Population Dynamics of Genus *Keratella* in Dal Lake, Kashmir

DISSERTATION

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By

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Certificate

Certified that the dissertation entitled **"Population Dynamics of Genus *Keratella* in Dal Lake, Kashmir"** submitted by **Mohd Shafi Bhat** for the award of **M.Phil.** Degree in Zoology, is based on original research work carried out by him under my supervision. This dissertation has not been submitted in part or in full, to any University/Institution for any degree. The candidate has fulfilled all the statutory requirements for the submission of the dissertation.

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Dedicated

To

My Beloved Parents

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ABSTRACT

Rotifera as a groups as well as a particular rotifer species are able to inhabit a variety of environments and are known to be mostly typically littoral forms. Rotifers are sensitive to changes in water quality through eutrophication process and play an important role in trophic dynamics of lake ecosystems. The community structure of rotifers within shallow and macrophyte dominated lakes is affected by a number of environmental factors. The valley of Kashmir is endowed with a unique geographical position. The valley is famous for its lakes, crystal clear tarns, mountains, snow and spring fed meadows and alpine forests. Kashmir is unique in India in having numerous lakes which grade from oligotrophic (Marsar, Vishensar, Sheshnag, Kishensar, Alpather, Kounsarnag etc), mesotrophic (Mansbal, Nilnag etc) and eutrophic (Dal, Anchar etc).The Dal lake is the second largest lake of Kashmir covering an area of about 11.56 sq km. The lake is surrounded by Zabarwan hills on three sides. It is a shallow open drainage type water body divided into five basins- Hazratbal basin, Gagribal basin, Nishat basin, Nigeen basin and Brarinambal basin. For the present study five sites were selected in different basin of the lake and each site represents ecologicaly different habitats in the lake. Site 1 was located near Telbal Nallah, Site 2 in Hazratbal basin, Site 3 in Nigeen basin, Site 4 near Centaur hotel in Nishat basin and Site 5 in Brarinambal basin. Water samples were collected for different physical, chemical and biological parameters on monthly basis form Jan. 2011 to Dec. 2011. Standard methods proposed by Welch (1984), APHA (1995), Mackereth *et al.* (1978) were employed for determination of physico-chemical parameters. Indentification of different zooplankton species was done with the help of standard taxonomic works by Edmondson (1959) and Pennak (1978).The Dal lake is in a state of stress and as a result ecological conditions have undergone tremendous changes. The present study was undertaken to study the population dynamics of rotifera with special reference to genus *Keratella*, other zooplankton associations and

physic-chemical environment. *Keratella* is an important genus of eurotatorian rotifers. Different species of genus *Keratella* can be distinguished on the basis of spination and sculpture of dorsal plate. In the present study only two species of *Keratella* were recorded i.e. *keratella cochlearis* and *Keratella quadrata*. *Keratella cochlearis* was the dominant one among two species.

Water temperature in the lake fluctuated from 3.5^{o}C to 26^{o}C and a close relationship was recorded between water temperature and air temperature. Transparency fluctuated form site to site and least transparency was found in Brarinambal. The lake was alkaline throughout the year as pH always remained above 7.0. Conductivity value ranged from 163µs/cm to 810µs/cm. Dissolved oxygen ranged from 0.8mg/l to 9.8m/l. Lower values were recorded during summer and higher during winter. Chloride concentration ranged from 11.9mg/l to 71.3mg/l. Total alkalinity ranged from 94.8mg/l to 360.9mg/l. No definite trend was recorded in ammonical nitrogen concentration throughout study period. The concentration of nitrate ranged from 72.1mg/l to 925.2mg/l. Nitrite nitrogen was present in low concentration. Increase in total phosphorous concentration indicates that lake is eutropic in nature and Brarinambal basin is in its advanced hypereutrophic stage. During present study a total of 42 other species of zooplankton were recorded of which 20 belonged to rotifera, 18 to cladocera and 4 to copepoda. On the basis of physico-chemical and biological features Brarinambal basin stands quite different from other basins in most of its limnolgical features.

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CHAPTER - 1

INTRODUCTION

Aquatic habitats are inhabited by a variety of living organisms. Of these planktonic communities respond quickly to environmental changes because of their short life cycle and hence their standing crop and species composition indicate the quality of water mass in which they live (APHA, 1985). The plankton is divisible into two interrelated components- Phytoplankton and zooplankton. Fresh water phytoplankton is overwhelmingly contributed by algae and bacteria while the zooplankton is mainly composed of rotifera, cladocera and copepoda.

Zooplankton form an important component of the secondary productivity in fresh water ecosystem and are the main link in the transfer of organic matter synthesized by the plants to the carnivorous invertebrates and vertebrates. The group acts as indicator of a variety of physico-chemical and biological conditions in lakes and is often good indicator of stressed/polluted conditions. Zooplankton often exhibit dramatic changes in response to changes in physico-chemical properties of the aquatic environments.

Rotifers as a group as well as particular rotifer species are able to inhabit a variety of environments and they are known to be mostly typically littoral forms (Pejler, 1995). The community structure of this group of animals within shallow and macrophyte dominated lakes is affected by a number of environmental factors. Apart from the nutritional source availability and invertebrate and vertebrate predator avoidance which belong to one of the most important factors shaping rotifer distribution between particular zones of the lake, the different habitat conditions provide certain suitability for different ecological types of organisms (Preissler, 1977) and thereby compelling the evolution of morphological adaptations of rotifers for inhabiting littoral or pelagic habitats (Preissler, 1983).

Rotifers are sensitive to changes in water quality through eutrophication process (Gannon and Stemberger, 1978; Pejler, 1983) and play an important role in trophic dynamics in lake ecosystems (Gilbert and Bogdan, 1984).

Rotifera has been one of the most extensively studied group of freshwater zooplankton for its role as indicator of trophic status. Several species like *Asplanchna priodonta, kellicotia longispina* have been associated with oligotrophic conditions (Pandit, 1992), while many others like *keratella cochlearis, Brachionus calyciflorus, B. plicatilis, B. quadridentata, Filinia longiseta* have been treated as true representatives of eutrophic and hypereutrophic waters (Gannon and Stemberger, 1978; Pandit, 1992).

The valley of Kashmir is endowed with a unique geographical position. The valley is famous for its lakes, crystal clear tarns, mountains, snow and spring fed meadows and alpine forests. The most fascinating character that nature has gifted it is its water resources. Kashmir is unique in India in having numerous lakes which grade from oligotrophic (Marsar, Vishensar, sheshnag, Kishensar, Alpather, Kounsarnag etc.), mesotrophic (Mansbal, Nilnag etc.) and eutrophic (Dal, Anchar etc.).

The Dal Lake is the second largest lake of Kashmir covering an area of about 11.56 sq. km. The lake is surrounded by Zabarwan hills on three sides. It is situated between $34^{o}5'$ – $34^{o}6'$ N latitude and $74^{o}8'$ – $74^{o}9'$E longitude. It is a shallow open drainage type water body divided into five basins- The Hazratbal basin, The Gagribal, The Nishat, The Nigeen and The Brarinambal basin which are interconnected. The main sources of water for the lake are Telbal Nallah, a perennial stream which brings water from a high altitude lake, Marsar draining Dachigam in the east of the lake from its northern end and Botkol, draining water mainly from the northern and north western catchments. Besides, a number of other small streams (Meerakshah and Pishpav streamlets) also enter into the Hazratbal basin, innumerable spring arising from bottom of the lake (Kundengar, *et al.*, 1995) and surface runoff from surrounding mountains from

Nishat and Gagribal side. Besides this a number of ephemeral channels also enter the lake from home settlements. Excess water flows out through weir and lock system at Dalgate and falls into river Jhelum. Part of the water flows out through Nallah Amir Khan which connects Nigeen basin with Anchar lake via Khushhal Sar. A good portion of the lake is covered by floating gardens. The Dal Lake has been receiving large quantities of organic wastes and its water quality has deteriorated greatly during past fifty years.

There have been a number of studies on this water body from time to time (Hutchinson, 1937; Keifer, 1939; Kaul, 1977; Zutshi and Vass, 1978; Trisal, C.L, 1985; Parveen, 1988; Yousuf and Parveen, 1992; Parveen and Yousuf, 1999; Jamila, 2003; Siraj, 2003). Still there is a great scope of more research in this field due to continuous changes in the aquatic habitat. Since the lake has been reported to show phenomenal changes in biotic communities, it was decided to have a year long study on the ecology of rotifera in the lake with special emphasis on *Keratella* group. The data obtained during the study are presented in the form of present dissertation.

CHAPTER - 2

REVIEW OF LITERATURE

The interest of man in aquatic life for one reason or the other dates back to late 19th century. Right from the late 19th century limnological studies attracted many workers in Europe as well as North America. During 20th century, the limnology got well established as a separate branch of science. In the second half of the 20th century a bulk of research work was carried out and many different aquatic habitats were investigated for their physical, chemical and biological features. As a result of ever increasing number of research works, an immense literature got accumulated. In the following pages a brief review of the world literature published of the last 30 years is printed.

Limnology outside India

Forsyth and McColl (1980) reported on the zooplankton of lake Tenpo, New Zealand. They concluded that *Boeckella Propingua* was the most common crustacean and the rotifers were dominated by *Polyarthra vulgaris.*

Moss (1980) reported that zooplankton are very valuable indicator not only of water pollution but also assessment of their effect on the total aquatic ecosystem.

Lair (1980) studied the effect of heated effluents of nuclear power plant on river Loire and found rotifers to be abundant followed by cladocera but copepoda was rare.

Sent (1981) conducted studies on Grapham water reservoir and found zooplankton to be affected by physical variables and macronutrients.

Stenson (1982) investigated the effect of reduction of fish population on rotifer abundance and found that larger species e.g., *Asplanchna priodonta* and *Conochilus unicornis* and grasping sp. e.g., *Gastropus stylifer* and *Ascomorpha* sp. became more abundant while smaller filter feeders e.g., *Keratella cochlearis* decreased after an experimental reduction of the fish population.

May (1983) conducted studies on the relationship between rotifer's occurrence and water temperature in Loch leven and concluded that there were main categories of rotifer species on the basis of response to water temperature which were named as strict stenotherms, warm and cold adopted eurytherms and lastly true eurytherms.

Maements (1983) found that rotifer species such as *keratella serrulata, Synchaeta grandis, Asplanchna herricki* to be good indicators of oligotrophic and mesotrophic lakes, while *Trichocerca capucina, Filinia longiseta, Filinia limnetica, K. quadrata, K. cochlearis tecta* were indicators of meso and eutrophic lakes.

Evans (1984) discussed the relationship of some water chemistry parameters with total rotifer density and densities of major genera and found that the abundance of the rotifers and major genera were positively correlated with alkalinity and negatively correlated with manganese. He also found that rotifer density was correlated with maximum and minimum monthly sediment temperature.

Soom (1984) reported about 140 species of zooplankton from Thailand. Out of these 80 belonged to Rotifers, 48 to Cladocera, 12 to Copepods, 1 to Ostracoda, 1 to Branchiura. They recorded 102 species from lentic environment, 34 from lotic and 21 from both.

Milstein and Juanico (1985) studied zooplankton dynamics in an estuarine area and found that zooplankton numbers ranged from 50 ind.m^{-3} to 15600 ind.m^{-3}, the annual mean being 3900ind.m^{-3}. They also found copepods to be dominant zooplankton all the year round, meroplankton in summer and the cladoceran *Pleopis polyphemoides* in late fall winter.

Green (1986) while studying the zooplankton associations in five Ethiopian crater lakes found the least alkaline lakes to have the most diverse zooplankton.

Turner (1986) carried sampling at ten locations from North Korea and recorded about 22 new rotifers. He also found *Keratella hiemalis* for the first time from Asia.

Egborge and Tawari (1987) took study of the rotifers of the Warri river, Nigeria and identified about 41 species of rotifers of which 65% were cosmopolitan and 20% were pantropical. The dominant ones being *Keratella tropica* and *Keratella cochlearis*. They also found temperature and conductivity to be low in rainy season and high in dry season months.

Walz *et al.* (1987) made a comparative study of population dynamics of rotifers, *Brachionus angularis* and *Keratella cochlearis* and reported that both rotifers have different life history strategies. *Brachionus angularis* appears to be r-strategist showing higher reproductive mortality and population growth rates than *Keratella cochlearis* which is k-strategist with lower growth rate.

Hofmann (1987) studied the relationship between the hypolimnetic rotifer assemblages and its environment. He also reported that rotifers like *Keratella hiemalis, Filinia terminalis, Filina hofmani* responded in a similar way to temperature changes, O_2 concentration and food availability.

Laxhuber (1987) while investigating the rotifer community structure of the oligotrophic alpine lake Konigssee, recorded twenty different species including several cold stenothermal and oligotrophic sps. of which *Polyarthra vulgaris, Kellicottia longispina* and *Keratella cochlearis* were the most abundant species throughout the year.

Malley *et al.* (1988) while studying the zooplankton community of a small Precambrian shield lake by the addition of nutrients. They reported that in less severe conditions the Cladocera capable of rigid reproduction and the

Copepods responded immediately which suggested that they were controlled directly by the chemical conditions. They also found that Cyclopoids were slightly better able to withstand the stressful conditions than Cladcerans and Calanoids.

Ernst Mikschi (1989) investigated a small lake Lunzerobersee, a small lake located at an attitude of 1100 m above sea level and reported the rotifer community to consist of 7 dominant species, 7 subdominant species and 14 species which occasionally occurred in the plankton. The dominant species showed different demands in relation to temperature and oxygen content.

Radwan and Popiolek (1989) reported on the indicators of eutrophication and human activities in lakes of Eastern Poland and concluded that rotifers are good indicators of eutrophication (*Keratella cochlearistecta* and *Keratella quadrata*). They also observed *Conochilus unicornus* and *Kellicotia longispina* prefer the mesotrophic lakes whereas *Daphnia* and *Bosmina* prefered the lakes subjected to intense human activities.

Morales–Baquero *et al.* (1989) discussed the effects of pH, conductivity and mineralization on the rotifer communities in Lakes of Sierra Nevada (Southern Spain) and found pH to show less influence on the rotifer communities but mineralization has a profound influence on the community. They also observed that low conductivity lakes yield greater densities of planktonic species where as high conductivity lakes contained predominantly benthic and periphytic species.

