonita Reservoir, SP, Brazil).*Hydrobiologia*, **542**(1): 367-378.

Mengistou, S. and Fernando, C.H. (1991). Species composition, distribution and seasonal dynamics of Rotifera in Rift Valley Lake in Ethiopia (Lake Awasa). *Hydrobiologia*, **209**:203-214.

Mergeay, J., Verschuren, D. and De Meester, L. (2006). Invasion of an asexual American water flea clone throughout Africa and rapid displacement of a native sibling species. *Proc. Roy. Soc., Biol. Sci.*, **273**:2839–2844.

Meschiatti, A. J. and Arcifa, M. S. (2002). Early life stages of fish and the relationships withzooplankton in a tropical Brazilian Reservoir, Lake Monte Alegre. *Braz.J.Biol.* **62**(1): 41-50.

Michael, R. G. and Sharma, B. K. (1987). Fauna of India and adjacent countries. Indian cladocera (Crustacea : Branchipoda : Cladocera), Zoological survey of India.

Moore, M.V., Folt, C.L. and Stemberger, R.S. (1996). Consequences of elevated temperatures for zooplankton assemblages in temperate lakes. *Arch. Hydrobiol.*, **135**:289–319.

Morgan, N. C., Backiel, G., Bretscko, A., Duncan, A., Hillbricht- Ilkowska, Z., Kajak, J. F., Kitchell, P., Larsson, C., Leveque, A., Nauwerck, F., Schiemer and Thorpe, J. E. (1980). Secondary production. **In**: *The functioning of freshwater ecosystems*. Le Cren, E. D. and Lowe-McConnell, R. H. (eds). I.B.P. No. 22: Cambridge University Press. Cambridge. Pp 247-340.

Nevalainen, L., Luoto, T. P., Kultti, S. and Sarmaja, K. K. (2013). Spatio-temporal distribution of sedimentary Cladocera (Crustacea: Branchiopoda) in relation to climate. *J. Biogeogr.*,**40**:1548–1559.

Nevalainen, L. (2008). Sexual reproduction inchydorid cladocerans (Anomopoda,Chydoridae) in southern Finland:implications for paleolimnology.Ph.D.Thesis,University of Helsinki, *Kumpula*, Finland. Pp 55.

Neves, I.F., Rocha, O., Roche, K..F. and Pinto, A.A. (2003). Zooplankton community structure of two marginal lakes of the River Cuiaba (Matograsso, Brazil) with analysis of rotifer and cladocera diversity. *Braz. J. Biol.*, **63**(3): 329-343.

Ngirinshuti, L. (2011). Seasonal variations in the abundance of zooplankton in the northern basin of Lake Kivu. BS.c.Theis, Huye, Pp 32.

Nielsen, D., Brook, M,, Rees, G. and Baldwin, D.(2003). Effect of increasing salinity on fresh water ecosystem in Australia. *Aust. J.Bot.*, **51**:655-665.

Norman, L., Davidson, J., William, E. and Rutherford, A.D. (1998). Relationships between environmental variables and the abundance of cladocerans and copepods in the Atchafalaya River Basin. *Hydrobiologia*, **379**: 175–181.

Okogwu, I. O. (2010). Seasonal variations of species composition and abundance of zooplanktonin Ehoma Lake, a floodplain lake in Nigeria. *Rev. Biol. Trop.*, **58** (1): 171-182.

Omori, M. and Ikeda, T. (1984). Methods in Marine Zooplankton Ecology. Wiley and Sons,New York., Pp 103.

Onyema, I.C. and Ojo, A.A. (2008). The zooplankton and phytoplankton biomass in a tropical creek, in relation to water quality indices. Akoka, Nigeria. *Life. Sci. J.*, **5**(4):1-82.

Orrock, J.L. and Fletcher, R.J. (2005). Changes in community size affect the outcome of competition. *Amer.Natur.*, **166**:107–111.

Osam, P. S. (2008). Seasonal and Interannual Variability of Pelagic Zooplankton Community Structure and Secondary Production in Lake Bosumtwi Impact Crater, Ghana.PhD Thesis, Kwame Nkrumah University of Science and Technology, Pp 240.

Paterson, M. (1993). The distribution of microcrustacea in the littoral-zone of a freshwater lake. *Hydrobiologia*, **83**: 167-170.

Pawar, S.K. and Pulley, J.S. (2005). Qualitative and quantitative study of zooplankton in Pethwadoj dam, Nanded district (Maharashtra), India. *J. Aqua. Biol.*, **20**: 53-57.

Peretyatko, A., Tessier,S., De Backer ,S. and Triest, L. (2009). Restoration potential of biomanipulation for eutrophic peri-urban ponds: the role of zooplankton size and submerged macrophyte cover. *Hydrobiologia*, **634**: 125–135.