Gulati (1990) studied three shallow and highly eutrophic lakes in the Loosdrecht area (The Netherlands) and reported *Keratella cochlearis* and *A. fissa t*o be the dominant rotifers which indicated the highly eutrophic condition in the lake. He also observed the crustacean Zooplankton which coincide with the rotifers abundance to be *Bosmina coregoni.* He also reported cyclopoids and copepods appeared to prefer food in a size range much larger than that of bacteria.

Gophan *et al.* (1990) while working on the zooplankton density in lake Kinneret, suggested that the observed changes in zooplankton communities was as a result of an increase of predation pressure produced by particulate and filter feeding fishes.

Mangestou *et al*. (1991) studied the species composition of rotifers in Lake Awasa and recorded about 40 rotifer species among which *Brachionus* and *Keratella* species contributed more than 50% and showed the seasonal pattern.

Havens (1991) recorded low species richness and biomass for limnetic zooplankton. Rotifera were reported to be dominated by *kellicottia bosteniensis* and *Polyarthra vulgaris*.

Lair (1991) studied grazing and assimilation rates of natural population of planktonic Cladocerans in eutrophic Lake and reported that in eutrophic conditions *Daphnia longispina* appears to be more efficient in energy utilization than other cladocerans. Some individuals of *Daphinia* and *Chydorus* continued to filter in the zone of low oxygen where an important biomass had developed.

Osore (1992) conducted survey on zooplankton composition both qualitatively and quantitatively and reported that zooplankton population are highest in March (374 ind./m^3), lowest in August (30 ind./m^3). They also found that the trend in temperature variation corresponds broadly with zooplankton abundance suggesting that zooplankton thrives best in warm water.

Neumann-Lietao *et al.* (1992) carried out limnological investigations on the estuarine area of Snape (Pernambuco Brazil) and found that the abundance of rotifers at Tipojuca river resulted in the decrease in oxygen concentration. They also found *Brachionus* to dominate the sample.

Shaw and Kelso (1992) carried out analysis to determine how well Lake characteristics (Lake size, Lake location and buffering capacity) could predict zooplankton community types and found that Lake size was limited though larger lakes tended to support more species. Lake location (Zoogeography) also influenced species composition/patterns. Buffering capacity was ranked third in the discriminant analysis models but pH and alkalinity were not significantly different between Lake groups.

Lair *et al*. (1993) found the density of macrophytes to affect the number of zooplankton. The number of small sized crustaceans perunit space was much in macrophyte thickets than in littoral regions which are free from macrophytic vegetation.

Elenbaas and Grundel (1994) studied the composition and abundance of the main zooplankton groups in Cleveland Dam(less eutrophic) and Lake Chivero (more eutrophic). They found the zooplankton density to be lowest in winter (Dec. and Feb.) after which it increased and reached a peak during summer (Aug.), mainly because of the increase in the rotifers and Nauplii. They also observed that cladocera was the main zooplankton group in winter making up 62% of the population in Cleveland dam in Dec. and Feb. and in Lake Chivero 49% of the plankton in June.

Ovie and Adeniji (1994) studied the newly created Shiroro lake (Nigeria) and reported that pH, dissolved Oxygen, Turbidity and Suspended solids were highest during high water level where as transparency, conductivity, NO_3-N, PO_4^{3-}_ P and Na^+ were higher during low water level. They also reported a total of 26 species of pelagic zooplankton of which 5 species belonged to cladocera, 8 to copepoda, and 13 to rotifera.

Walz (1995) discussed the impact of quantities and qualities of food predation on the rotifer population and found that in higher food concentration, rotifers may exhibit maximum growth rates. He also observed rotifers to be controlled by predators especially by copepods or mechanical interference by Daphnids.

Van-Dijk and Zanten (1995) worked on the zooplankton in the river Rhine and reported low abundance of zooplankton in winter. They also found zooplankton to be dominated by rotifers-*Brachionus angularis, Brachionus calyciflorus* and *Keratella quadrata.*

Danielids *et al.* (1996) studied limnological characteristic of the Lake Amvarika, a deep warm monomictic lake in western Greece and compared trophic status of the lake to that of other temperate and tropical lakes.

Ping *et al.* (1996) carried out comparative studies on community structure and biodiversity of rotifers and copepods with relation to different trophic levels (mesotrophic, eutrophic and hypereutrophic) in lake Donghu and reported that higher the trophic level of the lake water lower the species diversity.

Yan and Xiangfei (1997) worked on the Dongting Lake (China) and identified about 136 taxa of rotifers, of these one (*Keratella wangi*; n. sp.) is new to Science, thirty four are new records for China.

Milius and Henno (1997) carried out researches on trophic state of small Estonian lakes. Lakes of various type in Estonia were used in developing a trophic state index which was based on the content of total phosphorous, chlorophyll- a and water transparency. Total phosphorous was chosen as basic parameter.

Guntzel *et al.* (1998) discussed the relationship between zooplankton community and the trophic state of a small, shallow water body located in the northern coastal plain of Rio-Grande de-sul state, Brazil. They found rotifers to be main indicators of the trophic status followed by copepods and the cladocera.

Salmaso *et al.* (1999) carried out studies on the zooplankton of the deep subalpine lake Garda and reported the assemblage to be largely dominated by *Copipodiaptomus steuri*. They also observed a significant component of

Zooplankton from spring to autumn to be constituted by cladocera and small rotifers.

Jappenson *et al.* (1999) studied trophic dynamics in turbid and clear water Lakes with special emphasis on the role of zooplankton for water quality. They suggested that zooplankton by grazing on phytoplankton play a major role in maintaining clear water conditions in eutrophic macrophyte rich lakes, particularly during summer.

Butler *et al.* (2000) while studying temporal plankton dynamics in oligotrophic Maritime Antarctica Lake observed that the population density, diversity, productivity of the microbial plankton, concentration of nutrients and dissolved organic carbon were uniformly low with temperature varying over a small range of 0.1-3^{o}C. They also reported the marked seasonal and interannual variations in the plankton population density.

Armengol and Miraile (2000) observed diel vertical movements of zooplankton in lake Cruz (Spain).

Duggon *et al.* (2001) investigated the distribution and ecology of planktonic rotifers in 33 lakes in North Island (New Zealand) and identified about 79 species of Monogonont rotifers with an average of 21 species per lake. They also found most species to be widespread in their distribution over the North Island.

Chittapun *et al.* (2002) studied rotifer diversity in a peat-swamp in Southern Thailand (Narathiwas province) with the description of a new species of *Keratella* bory de st Vincent and recorded a total of sixty-seven species of rotifers. Of these *Keratella mixta*, *Lecane enowi* and *Monommata dentata* were new to oriental region and Thai fauna and *Keratella taksinensis* is new to Science.

Neves *et al.* (2003) while studying two small lakes on the margins of river Cuiaba recorded 79 Rotifer, 30 cladoceran and 6 copepod taxa out of which, 9 species of cladocera, 6 copepoda and 14 of rotifera were new records for this region. They also compared the zooplankton population of both lakes and found that rotifer and cladocera to be rich in lake Souza Lima during rainy season due to dense growth of macrophytes towards the littoral region. They also linked low density of rotifers in lake park Atalaia due to domestic sewage input.

Aziz *et al.* (2004) studied the structure of zooplankton community in lake Maryout, Alexandria, Egypt, and identified a total of 112 species of Zooplankton dominated by Rotifers (68.9%) followed by cladocera (5.8%) and copepoda (3.1%). They also reported that the main basin was characterized by low salinity, low oxygen content and it was also seen to harbour the highest number of species and densest population.

Waya *et al.* (2004) made an attempt to study species composition and biomass estimates of zooplankton in some water bodies within lake Victoria basin. They observed zooplankton community to comprise mainly of rotifers and crustacean represented by 28 species and 31 species respectively. They also recorded higher biomass in wet season.

Baloch *et al.* (2005) analysed spring zooplankton composition of Rawal Lake, Islamabad and reported the water to be alkaline (pH 7.7) and TDS value 2008 mg/litre. The Zooplankton community was dominated by rotifers, represented by 10 species of which *Pompholyx complanta* was most abundant. They concluded that this lake is mesotrophic and gradually changing to eutrophic state.

Kuczynska-Kippen (2006) studied the zooplankton structure in architecturally differentiated macrophytic habitats of shallow lakes in the Wielkopolska region, Poland. Low value of zooplankton species richness were recorded in open water zone and highest was recorded among macrophyte thickets. He also reported *Chara* bed to play an important role in determining the high densities of zooplankton.

Adel Ali. A. Mageed (2007) carried out investigation on the distribution and long term historical changes of zooplankton assemblages in Lake Manzala (South mediterranean Sea, Egypt) and reported that the Lake Manzala has changed from marine ecosystem to eutrophic, nearly freshwater system with the dominance of rotifers. Twenty new zooplankton taxa were recorded for the first time in the lake during study while 13 taxa disappeared in the last fifty years.

Ravera *et al.* (2007) reported that nutrient enrichment of a water body influences all the physical, chemical and biological characteristics of an ecosystem. They also recorded abundance of food and increase in population density of fish to be favourable for the Molluscan population while factors like depletion in oxygen level and toxic concentration of nitrates and ammonia to be dangerous for same.

Kuczynska-Kippen (2007) studied the occurrence of *Keratella cochlearis (Gosse)* in relation to season and station in a shallow macrophyte dominated lake and observed a significant difference in occurrence of *Kerallela cochlearis* between season and habitat. The densities of *K. cochlearis* ranged between 3 and 3680 ind.1^{-1}(mean 300±595) and differed between sampling stations.

Andrzej Demetraki-Paleolog (2008) carried out investigation on the distribution of planktonic rotifer communities in special angling site lake Skomielwo. The result showed the presence of 47 rotifer species with mean density ranging from 185 to 245 ind./dm^{-3}which indicate a strong influence of dense macrophyte beds in littoral zone on the species and ecological structure of planktonic rotifers.

Khuhawar *et al.* (2009) carried out limnological study of Baghsar lake District Bhimber Azad Kashmir and reported that water of the lake indicated average conductivity and Total Dissolved Solids at 499 µs/cm and 319.16mg/l respectively with pH 7.1. A total of 122 algal species were recorded.

Brakovska *et al.* (2009) worked on the ecological evaluation of zooplankton groups in lake Geranimovas-ilzas and lake Garais and found three zooplankton groups, i.e. rotatoria, cladocera and copepod. Further they reported that presence of zooplankton species such as *Keratella cochlearis*, *Keratella quadrata* and *Filinia longiseta* to indicate low pollution level of these lakes

Okogwu (2010) studied the seasonal variation of species composition and abundance of zooplankton in Ehoma lake, a flood plain lake Nigeria and recorded 67 species of zooplankton which included 42 rotifers, 19 cladocerans and 6 copepods of which *Daphnia abtusa Kurz, Keratella valga Ehrenberg, Keratella ticinensis callerrio, Keretella hiemalis Carlin and Lecane candida Hauer* were new records for Nigeria. The species richness was highest in dry season while peak zooplankton abundance was recorded in the rainy season.

Buyurgan *et al.* (2010) examined zooplankton community structure of Asartepe Dam lake (Ankara, Turkey) and found rotifera to be dominant group (43 species) followed by cladocera (3 species) and copepoda with 2 taxa respectively.

Limnology in India

In India limnology received attention very late. The important contributions to the science of Limnology in India include those of Prasad, (1916). Today a great deal of work is done in limnology in India.

Sharma (1980) conducted studies on the taxonomy of rotifer in India and recorded about 241 species. Out of these 21 belonged to Eurotatorian families and bulk was comprised by Monogononta.

Gopal *et al*. (1981) made a thorough study on limnological aspects of Jamwa Ramgarh reservoir near Jaipur and reported that human activities were responsible for deterioration of flora and fauna, physico-chemical characteristics and production in the reservoir.

Badola and Singh (1981) studied hydrobiology of river Alankhanda of Garhwal Himalaya and related peak population of plankton to low velocity, low temperature, more dissolved oxygen and clearness of water.

Das and Khanna (1982) observed that the factors responsible for eutrophication, pollution and shallowness in Lake Nainital are increased human habitation and addition of silt material from house building entering the lake.

Sharma (1983) reviewed the different species of Genus *Brachionus* from India and found them mostly to be cosmopoliton belonging to alkaline waters.

Rao and Mohan (1983) made a quantitative study of rotifers in relation to physico-chemical factors of water and showed that hydrogen ion concentration mainly influenced abundance of the group.

Singh (1984) conducted limnological studies on Renuka and Rawalsar lakes of Himachal Pradesh and recorded 24 species of zooplankton from Renuka lake, 18 species from Rawal Sar Lake followed by dominance of rotifers.

Unni (1985) worked on the comparative limnology of several reservoirs in central India and reported that the oxygen content was inversely proportional to the surface area of the reservoirs. He also reported that *Daphnia, Keratella, Polyarthra* to be abundant in oligo-mesotrophic Sampna reservoir while *Brachionus* was abundant in both eutrophic and mesotrophic reservoirs.

Ramakrishna and Sarkar (1986) worked on the planktonic productivity in relation to hydrological factors in Konar reservoir (Bihar) and observed plankton to show bimodal trend with two planktonic pulses, a post monsoon and spring/summer pulse.

Sharma and Michael (1987) reviewed taxonomic studies on freshwater cladocera from India and reported *Eurycercus lamellatus, Pleuroxus trigonellus* and *Alona guttata* to be confined to Kashmir and that the limnetic zooplankton in India were invariably dominated by *Daphnia, ceriodaphnia, Moina* and *Diaphanosoma* species.

Choubay (1988) while conducting studies on the community analysis of zooplankton in Gandhisagar, recorded 55 zooplankton species of which protozoa were represented by 12 species, rotifera 15 species, cladocera 19 species, Ostracoda 3 species, and calanoida by 2 species. They also found cladocera to be the most dominant group.

Ghosh and George (1989) while working on zooplankton in a polluted urban reservoir Husssain Sagar found rotifers in summer and copepoda and cladocera in monsoon. They also found cladocera to exhibit a trimodal distribution.

Ahmad and Singh (1989) reported that biological productivity of any aquatic body is judged through the qualitative and quantitative estimation of plankton which form the natural food of fish.

Srivastava *et al*. (1990) conducted studies on the zooplankton density of Ganga river and found *colpedium, Didinium, Euglena, Malteria, Paramaecium, Brachionus, Filinia* to be most dominant zooplanktons. They also reported that the quality of water was responsible for qualitative and quantitative variation in zooplankton. They also recorded *Brachionus, Keratella and Filinia* to be indicators of pollution among rotifers.

Mohan (1991) investigated the limnology of third lake station of lake Mir Alam, Hyderabad and found that low concentration of free ammonia was due to high biological activity leading to oxidation and slow rates of decomposition of organic material which reflected high level of nitrates.

Sinha (1992) studied the rotifer fauna of river Ganga and identified about 26 species of which 17 species belong to genus *Brachionus*, 2 each to *Keratella* and *Filinia* and one each to *testudinaria*, *Asplanchna priodonta*, *Polyarthra, Hexarthra* and *Monostyla*. He also reported *Keratella* and *Brachionus* to be most dominant.

Mishra and Saxena (1993) conducted limnological studies on Govritank Bhind (Madhya Pradesh) and identified about 27 species of zooplankton of which 15 species belonged to rotifera, 4 to copepods, 3 each to cladocera and protozoa and 2 to ostracoda. *Keratella tropica* and *Brachionus angularis* were recorded throughout winter.

Venu *et al.* (1993) studied lotic water bodies of Sikkim Himalaya and reported that lower production and poor plankton growth was attributable to lower temperature, poor light conditions, abiotic turbidity and speedy flow of water.

Joshi (1994) studied the diurnal cycles of abiotic factors of a hill stream in Kalpanigarh (Pithoragarh) during rainy season. He found air temperature to show greater variations than water temperature during diurnal cycle. They also reported a positive relationship between dissolved oxygen and oxygen saturation percentage with diurnal fluctuation in temperature.

Bais and Agarwal (1995) carried out comparative study of Sagar lake and Military Engineering lake and identified rotifera, cladocera, ostracoda and copepoda in both the lakes. Rotifers were found to be most dominant zooplankton in both the lakes.

Jana and Das (1995) while describing phosphorous in aquatic systems, reported that phosphorous acts as a limiting element in oligotrophic system but causes hazards in eutrophic lakes.

Misra (1996) worked on the impact of sewage and industrial pollution on physico-chemical characteristics of water in river Betwa at Vidisha, M.P.

Paka and Narsing (1997) while working on the physico-chemical factors of a pond, found all the variables to be low in concentration. They also found pH and carbonates to vary directly but pH and bicarbonates showed an inverse relationship. They also reported nitrates and dissolved oxygen to show direct relationship while as total dissolved solids and temperature showed an inverse relationship.

Mishra and Saksena (1998) studied seasonal variation of rotifers in Morak (Kalpi) river, Gwalior and identified about eighteen species of rotifers among which *Cephalodella auriculata* was sensitive to pollution whereas *Brachionus quadridentata* was tolerant to mild pollution but *Keratella tropica, Brachionus calyciflorus, Filinia longiseta* were tolerant to high pollution. They also found rotifers to increase with increasing load of pollution.

Sharma and Dutta (1999) while working on ecology of zooplankton of sewage fed Farooqnagar Pond, Jammu, found the total zooplankton to record annual maximum count in August and minimum in October. They also found them to show insignificant results with abiotic factors and phytoplankton.

Dadhich and Saxena (2000) conducted studies on the trophic status of some desert waters employing zooplankton as indicators of trophy. They observed that factors like high zooplankton population, diversity and dominance of rotifers were responsible for ranking the temple tank in highest trophy followed by a village pond and drinking water reservoir.

Shivkumar and Altaff (2001) analysed the diversity of rotifers from fifty different fresh water bodies of Dharampuri district of Tamil Nadu and recorded 26 species of rotifers of which 15 species occurred in winter and four during summer season whereas remaining seven species of rotifers occurred in both the seasons. They also observed water temperature to range between 22^{o}C and 34^{o}C, while pH ranged from 6.0 to 8.0.

Prakash *et al.* (2001) studied the seasonal dynamics of zooplankton in a freshwater pond developed from the waste land of brick kiln and reported water temperature, free CO_2, pH and chloride to show positive correlation with different zooplankton groups.

Yadav (2002) which studying variation in chloride concentration in a pond at Fatehpur Sikri, Agra reported that an inverse relationship existed between rains and chloride concentration. He also related higher values of chloride in spring and summer to accelerated activity of decomposition of aquatic macrophytes.

Sinha and Islam (2002) worked on the zooplankton abundance in relation to temperature and transparency of one fenced and other open pond at Assam and found temperature and transparency to affect the species diversity of zooplankton.

Mahapatro and Pandhy (2002) while studying seasonal variations of micronutrients in Rushikulya estuary (Bay of Bengal), found silicates and nitrates to show an inverse relation with salinity in all seasons, whereas phosphate varied directly with salinity in pre-monsoon and monsoon and inversely in post monsoon period.

Pulle and Khan (2003) took qualitative and quantitative study of zooplankton community in Isapur Dam and reported rotifera, cladocera, copepoda and ostracoda. They also found zooplankton to be responsible for determining the presence or absence of certain species of fishes.

Raut and Pejaver (2003) studied the rotifer diversity of three macrophyte infested lakes Ambegosole, Rewale and Makhmali. They recorded 19 species of rotifers belonging to 19 genera and concluded that macrophytes help to increase the diversity of rotifers.

Sharma and Sarang (2004) studied the physico-chemical limnology and productivity of lake Jaisamand (Udaipur) and found water temperature to show a positive significant relationship with pH, CO_2 and total zooplankton, whereas negative relationship was recorded with NO_3. They also observed density of total phytoplankton to vary between minimum 20 to highest 214 individuals/litre and the total zooplankton to vary between minimum of 1 to highest of 233 individuals/litre.

Pandey *et al*. (2004) studied the seasonal fluctuation of zooplankton community in relation to physico-chemical parameters in river Ramjan of kishanganga, Bihar. They found rotifers to dominate followed by cladocera and copepoda. Rotifera also showed a negative correlation with water temperature, nitrate and phosphates.

Sheeba *et al*. (2004) carried out qualitative and quantitative study of zooplankton population in Ithikara river (Kerala) and attributed poor density of Zooplankton to sand mixing. They recorded six species of protozoans, 13 species of rotifers, 14 species of crustaceans (especially cladocerans, copepods and ostracods) and six groups of meroplanktonic organisms.

Sharma (2006) conducted a survey on biomass and production of zooplankton community in Garhwal Himalayas and recorded positive regression coefficient between secondary production of zooplankton and primary production of phytoplankton and epiphytic algae.

Tijare *et al*. (2007) worked on the rotifer diversity in three lakes of Gadehiroli, a tribal district of Maharastra (India) and reported the rotifers to be dominant among total zooplankton population. They also found them to be maximum in winter months and minimum in summer months.

Jalilzadeh *et al*. (2007) conducted a general survey on the abundance of zooplankton in three contrasting lakes of Mysore city, Karnataka state, India and reported pH, conductivity, sulphate, phosphate, alkalinity, chloride to be high in Lingambudi during rainy season as compared to Bannur and Hebbal lakes. They also found rotifers and cladocerans of Hebbal lake to be higher during rainy season than Bannur and Lingambudi lakes which they attributed to polluted nature of the site.

Rajshekhar *et al.* (2009) investigated zooplankton diversity of three freshwater lakes with relation to trophic status, Gulbarga district, North east Karnataka, south India and recorded 39 species of zooplankton belonging to rotifera, copepoda, cladocera and ostracoda. They also reported zooplankton composition to change significantly in all three water bodies.

Garg *et al.* (2009) assessed the physico-chemical characteristics, trophic status, pollution studies and macrophytic community of Raensagar reservoir, Datia, Madhya Pradesh. They found the physicochemical parameters to exhibit seasonal as well as monthly fluctuations. They also found nutrients to be in sufficient quantities for the growth of aquatic plants and animals in the reservoir.

Basu *et al.* (2010) studied seasonal abundance of zooplankton in connection with physico-chemical parameters of Kamal Sagar, a low flushing freshwater lake at Burdwan. About 13 taxa of net zooplankton were recorded of which 2 each belonged to copepods and decapods, 5 to rotifers, 3 to cladocerans and 1 to ostracoda. The rotifers were seen to show superiority in species abundance followed by decapods, cladocerans and ostracods.

Sharma *et al.* (2011) investigated zooplankton diversity of Loktak lake, Manipur, India and recorded 162 species of zooplankton out of which 104 species belonged to rotifera, 41 to cladocera and 17 species to rhizopoda.

Limnology in Kashmir

The limnological studies in Kashmir were initiated in 1921 when Mukherjee studied some limnological aspects of Dal lake. After him Hutchinson and his associates published articles on the fauna of Kashmir lakes (Edmondson and Hutchinson, 1934; Kiefer, 1939). Afterwards, limnological investigations again got attention in late sixties by workers like Das *et al.,* (1969, 1970); Zutshi (1968); Kaul and Zutshi (1967).

Zutshi *et al.* (1980) investigated two lakes from the lower Siwalik Himalayas of Jammu region, five from Kashmir valley and two lakes from the alpine region of Kashmir Himalayas for physico-chemical and biological characteristics. They found the waters to be generally alkaline. They also found rotifers to be dominant among zooplankton.

Zutshi and Wanganeo (1980) while describing the comparative limnology of nine lakes of Jammu and Kashmir, Himalayan region, reported the order of cation progression as Ca^{++} >Mg^{++}> Na^{+}>K^{+} and that of anion to be $HCO3^{-}$> $C1^{-}$> SO_4^{2-}.

Subla and Vishin (1981) recorded maximum density of Zooplankton in summer at the bottom.

Qadri *et al*. (1981) studied limnology of Erin and Madhumati streams of Kashmir. They found the waters of Madhumati stream soft type throughout the year while Erin was soft only during spring and summer. High concentration of chlorides, silicates and sulphates was related to the flushing of these ions into the stream from surface run-off during spring rains.

Shah (1981) made a survey of cladocera and copepoda in relation to physico-chemical factors in Hokersar Wetland.

Naqash (1982) while studying hydro-biological characteristics of Wular lake reported that rotifers constituted most dominant group followed by copepoda and cladocera. All the three showed a bimodal pattern of seasonal distribution and that the zooplankton were more abundant in deeper zones than the shallow regions.

Qadri and Yousuf (1982) studied the effects of some physico-chemical parameters on the distribution of two rotifer species *Anuraeopsis fissa* Gosse and *Notholca acuminata* in lake Mansbal Kashmir. They found the thermal structure of water to be responsible for the appearance and abundance of both these species.

Vass and Zutshi (1983) described the ecology, energy flow and trophic evolution of Kashmir Himalayan lakes.

Qadri *et al.* (1983) carried out limnological investigation on some freshwater bodies of Kashmir and observed that all water bodies are alkaline and medium to very hard type with large quantities of bicarbonates of calcium and magnesium. The nutrients are contained in small quantities.

Balkhi *et al.* (1984) discussed the limnological aspects of the Anchar lake. They observed that the relationship of dissolved oxygen and temperature affected the composition of rotifers and grouped them as warm stenothermal, cold stenothermal and eurythermal. They also found that low temperature and oxygen content were not conducive for rotifera population.

Subla *et al.* (1984) conducted studies on limnology of nine Kashmir Himalayan lakes and found rotifera to be dominant group indicating high trophic level. Zooplankton exhibited unimodal pattern.

Trisal (1985) while assessing the trophic status of three series of lakes viz., the valley lakes, upper mountain lakes and the forest lakes observed that the valley lakes and forest lakes to be eutrophicated due to high nutrient supply within sediment system being utilized by macrophytes.

Yousuf and Qadri (1985) reported that in Mansbal lake, Kashmir, the copepoda and rotifera show a unimodal pattern of fluctuation whereas cladocera showed a single peak. They also reported that more than half of the total zooplankton was represented by Copepods.

Yousuf *et al.* (1986) carried out studies on limnological aspects of Mirgund wetland and recorded seasonal changes in dissolved oxygen, carbon dioxide content and nutrient concentration. They also related the sparseness of zooplankton associations to fluctuations in the volume of water.

Zutshi (1987) while studying the impact of human settlement on the ecology of rural lakes of Kashmir, designated *Keratella cochlearis, Brachionus angularis, Brachionus caudata* as indicators of eutrophy.

Balkhi *et al.* (1987) reported that zooplankton in Anchar lake, Kashmir revealed a bimodal pattern in seasonal fluctuations which comprised of 41 species of rotifers, 33 species of cladocera and 13 species of copepods.

Kundangar and Zutshi (1987) while investigating Ahansar and Waskur lakes of Kashmir reported that these lakes did not show significant variations in water chemistry and the most important community was of *Myriophyllum* and *Ceratophyllum*.

Yousuf *et al.* (1988) discussed the changes in the physical and chemical limonology of the Mansbal lake and found its water to be alkaline and remaining always hard which they attributed to presence of carbonates and bicarbonates of calcium and magnesium. They also found that gradual eutrophication of the lake increased the concentration of nitrite, NH_3-N, chloride but silica concentration declined with the increase in population density of phytoplankton higher quantities of silica are necessary.

Parveen (1988) while studying the ecology of zooplankton of Dal lake (Kashmir) recorded 72 species of zooplankton. Rotifers dominated the population contributing generally more than 50% of the total number of individuals.

Zutshi and Wanganeo (1989) carried out studies on the rate of nutrient loading particularly nitrogen and phosphorus in three lake of Kashmir i.e. Dal lake, Anchar lake and Mansbal lake and observed that maximum input of phosphorus and nitrogen from catchment area and human wastes received by Dal lake whereas the Mansbal lake receives high quantity of nutrients from springs which are located close to the lake bank and discharge their water into the lake. Thus interms of nutrient input, Dal lake comes first followed by Mansbal and then Anchar lake.

Zutshi and Ticku (1990) assessed the impact of deweeding on water quality, plankton population, macrophyte and fish and observed immediate changes in physico-chemical parameters, phytoplankton composition and plankton population for a shorter period of time. They also recorded a decrease in transparency, increase in dissolved oxygen, phosphorous, turbidity and nitrate nitrogen concentration. They further reported an increase in a number of rotifer species e.g. *Keratella cochlearis, Keratella quadrata, Karatella serrulata, Brachionus bidentata, Anuraeopsis fissa, Lecane luna* and *Trichocerca longiseta.*

Balkhi and Yousuf (1992) carried out a study to assess the impact of eutrophication on the species composition and abundance of crustacean plankton in 100 freshwater bodies and recorded about 44 species of cladocera and 20 species of copepoda. They also reported the calanoids to be represented well in the oligotrophic water while as eutrophic waters supported larger population of cladocera and cyclopoida.