Perumal, V.N., Rajkumar, M., Perumal, P. and Thillai Rajasekar, K. (2009). Seasonal Variations of plankton diversity in the kaduviyar estuary, Nagapattinam, Southeast coast of India. *J. Envi. Biol.*, **30**(6):1035-1046.

Pielou, E.C. (1966). Shannon 's formula as measure of specific diversity: Its use and misuse. *Am. Nat.*, **100**: 463-465.

Primicerio, R. (2000). Seasonal changes in Vertical Distribution of Zooplankton in an Oligotrophic, Subarctic Lake (Lake Takvatn, Norway). *Limnologica*, **30**: 301-310.

Rajagopal, T., Thangamani,A., Sevarkodiyone,S.P., Sekar, M. and Archunan, G. (2010). Zooplankton diversity and physic-chemical conditions in three perennial ponds of Virudhunagar district Tamilnadu. *J.Envi. Biol*., **31**:265-272.

Rao, K. J. (1986). Studies on the seasonal and diel variations in some physico-chemical condition of a pond under prawn culture. *Proc. Nat. Symp. Fish .Env*., Pp 96-102.

Rautio, M. (1998). Community structure of crustacean zooplankton in subarctic ponds effects of altitude and physical heterogeneity. *Ecography*, **21** (3): 327-335.

Ricardo, A. G., Serafim, M. J., Perbiche, G. N. and Debrito, L. (2009). Distribution of planktonic cladocerans (Crustacea: Branchiopoda) of a shallow eutrophic reservoir (Paraná State, Brazil). *Pan.Am. J.Aquat.Sci*., **4**(3): 294-305.

Riessen, H.P. (1999). Predator-induced life history shifts in *Daphnia*: a synthesis of studies using meta-analysis. *Can. J. Fish. Aquat. Sci*., **56**: 2487-2494.

Rivier, I. K. (1998). *The Predatory Cladocera (Onychopoda: Podonidae, Polyphemidae, Cercopagidae) and Leptodorida of the World*. Backhuys Publishers Leiden, the Netherlands.

Romanovsk, Y. E. and Feniova, I. Y. (1985). Competition among Cladocera: effect of different levelsof food supply. *Oikos*, **44**: 243–252.

Sampaio, E. V., Rocha, O., Matsumura-Tundisi, T. and Tundisi, J. G. (2002). Composition and abundance of zooplankton in the limneticzone of seven reservoir of Paranapanema River, Brazil. *Braz. J. Biol*., **62**(3): 525-545.

Santos-Flores, C. J. and Dodson, S. I. (2003). Dumontia oregonensis a cladoceran representing a new family of 'water-fleas' (Crustacea, Anomopoda) from U.S.A., with notes on the classification of the Order Anomopoda. *Hydrobiologia*, **500**: 145–155.

Sarma, S.S.S., Nandini, S. and Gulati, R.D. (2005). Life history strategies of cladocerans: comparisons of tropical and temperate taxa, *Hydrobiologia*, **542**:315–333.

Sarnelle, O. (2005). *Daphnia* as keystone predators: effects on phytoplankton diversity and grazing resistance. *J. Phytopl. Res*., **27**: 1229-1238.

Sayer, C.D., Davidson, T., Jones, J.I. and Langdon, P.G. (2010). Combining contemporary ecology and palaeolimnology to understand shallow lake ecosystem change. *Freshwat.Biol*., **55**:487–499.

Scheffer, M., van Geest, G. J. K., Zimmer, E., Jeppesen, M. Sondergaard, M. G., Butler, M., Hanson, S. and De Meester, L. (2006). Small habitat size and isolation promote species richness: second-order effects on biodiversity in shallow lakes and ponds. *Oikos*,**112**: 227–231.

Serrano, L. and Toja, J. (1995). Interannual variability in the zooplankton community of a shallow temporary pond. *Inter. Assoc.Theor. Appl.Limnol.,* **26**(4):1575-1582.

Shannon, C.E. and Weiner, W. (1949). The mathematical theory of communication, Univ.Illinois press, Urbana, I, 11. Pp 117.

Sharma, B. K. and Sharma, S. (2008). Faunal diversity of Cladocera (Crustacea: Branchiopoda) of Deepor beel, Assam (Northeast India). *J. Bom.Nat.Hist.Soc.*, **105** (2):196–201.

Sharma, C., Prasad, R.T. and Tiwari, R.B. (2011). Studies on Cladoceran zooplanktonic population and their correlation coefficient with some physicochemical factors of Lony dam Theonthar, Rewa (M.P.). *Int.J. Phar. L. Sci.*,**2**(9): 1059-1061.