Pandit (1993) reviewed entire work on the ecology of Dal lake ecosystem in Kashmir Himalayas and suggested management tools to save the dying lake.

Yousuf and Mir (1994) while studying the vertical distribution of rotifera in the warm monomitic lake (Kashmir) recorded about 23 species of rotifera among which *keratella cochlearis* and *polyarthra vulgaris* were dominant.

Kaloo *et al.* (1995) studied nutrient status and phytoplankton dynamics of Dal lake under *salvenia natans* and reported that hydro-chemical features and plankton populations were indicative of trophic evolution.

Sarwar *et al.* (1996) investigated the impact of floating gardens on the limnological features of Dal lake and reported the floating gardens to be rich in chloride, Sodium, calcium, potassium, nitrate, ammonia and total phosphorous, thereby indicating the enriched pollution of the lake.

Sarwar and Parveen (1996) recorded 59 species zooplankton from Khushalsar and Gilsar lakes comprising 43 species of Rotifers, 11 species of cladocera and 5 species of copepods. The dominance of rotifera was attributed to thermal and nutrient conditions.

Pandit (1998) carried out detailed studies of plankton dynamics of freshwater wetlands of Kashmir.

Sarwar *et al.* (1999) while studying variations in the hydrobiological characteristics of Nigeen lake reported about 87 species of zooplankton dominated by rotifers followed by cladocera and copepoda.

Bucch and Kundangar (1999) studied the impact of marginal dredging on the ecology of Dal lake and found the sediment analysis revealed a high content of organic carbon, available phosphorous and potassium. In dredged area silcates and nitrate-nitrogen depicted an increasing trend while as Iron and total phosphorous recorded low values. The rotifera formed the dominant group with *Ascormorpha saltans* and *Asplanchna priodonta* being the dominant ones.

Shamim *et al* (2000) carried out studies on the water chemistry of Anchar lake and reported that level of nutrient in the lake indicates its pollution status.

Slathia *et al.* (2001) while investigating physicochemical characteristics and zooplankton of Rehtari spring (Udhampur) found seasonal presence of protozoans (15 species) and rotifers (4 species) only.

Bhat *et al.* (2001) studied impact of effluents coming from SKIMS on Anchar lake and reported that these effluents caused pollution in Anchar lake and the usual cation progression was $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$.

Pandit and Yousuf (2002) investigated six Kashmir Himalayan lakes and observed that total phosphorous and dissolved organic nitrogen in the epilimnetic layers were best chemical indications of the trophic state of these aquatic systems.

Bhat and Yousuf (2002) studied seven springs of the Kashmir valley and reported that high oxygen concentration in the springs was due to increase in photosynthetic activity by periphytes. They also observed that carbon dioxide and alkalinity to be inversely related, pH ranged between 7.63-8.0, concentration of cations was in the progression as Ca^{++}> Mg^{++}> Na^{+}> K^{+}. High concentration of chloride was attributed to human interferences.

Yousuf *et al*. (2003) studied the relationship of several physicochemical parameters with the distribution and abundance of zooplankton community and reported that *Keratella cochlearis, Keratella quadrata, Keratella quadridentata, Filnia longiseta, Brachionus calyciflorus, Brachionus angularis, Monostyla bulla, Lepadella ovalis, Philodina* sp., *Chydorus sphaericus, Graptolebris testudinaria, Daphnia pulex, Daphnia longispina. Bosmina longirostris, Cyclops* sp., *Macrocyclops albidus* are true representatives of eutrophic habitat.

Jamila (2003) while studying the population dynamics of *Brachionus pallas* in Dal lake (Kashmir) recorded five species namely *Brachionus angularis, Brachionus bidentata, Brachionus plicatilis, Brachionus calyciflorus* and *Brachionus quadridentata.* Out of these *Brachionus calyciflorus* dominated the population contributing about 55% of total number of individuals.

Ara *et al.* (2004) while conducting the physico-chemical investigation of Dal lake, reported that the lake shows richness in chloride, nitrogen (nitrite, nitrate and Ammonia) and orthophosphate in addition to high values of total dissolved solids, electrical conductivity, BOD, low transparency value. The cation composition of lake is Ca^{2+}>Na^{+}> Mg^{2+}.They attributed deterioration in water quality to multiple anthropogenic pressures.

Munshi and Yousuf (2007) studied limnology of Dagwan stream of Kashmir and reported that concentration of sodium and potassium increased in lower reaches which they related with increase in human habitation.

Wanganeo *et al.* (2008) made a comparative study of the vertical variation in physico-chemical parameters of Manasbal lake during the period of stratification with his previous observations (1980) and found bottom waters to be more anoxic. Specific conductivity, Ammonical nitrogen, phosphate phosphorous and nitrate nitrogen etc also showed enhancement.

Hussain *et al.* (2010) studied the various physico-chemical parameters of sub-surface waters of Drass, Kargil and found that data obtained from various sites was within the permissible limits of physico-chemical standards of world health organization (WHO), 1984 except for alkalinity.

CHAPTER -3

MATERIALS AND METHODS

For collection of data for the present study, five sites were selected in different basins of the lake. These sites represent ecologically different habitats in lake.

1. **Site 1:** This site was located on the north-west of the lake near Telbal nallah which is the main source of inflow into the lake. The dominant macrophytes comprised of *Nymphaea* sp. *Potamogeton crispus, Ceratophyllum* sp. and *Lemna minor*.
2. **Site 2:** This site was located in Hazratbal basin near Shrine and supported thick submerged, emergent and free floating vegetation.
3. **Sites 3:** This site was located in Nigeen basin of the lake. Here the macrophytic association comprised of *ceratophyllum demersum, potamogeton natans, P. crispus, Hydrilla* sp.
4. **Site 4:** This site was located in lokut- Dal opposite Sheri Kashmir international Golf course along the sides of which extends Boulevard road. Centaur Hotel is situated on its western bank from which heavy amounts of waste finds its way into it. The macrophytic associations comprised of *potamogeton natans*, *Nelumbo nucifera*, *Hydrilla* sp., *Myriophyllum* sp.
5. **Site 5:** This study site was located in Brarinambal basin on south eastern corner of Dal lake. Macrophytic associations include *Lemna* sp., *Salvenia* sp., and *ceratophyllum* sp. *Typha, salix*, *Phragmites* plantation has occupied large part of the basin.

Water samples were collected for different physical, chemical and biological parameters on monthly basis from Jan. 2011 to Dec. 2011. The methods employed for determination of different physico-chemical characteristics are as follows.

PHYSICAL PARAMETERS

1. **Temperature:** Air temperature was taken by keeping the thermometer (Celsius) in shade for about two minutes and water temperature was determined by immersing the thermometer in water along the shady side of the boat for about two minutes. (Welch, 1984).
2. **Transparency (Secchi disc, Welch, 1948):** Secchi disc with marked rope was used for obtaining the light penetration in the lake. Mean of the depth at which Secchi disc disappeared and then reappeared was taken as transparency of water.

CHEMICAL PARAMETERS

1. **Hydrogen ion concentration (PH) (Digital PH meter):** The hydrogen ion concentration was determined by using digital PH meter (Model systronics 335). Before use the PH meter was standardised with known buffer solutions (PH 4.00 & 9.2)
2. **Conductivity:** The conductivity of water samples was measured by portable digital conductivity meter (DB, 104) and the instrument was standardised before use with standard potassium chloride solution (N/100 KCl).
3. **Dissolved oxygen:** (Winklers method, APHA, 1995).
   i. The water samples for analysis were collected in air tight stoppered glass bottles of 250ml capacity.
   ii. The dissolved oxygen was fixed on spot by adding 1ml of $MnSO_4$ (91 g $MnSO_4$ dissolved in 200ml of distilled water and 1ml of alkaline iodide (125g NaOH and 33. 75 g sodium iodide dissolved in 250ml of distilled water). The contents were mixed by inverting

and rotating the bottle several times for about 10 seconds to develop the precipitate.

iii. The precipitate was then allowed to settle and then dissolved by adding 1ml of concentrated sulphuric acid.

iv. The bottles were then transferred to laboratory and the samples were titrated against 0.02N sodium thiosulphate, using starch solution as indicator.

v. The end point was noted at first disappearance of blue colour. The amount f oxygen present was then calculated by using formula.

$$/ \quad = \frac{\quad .}{\quad}$$

Where 0.2 value represents 1ml of sodium thiosulphate equivalent to 0.2 mg of O_2.

4. Free carbon dioxide (Titrimetry with NaoH, Mackereth *et al*., 1978)

The free Co_2 content of samples was determined by titrating 50ml of sample against 0.027N sodium hydroxide using phenolphthalein as indicator till faint pink colour appears.

The Co2 present was calculated as:

$$\text{Co} \ (\text{mg/l}) = \frac{\text{volume of titrant used}}{\text{vol. of water sample}} \text{x } 1000$$

5. Chloride (Titrimetry with $AgNO_3$, Mackereth *et al*., 1978).

The water samples were titrated with 0.014N Silver Nitrate solution till the yellow colour formed by potassium dichromate changed into faint brick colour. The chloride content of the samples was determined by formula give below

$$\text{Chloride mg/l} = \frac{\text{volume of titrant used x 35.4 x 1000 x 0.014}}{\text{volume of water sample.}}$$

Where 35.4 is the atomic weight of chloride.

0.014 is the Normality of titrant.

6. Total alkalinity (Titrimetry with H_2So_4, Mackereth *et al.,* 1978).

Total alkalinity was determined by titrating the water sample against 0.02N H_2SO_4 using phenolphthalein as indicator in the first step and methyl orange in the second step. The change of colour was pink to colourless in the first step and yellow to orange in the second step. From this total alkalinity was determined as per Mackereth *et al.,* 1978.

7. Ammonical Nitrogen (Phenate method, APHA, 1995)

i. To a 25ml sample, 1ml each of phenol solution and 1ml of sodium nitroprusside solution was added.
ii. To the sample 2.5 ml of oxidizing solution was added.
iii. The sample was then covered with aluminium foil and kept in darkness for about 1 hour so that blue colour develops. Then absorbance was measured spectrophotometricaly at 640 nm.
iv. Different concentrations of ammonium chloride were used for preparation of standard curve.

8. Nitrate- Nitrogen (Salicylate method (CSIR, 1974)

i. To 50ml of water sample, 1ml of sodium salicylate was added which was evaporated to dryness on a water bath.
ii. To the residue 1ml of concentrated sulphuric acid was added. The beaker was tilted to wet the bottom completely and then allowed to stand for 10 minutes.
iii. After this 6ml of distilled water and 7ml of 30% sodium hydroxide was added and diluted to 50ml.
iv. The optical density was measured spectrophotometricaly at 410 nm.
v. Different concentrations of sodium nitrate were used for preparation of standard curve.

9. Nitrite-Nitrogen (Sulphanilamide method)

i. To 45ml of water sample 1ml of sulphanilamide reagent was added.
ii. After 5 minutes, 1ml of N-1 naphthylethylene diamine dihydrochloride reagent was added and mixed well.
iii. Volume was raised to 50ml and shaken thoroughly.
iv. Optical density was measured spectrophotometricaly at 543 nm after about 10 minutes.

10. Total phosphorus (Stannous chloride method after digestion with H_2SO_4 and HNO_3, APHA, 1995).

i. To 25ml of water sample 1ml of concentrated sulphuric acid and 5ml of nitric acid were added.
ii. The sample volume was then digested upto 1ml.
iii. The sample was then cooled and 250ml of distilled water was added to it.
iv. After this 1 drop of phenolphthalein indicator and 1N sodium hydroxide was added to produce faint pink colour.
v. To 100ml of above sample a drop of phenolphthalein was again added.
vi. The pink colour so developed was discharged by adding strong acid solution.
vii. After this 4ml of molybdate reagent and 10 drops of stannous chloride reagent was added to the sample.
viii. Absorbance of the sample was measured spectrophotometricaly at 690 nm.

BIOLOGICAL PARAMETERS

Qualitative and quantitative enumeration of Zooplankton.

For qualitative estimation of zooplankton species, drifting of plankton net was carried out at each sampling site upto a distance of 100 meters. The contents collected in the tube were transferred to another tube and preserved in 4% formalin and carried to laboratory for investigation under microscope. Identification of different zooplankton species was done with the help of standard taxonomic works **(Edmondson (1959)** and **Pennak (1978).**

For quantitative estimation 10 liters of water were sieved through Plankton net with the help of Van Dorn water sampler. The content collected in the tube was immediately transferred to another tube where it was preserved in 4% formalin. The sample was carried to laboratory where it was concentrated to a known volume and shaken gently. 1ml of sample was placed on a sedgewick rafter cell and then studied under binocular microscope. The counting was done in triplicate and average of three counts was used to calculate the population dynamics of various species and hence of the total zooplankton in one litre by formula used by Parveen (1988)

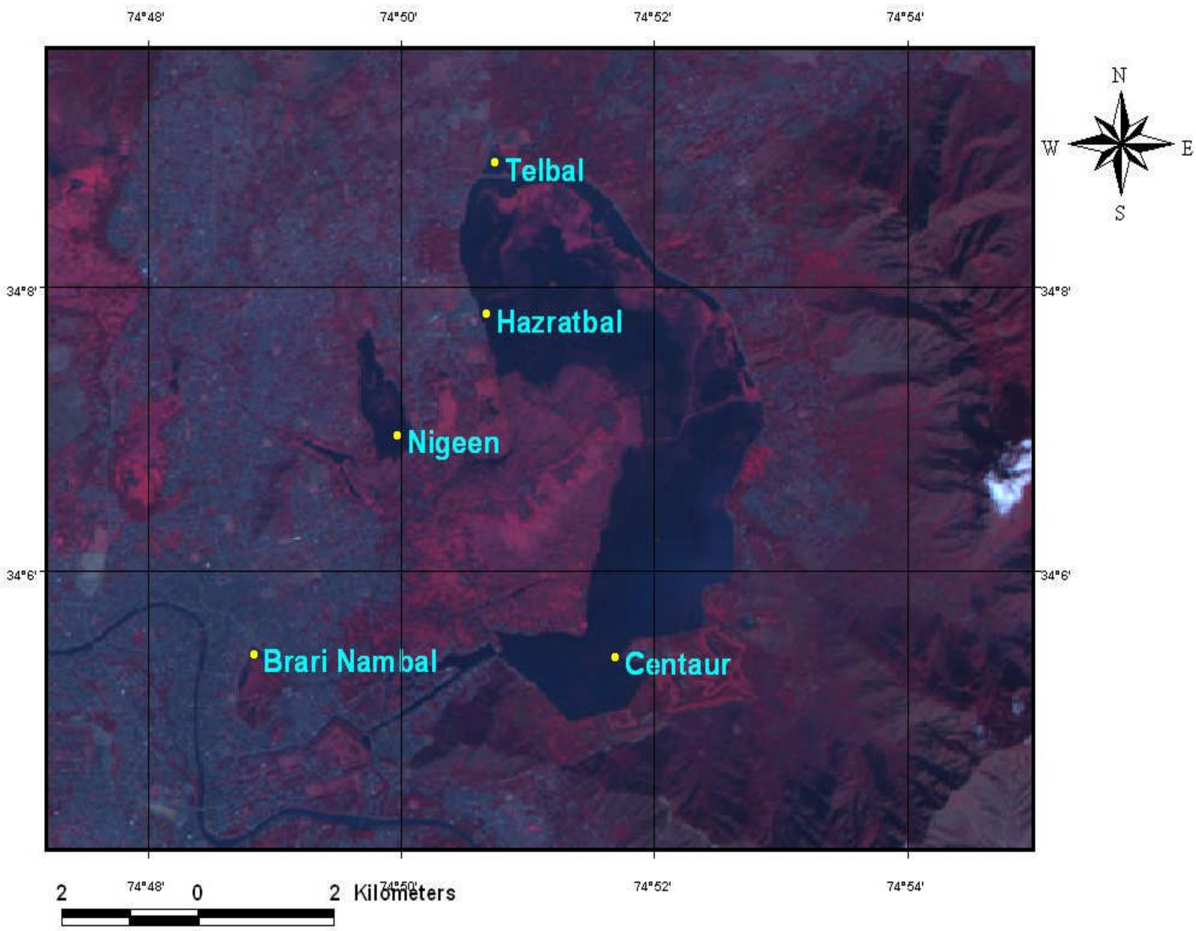
$$= \frac{\times}{\quad} \times 1000$$

Where n= number of individuals per cubic meter of water.

a = no. of individuals in one ml of concentrated sample.

c = volume of concentrated sample.

l = vol. of water sieved.



Satellite Imagery of Dal Lake showing different study sites

Site 1: Located in Telbal Basin

Site 2: Located in Hazratbal Basin

Site 3: Located in Nigeen Basin

Site 4: Located in Nishat Basin near Centaur Hotel

Site 5: Located in Brarinambal Basin

CHAPTER - 4

RESULTS

The Dal lake is in a state of stress and as a result ecological conditions have undergone tremendous changes. A no. of studieshave been undertaken on the physico-chemical characteristics and primary productivity of this important lake. The present study was undertaken to study the ecology of Rotifer communities in different areas of the lake with special reference to genus *Keratella*. The present dissertation embodies the data obtained during Jan. 2011 to Dec. 2011 on population dynamics of rotifers including *Keratella*, other Zooplankton and physico-chemical environment.

I.*Keratella* in Dal lake

A.Species composition of *Keratella* bory de st. Vincent

Genus *Keratella*

Keratella is an important genus of Eurotatorian rotifers. It is an important member of sub class Monogononta found in abundance in lakes, ponds etc. The lorica is thick, dorsally curved and ventrally flattened or concave. Dorsal plate is strong with polygonal facets. Ventral plate is delicate. Six anterior spines are present and posterior spines mostly present. Foot and toes are absent. The different species of the genus*Keratella* can be distinguished on the basis of spination and sculpture of dorsal plate**.**

Classification

Phyllum	:	Rotifera
Class	:	Eurotatoria
Subclass	:	Monogononta
Order	:	Ploima
Family	:	Brachionidae

Genus : *Keratella*

Species : *K. cochlearis* (Gosse, 1851)

K. quadrata(Muller, 1786)

1.*Keratella cochlearis*

Lorica is spoon shaped. Lorica terminates in a stout median posterior spine which usually varies in length from as long as the body proper to one third as long. Anterior dorsal margin with six spines, median ones longest, curve ventrally, intermediates usually slightly divergent. The lorica has the usual pattern of minute interlacing areolations on both plates.

2.*Keratella quadrata*

Lorica terminates into two widely separated subequal posterior spines, usually divergent or bowed, varying in length from about as long as the body proper to very short. The lorica is much compressed dorsoventrally. Anterior dorsal margin with six spines, the median ones longest and stoutest, curved ventralward. The laterals are usually somewhat longer than intermediates. The intermediates are slightly divergent. The loricahasa pattern of minute interlacing areolations.

B. Population dynamics of *Keratella*

Keratella Cochlearis

This species was recorded at all the five sampling sites. At site1, it was first recorded from march to June and then from August to October with peak population in April (2460 ind./m^3).At site 2,it was absent from January to April then it showed its presence from May to October with peak population in October (3260 ind./m^3). At site 3, it was recorded from April to September only recording its peak population in April (2100ind. /m^3). At site 4, it made its appearance first in April (290 ind.m^3), after disappearing in May and it again showed its presence in June, July, September and October with peak population in June (3000 ind./m^3). At site 5, it was recorded in February and March, after remainingabsent in April and May, it again showed its appearance in June and July. The peak population was recorded in the monthly of July (2480 ind./m^3)

Keratella quadrata

This species was absent at site I throughout the study period. At site II, it was first recorded in January (380 ind./m^3) and then remained absent from February to October. It again made its appearance in November and December with peak population in November (2100 ind./m^3). At site III this species was recorded from February to April only. The peak population was recorded in April (1860 ind./m^3). At site IV, this species was recorded only once in April (380 ind./m^3). At site V, it was recorded in the months of April, May, July, September and December with peak population in the month of May (2160 ind./m^3).

Population dynamics of various species of *Keratella*

Table 1: *Keratella cochlearis*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1			964	2460	2000	1080		1200	2200	964		
Site 2					780	920	1700	765	620	3260		
Site 3				2100	1880	1350	890	1600	1650			
Site 4				290		3000	2250		2160	1898		
Site 5		2100	1820			1800	2480					

Table 2: *Keratella quadrata*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2	380										2100	1680
Site 3		1400	900	1860								
Site 4				380								
Site 5				1980	2160		1850		1700			1750

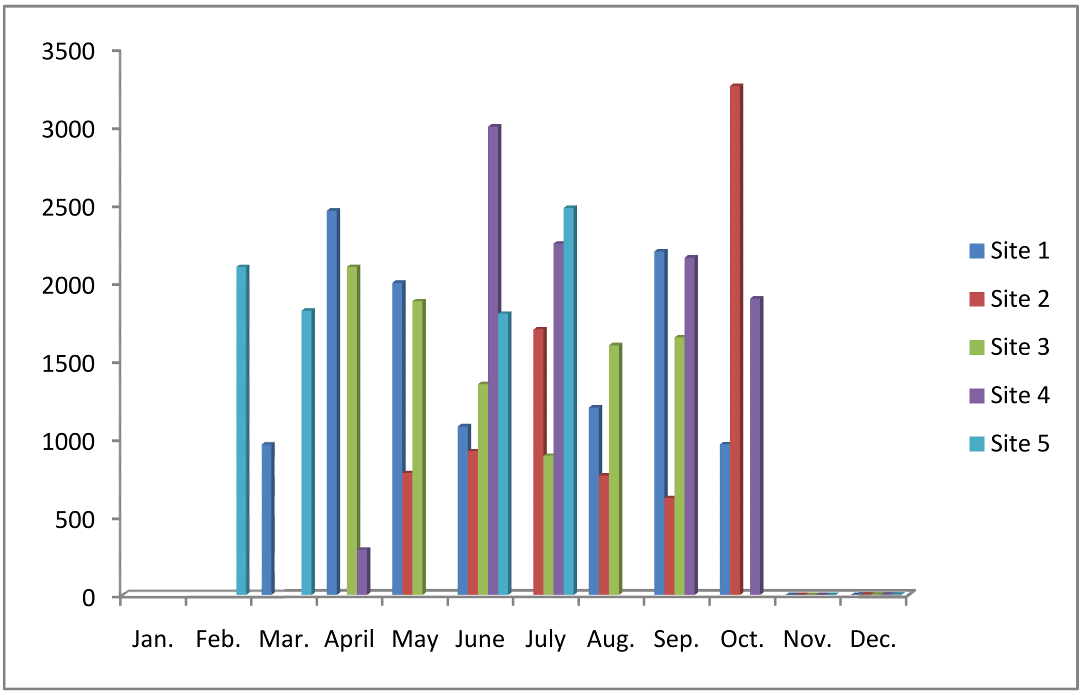


Fig.1: *Keratella cochlearis*

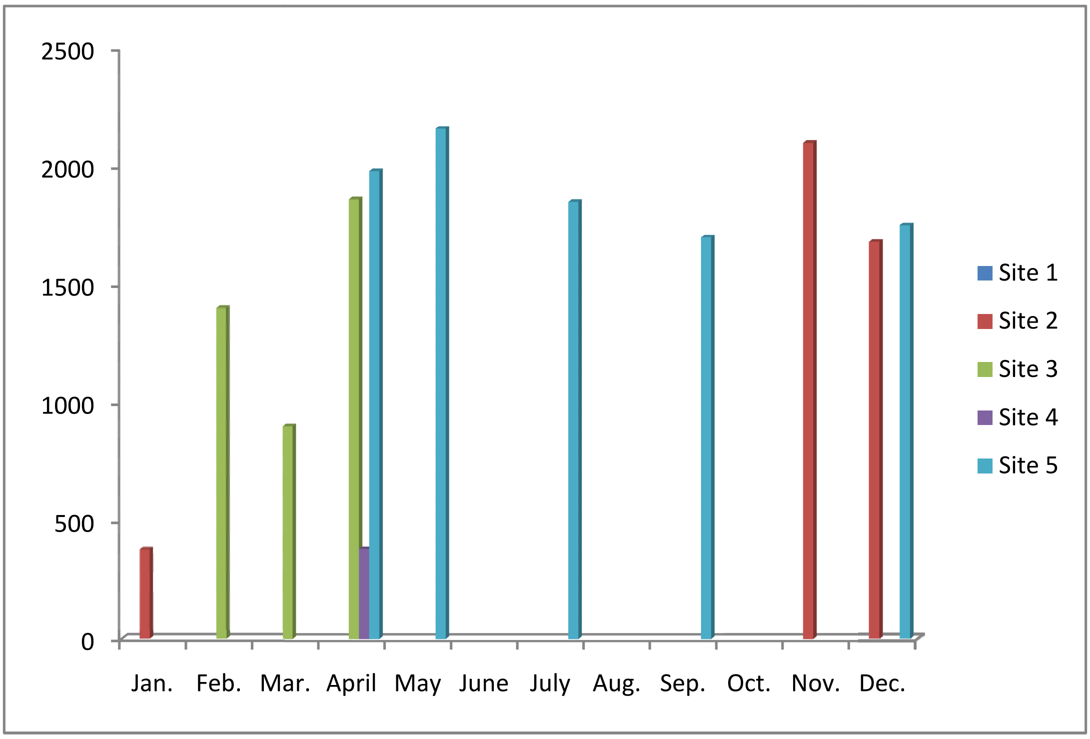


Fig. 2: *Keratella quadrata*

C. Ecology of Keratella in Dal lake

I. Physico-chemical characteristics

Temperature

The data on atmospheric temperature and water temperature are presented in the tables (3&4) (Fig. 3&4) respectively. During the study period, the atmospheric temperature ranged from 4.9^{o}C in January at site 1 to as high as 32.5^{o}C in August at site 2 and site 5. No significant variation was found in atmospheric temperature from one site to other. The monthly fluctuation in the atmospheric temperature followed closely those of water temperature. The water temperature was found to be lower than the air temperature at all sites, throughout the study period. It varied from the lowest mean value of 15.2^{o}C±6.9 at site 1 to the highest mean value of 16.9^{o}C±7.1 at site 2. Lowest monthly mean value of 4.8^{o}C±0.7 was obtained in the month of January and the highest of 25.6^{o}C±0.5 was obtained in the month of August.

Transparency

The data on transparency observed during the study period is presented in (Table 5) and (Fig. 5). The transparency as determined by the Secchi disc fluctuated from site to site as well as showed monthly changes. The lowest value of 0.14m was recorded in the month of June at site 5. The highest value of 2.10m was recorded in the month of March at site 3 and site 4. While comparing the mean values of five study sites, the lowest mean value of 0.26±0.15 was obtained at site 5 and highest mean value of 1.55±0.41 was obtained at site 3. The monthly mean value fluctuated from 0.72±0.34 in June to 1.66±0.82 in March.

Hydrogen Ion Concentration (pH)

The data on the pH value are presented in (Table 6) and (Fig. 6). During the present investigation, pH value in the lake water fluctuated between 7.19 in January at site 5 and 9.6 at site 3 in June. On an average, the mean value fluctuated from 7.5±0.2 at site 5 to 8.8±0.4 at site 4. The monthly mean value ranged from 7.9±0.3 in December to 8.8±0.6 in July.

Conductivity

The conductivity values obtained during the study period presented in (Table 7) and (Fig. 7) fluctuated from163µs/cm in December at site 1 to 810µs/cm in September at site 5. The monthly mean conductivity values fluctuated from 292.4µs/cm ±192.4 in month of May to 406.2µs/cm ±231.1 in the month of September.

A comparison of the data pertaining to different study sites revealed that mean conductivity values in the water recorded an increase from 196.8µs/cm ± 26.7 at site 1 to 278.0µs/cm ±39.9, then fell to 265.8µs/cm ±59.1 at site 3 to 250.4µs/cm ± 32.9 at site 4 and again rose to 651.3µs/cm ± 75.1 at site 5. On the whole, Brarinambal basin (site 5) showed highest conductivity.