Sharma, V., Kumar, B.V., Sharma, R., Sudan, M. S. and Singh, K. G. (2012).A report on the freshwater Cladocera (Crustacea: Branchiopoda) of south Rajasthan (India). *Inter. J.Env.Sci*, **3**:1.

Shiddamallayya, N. and Pratima, M. (2008). Impact of domestic sewage on fresh water body. *J.Biol.*,**29**:303-308

Shurin, J.B., Havel, J.E., Liebold, M.A and Pinel-Alloul, B. (2000). Local and Regional Zooplankton Species Richness; a Scale Independent Test for Saturation. *Ecology*, **81**(11): 3062-3073.

Sinha, M. P., Kumar, R., Srivastava, R., Mishra, S. K. and Choudhuri, A. K. (2002). Ecotaxonomy and biomonitoring of lake for conservation and managemen 2nd edition. In: *Ecology and Conservation of Lakes, Reservoirs and Rivers* Biotic Profile. Pp 248-289.

Siokou-Frangou, I. and Papathanassiou, E. (1991). Differentiation of zooplankton populations in a polluted area. *Mar. Ecol. Prog. Ser.*, **76**: 41-51.

Smirnov, N. N., Kotov, A. A. and Coronel, J. (2006). Partial revision of the aduncus-like species of Pleuroxus Baird, 1843 (Chydoridae, Cladocera) from the southern hemisphere with comments of subgeneric differentiation within the genus. *J. Nat. Hist.*, **40**: 1617–1639.

Smith, V.H. and Schindler, D.W. (2009). Eutrophication: where we go from here? *Trends Ecol.Evol.*, **24**:201-207.

Smol, J.P. and Birks, H.J.B. (2001). *Tracking environmental change using lake sediments*, volume 4 zoological indicators. Boston: Lower Academic Publishers, Pp 217.

Solomon, S.G., Ataguba, G. A. and Baiyewunmi, A.S. (2009). Study of dry season zooplankton of Lower River Benue at Makurdi, Nigeria. *J. Anm. Plan.Sci.*,**1**(3): 42 - 50.

Sommer, U., Gliwicz, Z., Lampert, M. W. and Duncan, A. (1986). PEG-model of Seasonal Succession of Planktonic Events in Fresh Waters. *Arch. Hydrobiol.*, **106**: 433-471.

Sorf, M. and Devetter, M. (2011). Coupling of seasonal variations in the zooplankton community within the limnetic and littoral zones of a shallow pond. *Ann.Limno.Int. J.Limn*.,**47**: 259–268.

Sterner, R. (1994). Algal nutrient limitation and the nutrition of aquatic herbivores. *Annu. Rev .Ecol. Evols*.,**25**:1-29. .

Story, A., Richards, G., and Moore, R. D. (2008). Electrical Conductivity as an indicator of water chemistry and hydrologic process. *Wat.Mana.Bull.*, **11**:1-26.

Talling, J. F. and Lemoalle, J. (1998). *Ecological Dynamics of Tropical Inland Waters.* Cambridge University Press, Cambridge. Pp 452.

Tamire, G. and Mengistou, S. (2013). Zooplankton community grazing rates in a small crater lake: Lake Kuriftu, Ethiopia. *Ethio. J. Sci*., **36**(1):1–8.

Tanner, C.C., Craggs, R.J. Sukias ,J.P. and Park, J.B. (2005). Comparison of maturation ponds and constructed wetlands as the find stage of an advanced pond system. *Wat. Sci. Technol.,* **51**: 307-314.

Tariku, M. and Abebayehu , A. (2011). The driving forces of Boye wetland degradation and its bird species composition, Jimma, Southwestern Ethiopia. *J.Ecol.Nat.Env.,***3**(11):365-369.

Tessier, A. J. and Hortwitz, R. J. (1990). Influence of water chemistry on size structure of zooplankton assemblages. *Can. J.Fish. Aquat. Sci.,* **47**: 1937-1943.

Thorp, J.H. and Covich, A.P. (1991**)**. *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press, New York, NY.

Threlkeld, S.T. (1986). Resource-mediated demographic variation during the mid summersuccession of a cladoceran community. *Freshwat. Biol.,* **16**:673-683.

Ulloa, O. and Pantoja, S. (2009). The oxygen minimum zone of the eastern South Pacific Deep-sea. *Res.Pt.,* **56:** 987–991.

Van Damme, K. V., Kotov, A. A. and Dumont, H. J. (2010). A checklist of names in *Alona* Baird 1843 (Crustacea: Cladocera: Chydoridae) and their current status: an analysis of the taxonomy of a lump genus, Zootaxa, 2330, Pp 1–63.

Vanni, M. J. (1986). Competition in zooplankton communities: Suppression of small species by *Daphniapulex*. *Limnol. Oceanogr.,* **31**: 1039–1056.