Dissolved Oxygen

The data obtained on dissolved oxygen during the study period is presented in (Table 8) (Fig. 8). The dissolved oxygen concentration varied from 0.8mg/l in July and August at site 5 to 9.8mg/l in April at site 1 and site 3. The highest concentration was obtained in spring season at all stations which started to decrease towards summer and then recorded an increase in winter. While comparing the mean values of the five sites, the highest mean value of 8.1mg/l ± 1.2 was obtained at site 3 and the lowest value of 0.8mg/l ± 0.7 at site 5.

Free CO_2

The data obtained on free CO_2 during the study period is presented in (Table 9) (Fig. 9). The concentration of free carbon dioxide showed a considerable variation from site to site. It remained absent during the months of May, June, July and August at site 2 and site 3 whereas at site 4 it remained absent during the months of April, May, June, July, August and September.

The concentration of free CO_2 varied from 3mg/l at site 2 (September) to 38.0mg/l at site 5 (January). The monthly mean concentration of free carbon dioxide varied from 8.8mg/l ± 4.5 (August) to 20.5mg/l ± 9.9 (January). Its concentration increased from August to January and then decreased from February to July.

A comparison of the data revealed that CO_2 concentration was quite high in Brarinambal basin where it showed an annual mean concentration of 26.1mg/l ± 7.0 while as at other sites its concentration remained low (11.5mg/l ± 4.6, 9.5mg/l ± 4.7, 9.6mg/l ± 4.3 and 11.9mg/l ± 3.5) at site 1,2,3 and 4 respectively.

Total Alkalinity

The data obtained for total alkalinity values during the present study is presented in (Table 10) (Fig. 10). During the present study, the alkalinity values ranged from 94.8mg/l at site 1 in the month of July to 360.9mg/l at site 5 in the month of February. A comparison of the data reveals that total alkalinity was relatively high at site 5 with a mean value of 276.7mg/l± 51.5 followed by site 2 mean value of 121.0mg/l ± 15.3, site 3 mean value of 120.7mg/l ± 14.5, site 1 mean value of 117.7mg/l ± 16.8 and site 4 mean value of 112.7mg/l ± 10.8.

Chloride

Data on chloride content of water is presented in (Table 11) (Fig. 11). The chloride concentrations fluctuated from 11.9mg/l in the month of July at site 1 to the highest value of 71.3mg/l in the month of April at site 5. While comparing the mean values of five sites lowest mean value was observed at site 1 which is 19.0mg/l ± 3.5 and the highest mean value was observed for site 5 which is 52.9mg/l ± 11.2. The monthly mean values fluctuated from 19.7mg/l ± 14.0 in July to 32.3mg/l ± 20.8 in October.

Ammonical Nitrogen

Data obtained on the concentration of ammonical-nitrogen is presented in (Table 12) (Fig. 12). During the present investigation ammonia concentrations ranged from 100.0μg/l at site 1 in the month of December to 1222.8μg/l at site 5 in the month of July. No definite trend was recorded in ammonia concentration throughout the study period. The monthly mean concentration in the lake varied from 297.1μg/l ± 311.0 (November) to 415.4μg/l ± 422.3 (June). While comparing the annual mean values of five sampling sites, the highest concentration was found at station 5 (964.8μg/l ± 149.2) followed by site 3 (222.2μg/l ± 56.6), site 2 (218.2μg/l ± 32.1 and site 1 (217.7μg/l ± 72.6). The lowest concentration was recorded at site 4 (171.0μg/l ± 49.2).

Nitrate – Nitrogen

The data obtained on Nitrate – Nitrogen concentration at five sampling sites during the study period are presented in (Table 13) (Fig. 13). It is the main form of inorganic nitrogen in the lake. The concentration of nitrate nitrogen ranged from 72.1μg/l at site 5 in July and September to 925.2μg/l at site 3 in September. The mean minimum concentration was recorded in May (365.1μg/l ± 128.4) & the mean maximum in September (607.2μg/l ± 356.2). The maximum concentration of nitrate was observed at site 2 showing an annual mean concentration of 599.6µg/l ± 124.8. At site 1, the mean concentration was 479.5µg/l ± 131.1, at site 3,596.0µg/l ± 156.5, at site 4, 501.7µg/l ± 92.5 and site 5 showed a mean concentration of 151.6µg/l ± 60.0.

Nitrite – Nitrogen

Nitrite Nitrogen was recorded in very small quantities (Table 14) (Fig. 14). It fluctuated from 19µg/l at site 1 and 3 in May to 102µg/l at site 5 in November. The mean monthly value fluctuated from 31.2µg/l ± 21.9 in May to 60.8µg/l ± 24.4 in November. The maximum concentration was recorded at site 5 (Brarinambal basin) (Mean = 67.6µg/l ± 27.5), followed by site 4 (mean = 52.2µg/l ± 14.8), site 3 (mean = 39.3µg/l ± 17.1) & site 2 (mean = 36.2µg/l ± 12.7). The minimum concentration was recorded at site 1 (mean = 30.3µg/l±7.7). The mean values of different sites showed a gradual increase from site 1 to 5.

Total Phosphorous

The data on total phosphorous content at five sampling sites is presented in (Table 15) (Fig. 15). Total phosphorous in the lake fluctuated throughout the study period from 312.6µg/l at site 1 in the month of November to 2325µg/l at site 5 in the month of September. The monthly mean value varied from 604.0µg/l±195.6 (January) to 944.2µg/l±778.4 (September). The highest concentration of total phosphorous was recorded at site 5 (Mean = 1598.7µg/l ±499.3) and the lowest concentration was recorded at site 1 (mean=445.8µg/l±83.6. The present data did not record any definite trend in the seasonal fluctuations.

Table 3: Monthly fluctuations in Air temperature (^oC) at five sampling sites

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	4.9	7.2	7.4	7.8	7.9	7.0	1.2
Feb	11.1	15	15	15.2	14.6	14.2	1.7
March	17.2	18.1	17.6	18.2	18.4	17.9	0.5
April	19.5	19.2	18.8	19.6	20.0	19.4	0.4
May	20.8	25.2	24.3	24	24.5	23.8	1.7
June	25.0	28.1	28.5	27.9	28.3	27.6	1.4
July	31.6	31.9	31.7	31.5	31.9	31.7	0.2
August	32.2	32.5	31.9	32.0	32.5	32.2	0.3
September	28.4	29.7	28.6	28.9	29.0	28.9	0.5
October	20.7	21.3	21	21	21.2	21.0	0.2
November	14	14.4	14.2	14.3	14.5	14.3	0.2
December	10.2	10.6	10.4	10.4	10.3	10.4	0.1
Mean	19.6	21.1	20.8	20.9	21.1		
S.D	8.7	8.4	8.3	8.1	8.3		

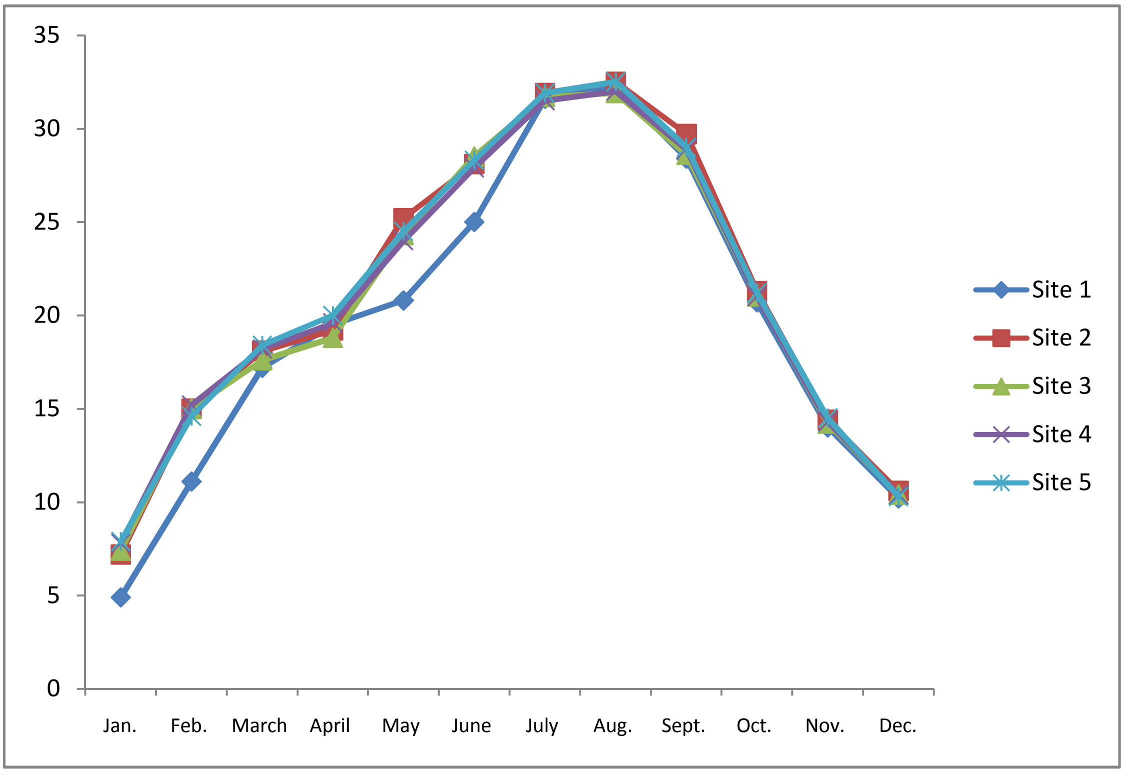


Fig. 3: Monthly fluctuations in Air temperature (^oC) at five sampling sites

Table 4: Monthly fluctuations in water temperature (°C) at five sampling sites

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	3.5	5.3	4.9	5.1	5.0	4.8	0.7
Feb	8.4	11.5	11.1	11.3	11.2	10.7	1.3
March	14.5	15.4	15.5	15.2	15.1	15.1	0.4
April	14.3	15.5	14.9	15.3	15.3	15.1	0.5
May	18.3	19.5	19.5	19.4	19.6	19.3	0.5
June	20.3	23.6	23.1	23.5	23.0	22.7	1.4
July	21.9	24.5	24.6	24.3	24.1	23.9	1.1
August	24.7	26.0	25.9	25.9	25.7	25.6	0.5
September	22.7	23.6	23.5	23.4	24.2	23.5	0.5
October	17.8	19.4	19.1	19.3	19.3	19.0	0.7
November	9.9	11.5	10.8	11.4	11.1	10.9	0.6
December	6.2	6.5	6.9	6.3	6.4	6.5	0.3
Mean	15.2	16.9	16.7	16.7	16.7		
S.D	6.9	7.1	7.1	7.1	7.1		

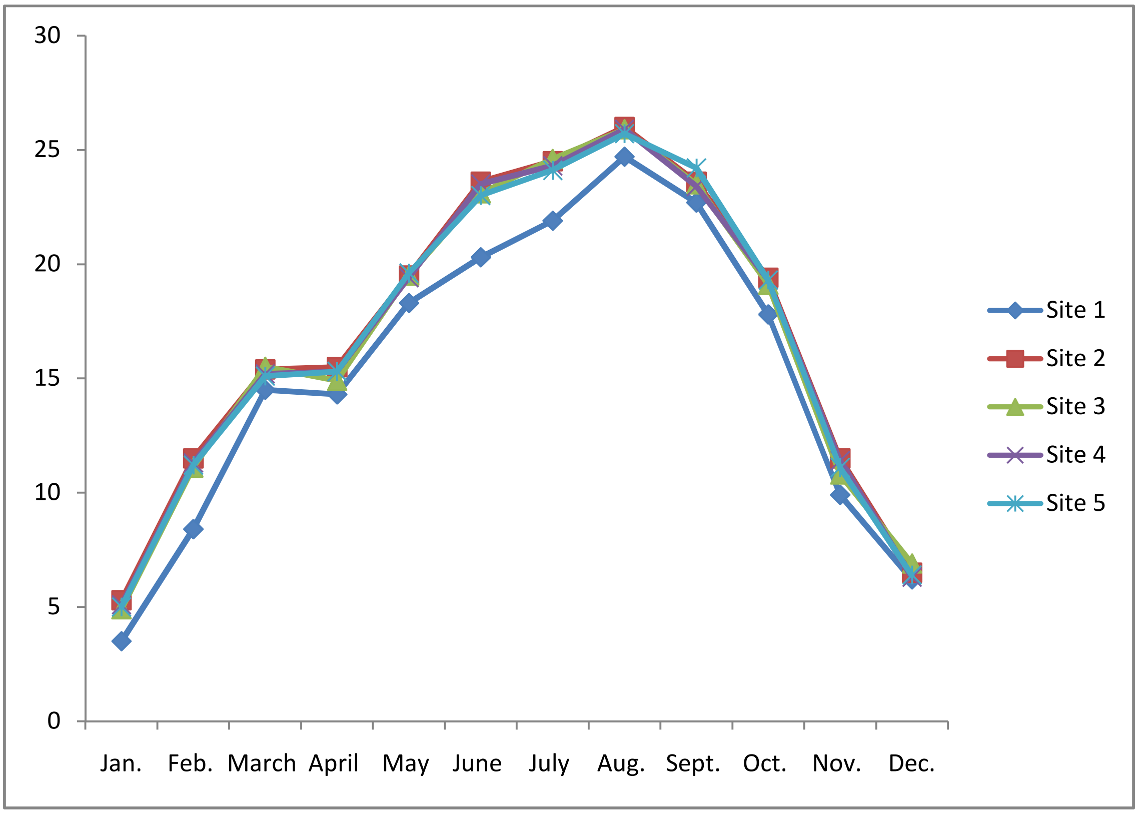


Fig. 4: Monthly fluctuations in water temperature (°C) at five sampling sites

Table 5: Monthly fluctuations in transparency (m) at five sampling sites

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	1.60	1.80	2.0	1.90	0.16	1.49	0.76
Feb	1.51	1.60	1.91	1.80	0.20	1.40	0.69
March	1.90	2.10	2.10	2.00	0.19	1.66	0.82
April	1.42	1.92	1.80	1.42	0.30	1.37	0.64
May	1.23	1.10	1.10	1.10	0.21	0.95	0.42
June	0.74	0.90	1.00	0.80	0.14	0.72	0.34
July	0.74	0.80	1.21	1.41	0.57	0.95	0.35
August	0.63	0.70	1.10	1.22	0.24	0.78	0.39
September	0.62	1.31	1.23	1.00	0.20	0.87	0.46
October	1.52	1.21	1.44	1.00	0.19	1.07	0.53
November	1.71	1.32	1.85	0.90	0.17	1.19	0.68
December	1.64	1.51	1.85	0.81	0.57	1.28	0.56
Mean	1.27	1.36	1.55	1.28	0.26		
S.D	0.46	0.45	0.41	0.43	0.15		

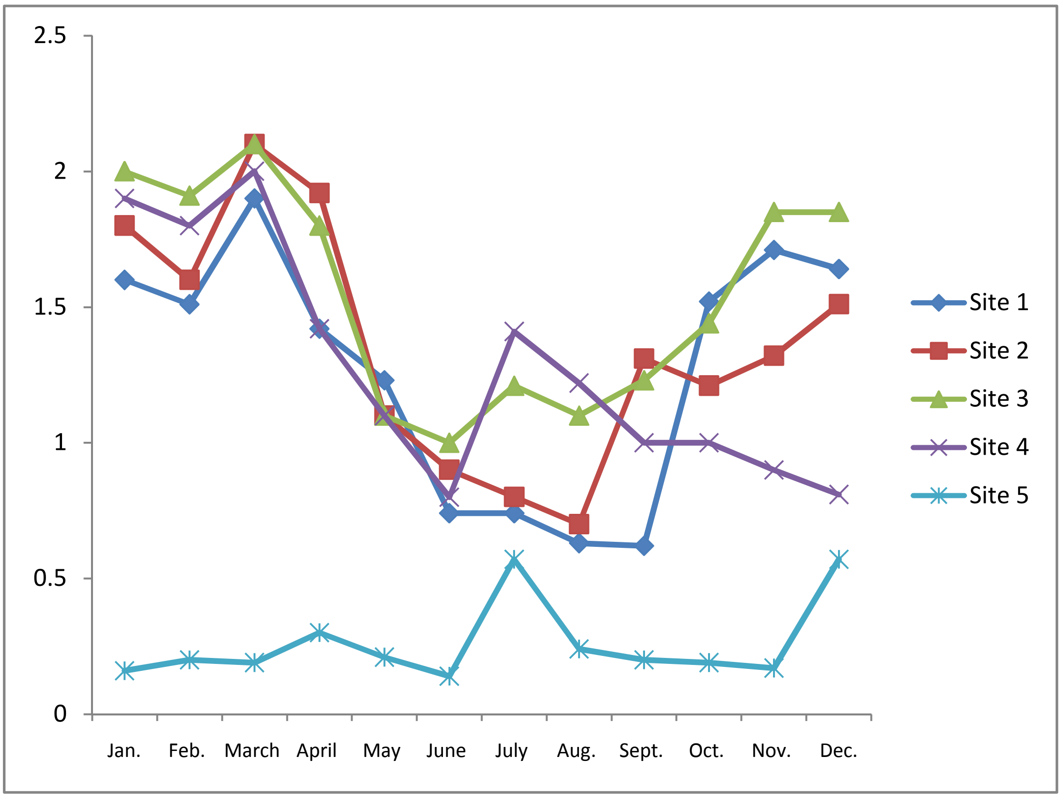


Fig. 5: Monthly fluctuations in transparency (m) at five sampling sites

Table 6: Monthly fluctuations in pH value (units) at five sampling sites

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	7.8	8.0	8.0	8.10	7.19	7.8	0.4
Feb	7.8	8.4	8.0	8.7	7.28	8.0	0.5
March	8.0	8.5	8.8	8.6	7.3	8.2	0.6
April	8.2	8.8	8.9	9.10	7.4	8.5	0.7
May	8.2	9.0	9.3	9.13	7.60	8.6	0.7
June	8.0	9.1	9.6	9.46	7.78	8.8	0.8
July	8.7	8.9	9.1	9.30	7.85	8.8	0.6
August	7.9	8.3	8.1	9.20	7.75	8.3	0.6
September	8.2	8.3	8.5	9.1	7.6	8.3	0.5
October	8.1	8.1	8.4	8.65	7.3	8.1	0.5
November	8.0	8.1	8.2	8.40	7.4	8.0	0.4
December	8.1	8.0	8.0	8.20	7.35	7.9	0.3
Mean	8.1	8.5	8.6	8.8	7.5		
S.D	0.2	0.4	0.6	0.4	0.2		

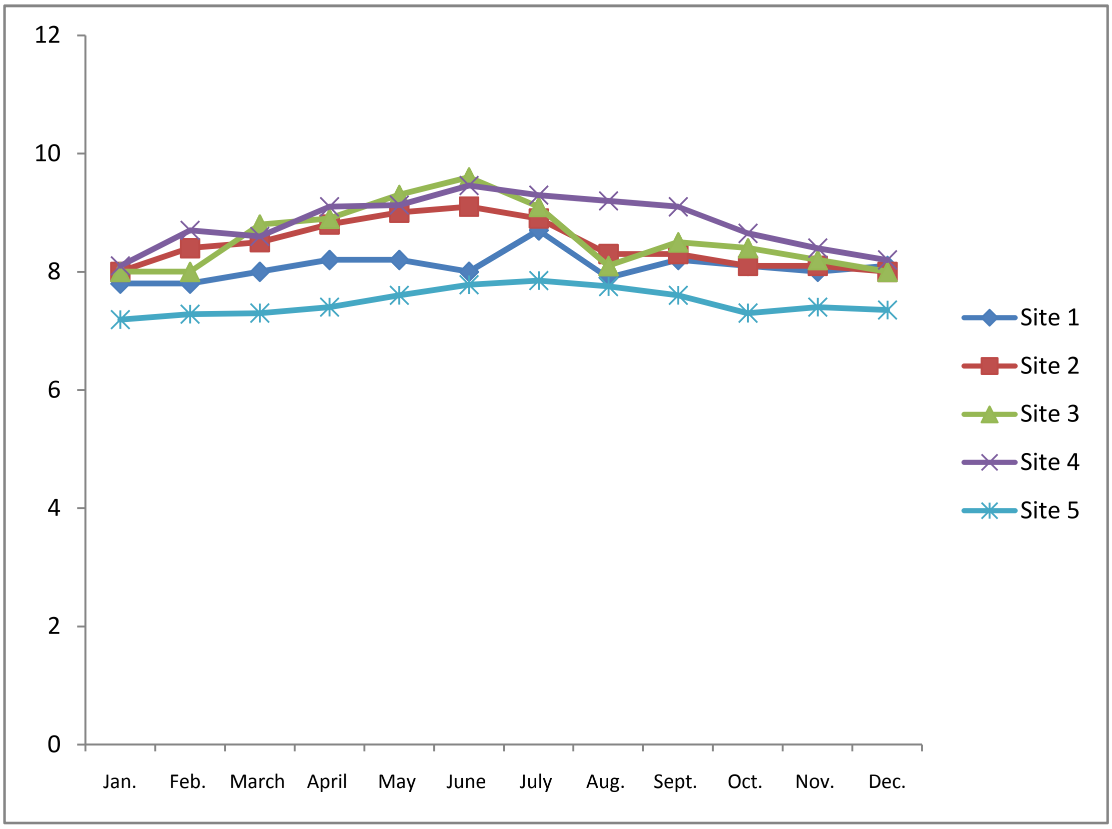


Fig. 6: Monthly fluctuations in pH value (units) at five sampling sites

Table 7: Monthly fluctuation in conductivity (µs/cm) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	250	285	275.5	255	591	331.3	145.9
Feb	196	290	196	223	565	294.0	156.3
March	200	250	217	244	561	294.4	150.4
April	186	263	220	203	622	298.8	182.9
May	182	236	203	203	638	292.4	194.2
June	165	195	197	296	642	299.0	198.0
July	175	265.8	317	285	657	340.0	184.9
August	208	289	341	287	775	380.0	225.9
September	231	350	350	290	810	406.2	231.1
October	221	315	327	246	680	357.8	185.6
November	184	302	296	241	635	331.6	176.2
December	163	295	250	232	640	316.0	187.2
Mean	196.8	278.0	265.8	250.4	651.3		
S.D	26.7	39.9	59.1	32.9	75.1		

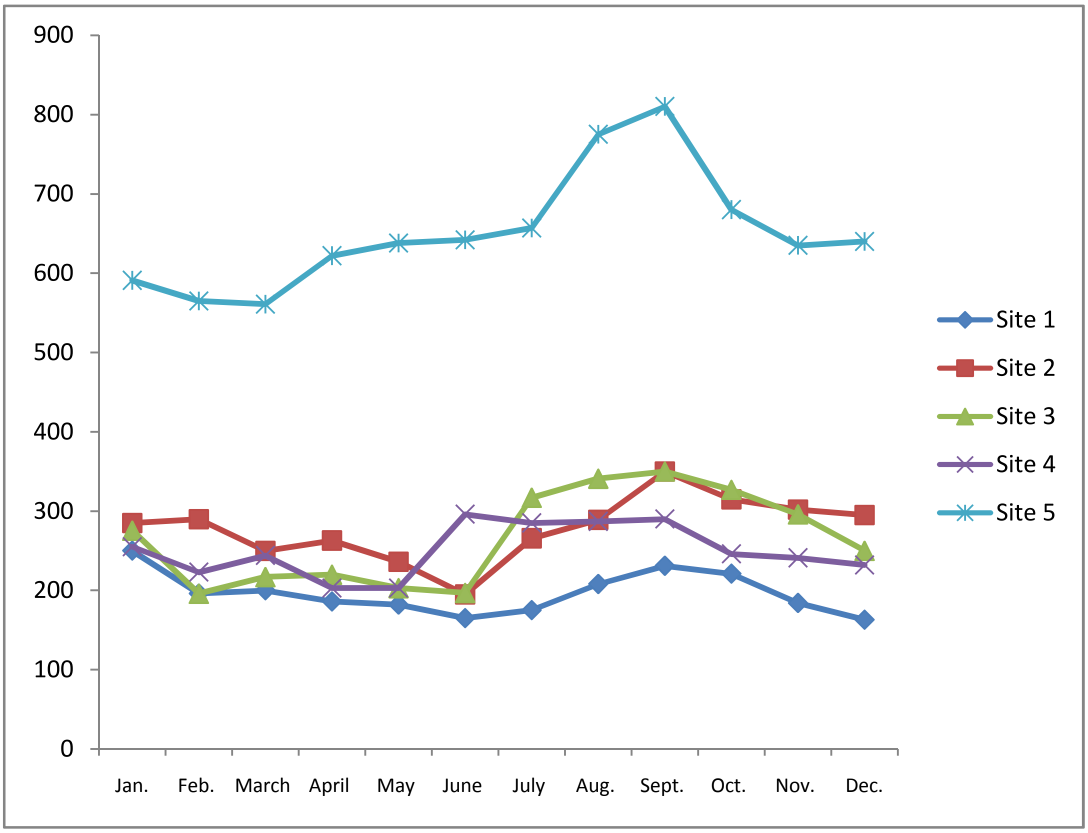


Fig. 7: Monthly fluctuation in conductivity (µs/cm) at five sampling sites.

Table 8: Monthly fluctuation in dissolved oxygen (mg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	8.9	7.1	9.3	8.3	2.4	7.2	2.8
Feb	9	8.8	9.4	7.2	2.6	7.4	2.8
March	8.6	9.2	9.3	8.4	2.6	7.6	2.8
April	9.8	8.9	9.8	8.8	2.2	7.9	3.2
May	8.6	8.4	8.6	8.2	1.6	7.1	3.1
June	6.5	6.5	7.5	5.4	1.2	5.4	2.5
July	6.0	5.5	6.7	5.3	0.8	4.9	2.3
August	5.4	5.9	6.2	5.1	0.8	4.7	2.2
September	5.0	5.7	6.3	5.0	1.5	4.7	1.9
October	7.2	7.9	8.0	6.8	1.6	6.3	2.7
November	6.4	7.8	8.1	6.3	1.8	6.1	2.5
December	6.8	6.3	8.0	6.4	3.0	6.1	1.9
Mean	7.4	7.3	8.1	6.8	1.8		
S.D	1.6	1.3	1.2	1.4	0.7		

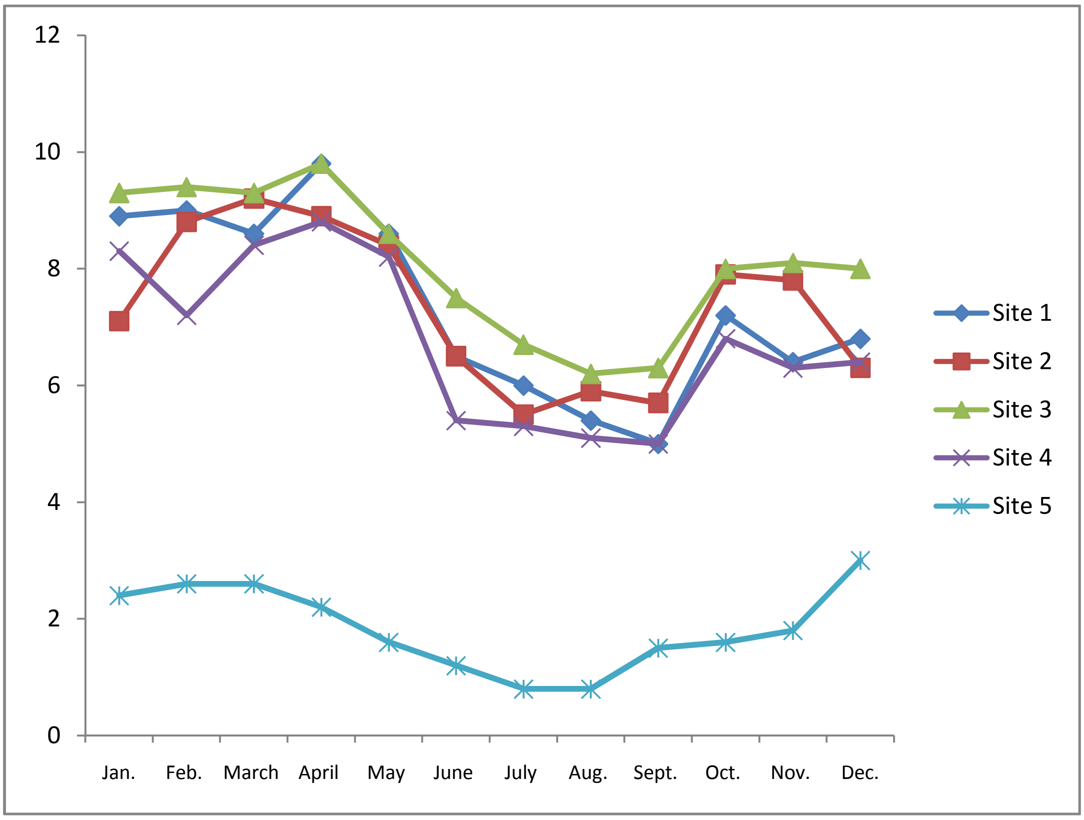


Fig. 8: Monthly fluctuation in dissolved oxygen (mg/l) at five sampling sites.