Walseng, B., Hessen, D. O., Halvorsen, G. and Kristin, A.S. (2006). Major contribution from littoral crustaceans to zooplankton species richness in lakes. *Limnol. Oceanogr*., **51**(6): 2600–2606.

Weetman, D. and Atkinson, D. (2004). Evaluation of alternative hypotheses to explain temperature induced life history shifts in *Daphnia*. *J. Plank. Res.,* **26**:107–116.

Welch, P.S. (1952). *Limnology.* Mcgraw Hill Publications.

Wetzel, R. G. (1983). *Limnology*. Second edition. Saunders College Publishing, USA. Pp 980.

Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems. 3rd ed. Academic Press. N.Y. Pp 1006.

WHO (1996). *Guidelines for drinking water quality*. 2nd edition, volume 2. WHO Geneva.

WHO (1998). *Guidelines for Safe Recreational-Water Environments*.Vol. 1. Coastal and Fresh-Waters. World Health Organization,Geneva

Williams, P., M. Whitfield, J., Biggs, S., Bray, G., Fox, P. and Sear, D. (2004). Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape inSouthern England. *Biol.Con.,* **15**: 329–341.

Williams, W.D. (2001). Anthropogenic salinization of inland waters. *Hydro.Boil.,* **466**:329 -337.

Williamson, C. (1991). *Copepoda*, Thorp J.H. and Covich A.P (ed.). Ecology and Classification of North American freshwater invertebrates, Academic Press Inc, SanDiego, California, 92101.

Williamson, C. E., Sanders, R. W., Moeller, R. E. and Stutzman, P. L.(1996). Utilization of subsurface food resources for zooplankton reproduction: Implications for diel vertical migration theory. *Limnol. Oceanogr.,* **41**(2): 224-233.

Witty, L. M. (2004). *Practical guide to identifying freshwater crustacean zooplankton*: Cooperative freshwater ecology unit. Ontario, Canada, Pp 60.

Wodajo, K. and Belay, A. (1984). Species composition and seasonal abundance of zooplankton in two Ethiopian Rift Valley lakes, Lakes Abiata and Langano. *Hydrobiologia* ,**113**:129-136.

Yarwood, S. B. (2005). Cladoceran assemblages of small freshwater bodies in lowland England and Wales.PhD. Thesis, Oxford Brookes University, Pp 243.

8. APPENDICES

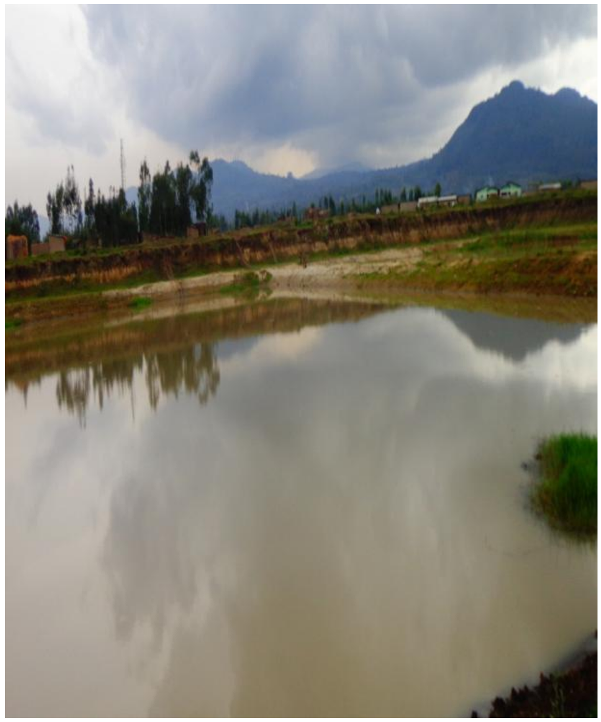
Appendix I: Cladoceran species mean body length and width (mm): The range for each variable is reported below the mean.

Species	Length	Width	N
Alona rectangula	0.4025	0.2513	5
	(0.37-0.44)	(0.23-0.27)	
Ceriodaphnia cornuta	0.3392	0.2067	5
	(0.29-0.40)	(0.17-0.24)	
Chydorous sphericus	0.2780	0.2160	5
	(0.24-0.32)	(0.18-0.24)	
Daiphanosoma excisum	0.7867	0.2673	5
	(0.72-0.92)	(0.22-0.38)	
Daphnia lumholtzi	0.6600	0.2900	5
	(0.64-0.68)	(0.26-0.32)	
Macrothrix laticornis	0.3922	0.2267	5
	(0.32-0.46)	(0.19-0.26)	
Moina micrura	0.6057	0.3967	5
	(0.55-0.74)	(0.32-0.49)	

Appendix II: The three study ponds

Pond I

Pond II



Pond III