Table 9: Monthly fluctuations in free Co_2 (mg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	18	15.1	15.1	16.2	38.0	20.5	9.9
Feb	18.1	16.3	15.0	16.0	31.6	19.4	6.9
March	11.2	9.9	10.3	9.0	30.5	14.2	9.2
April	9.6	4.2	4.8	-	24.5	10.8	9.5
May	9.3	-	-	-	23.2	16.3	9.8
June	6.7	-	-	-	20.0	13.4	9.4
July	4.4	-	-	-	25.0	14.7	14.6
August	5.6	-	-	-	12.0	8.8	4.5
September	10.6	3	3.2	-	19.5	9.1	7.8
October	14.2	7.8	8.0	8.4	26.0	12.9	7.8
November	15.0	9.2	9.4	9.8	29.6	14.6	8.7
December	15.3	10.5	11.1	12.0	32.8	16.3	9.4
Mean	11.5	9.5	9.6	11.9	26.1		
S.D	4.6	4.7	4.3	3.5	7.0		

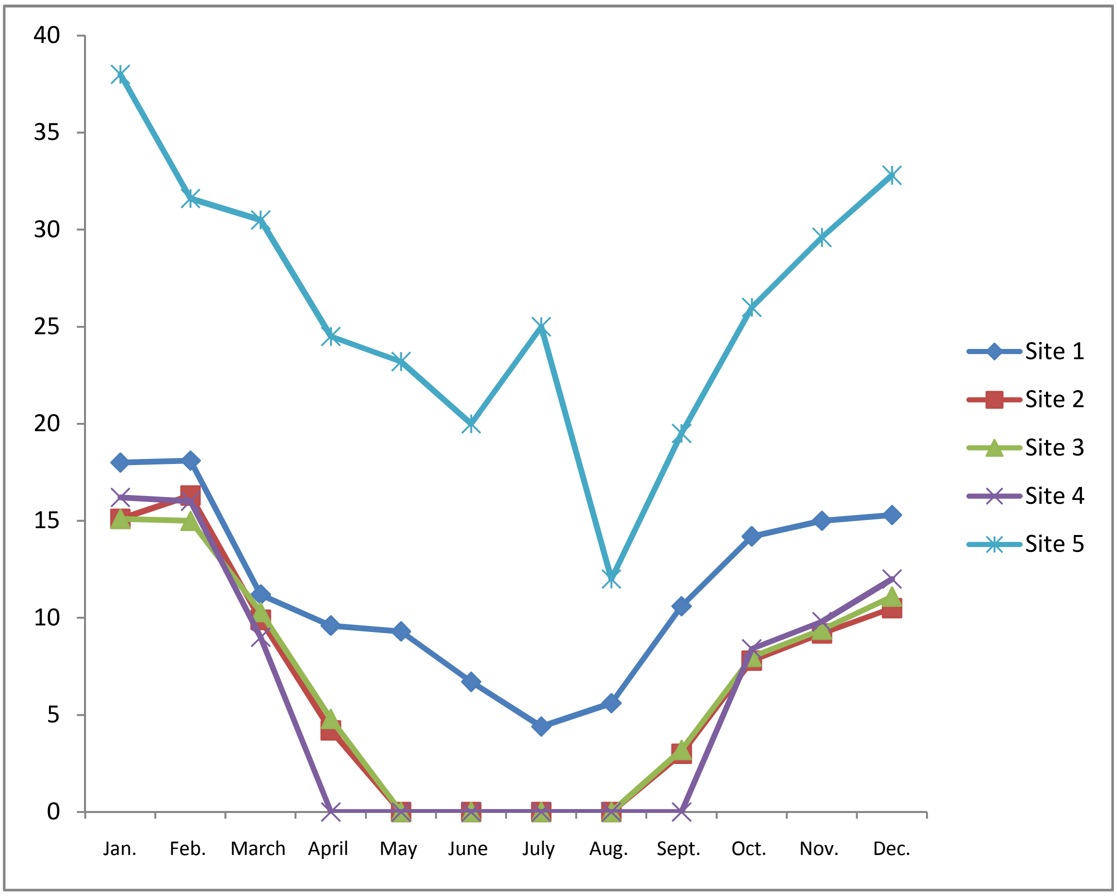


Fig. 9: Monthly fluctuations in free Co_2 (mg/l) at five sampling sites.

Table 10: Monthly fluctuation in total Alkalinity (mg/l) at five sampling sites

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	148	145.1	145	121.2	345.4	180.9	92.6
Feb	123.8	143.2	144.7	132.6	360.9	181.0	100.9
March	139.9	133.0	129.3	115.3	310.8	165.7	81.6
April	125.3	116.4	110.3	103.3	308.6	152.8	87.5
May	98.8	102.3	107.6	99.4	260.9	133.8	71.1
June	95.6	101.9	105.1	102.0	248.8	130.7	66.1
July	94.8	100.6	105.0	105.3	248.0	130.7	65.7
August	104.9	120.2	115.8	106.7	250.6	139.6	62.4
September	120.6	124.4	117.9	113.6	258.2	146.9	62.3
October	118.8	115.7	114.2	109.4	210.2	133.7	42.9
November	118.2	116.2	118.4	112.3	198.7	132.8	36.9
December	124.0	132.8	135.2	130.9	318.9	168.4	84.3
Mean	117.7	121.0	120.7	112.7	276.7		
S.D	16.8	15.3	14.5	10.8	51.5		

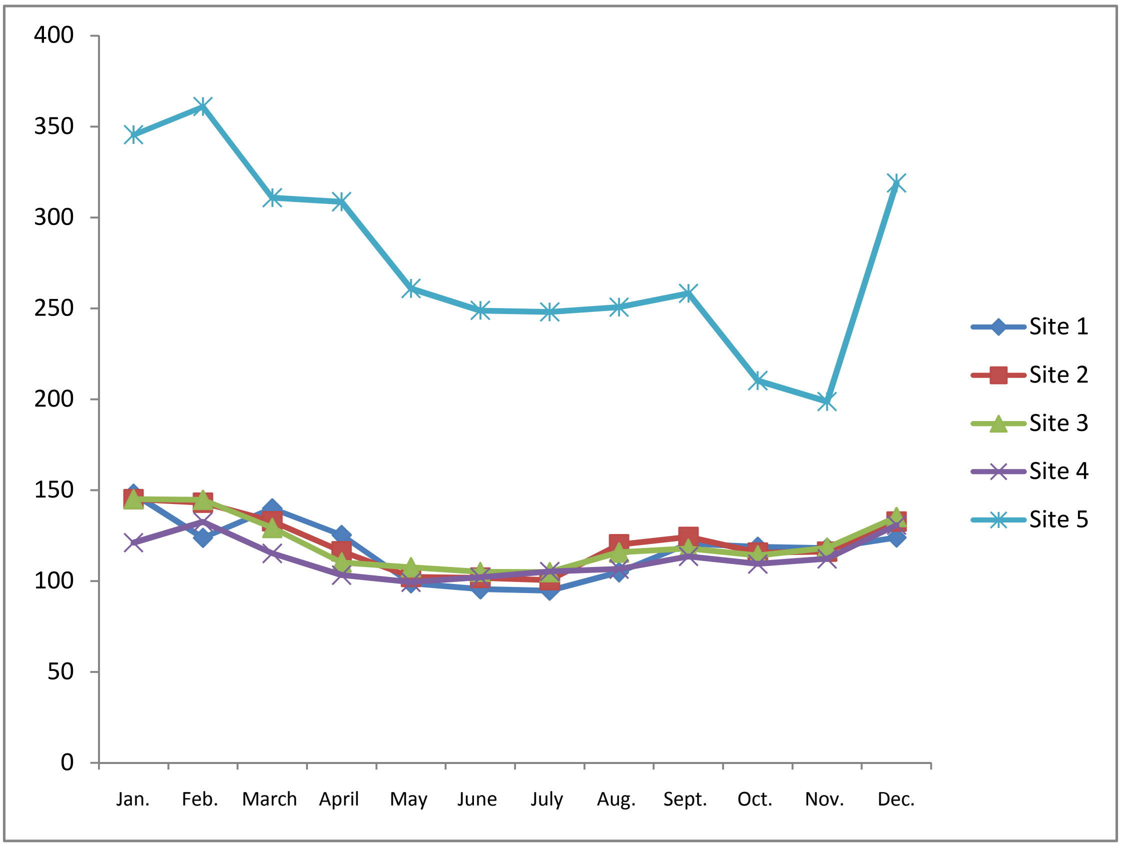


Fig. 10: Monthly fluctuation in total Alkalinity (mg/l) at five sampling sites

Table 11: Monthly fluctuation in Chloride (mg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	22.3	29.6	20.4	23.1	56.2	30.3	14.9
Feb	17.9	30.6	22.4	21.4	62.1	30.9	18.1
March	19.8	25.9	30.5	22.2	34.4	26.6	6.0
April	20.2	24.1	22.6	19.7	71.3	31.6	22.3
May	19.9	17.3	19.5	16.9	59.0	26.5	18.2
June	13.0	13.4	17.1	17.3	56.3	23.4	18.5
July	11.9	15.2	12.5	14.5	44.6	19.7	14.0
August	19.1	20.6	17.4	27.3	45.9	26.1	11.7
September	18.9	17.0	20.8	29.1	49.1	27.0	13.2
October	19.5	18.2	24.0	31.5	68.3	32.3	20.8
November	21.6	19.8	24.2	36.2	42.6	28.9	10.0
December	24.1	25.3	24.5	22.1	44.5	28.1	9.2
Mean	19.0	21.4	21.3	23.4	52.9		
S.D	3.5	5.6	4.6	6.4	11.2		

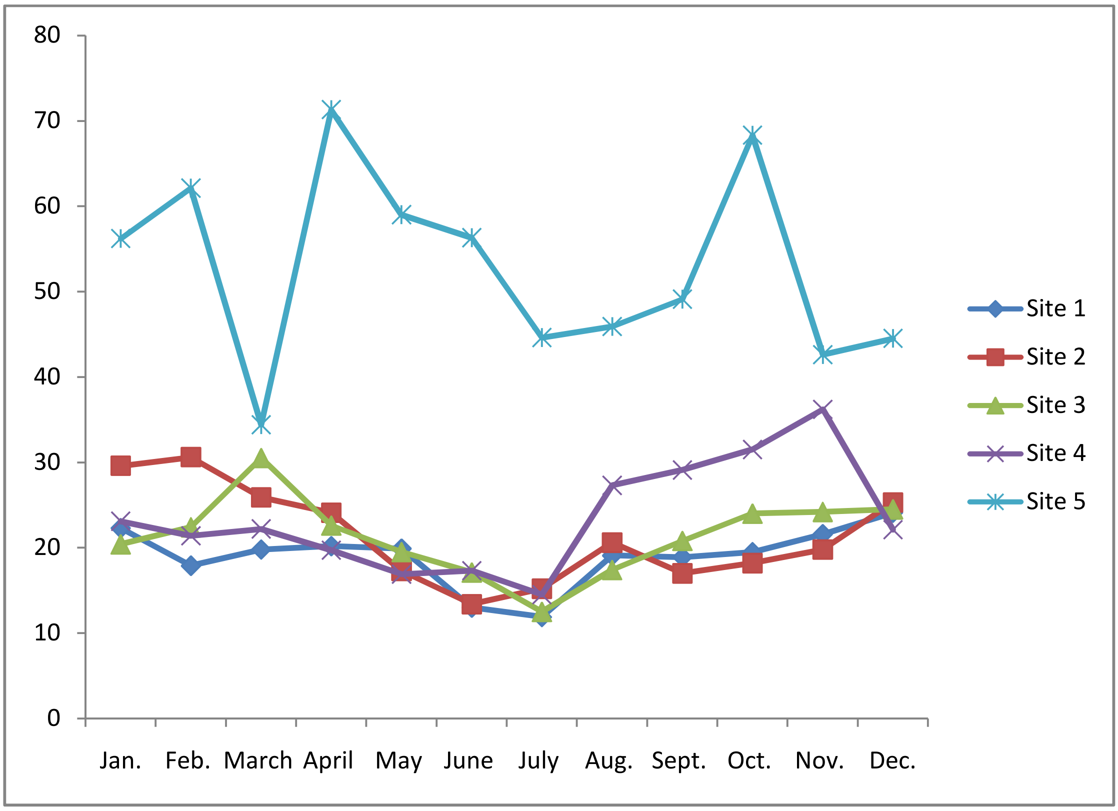


Fig. 11: Monthly fluctuation in Chloride (mg/l) at five sampling sites.

Table 12: Monthly fluctuation in Ammonical-Nitrogen (µg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	165.4	250.3	293.5	145.1	811.2	333.1	274.1
Feb	215.6	235.6	301.1	169.4	825.2	349.4	270.2
March	235.8	248.2	285.6	250.2	1025.3	409.0	345.0
April	234.5	197	200.5	186.4	981.6	360.0	348.0
May	195.5	238	192.6	125.6	1080.2	366.4	401.1
June	301.9	224.2	221.3	163.7	1165.7	415.4	422.3
July	310.6	235.6	182.5	102.8	1222.8	410.9	460.2
August	300.0	255.3	225.5	115.4	902.0	359.6	310.7
September	278.4	205.5	286.6	129.4	970.1	374.0	339.2
October	150.1	196.8	152.4	211.5	1018.2	345.8	376.8
November	125.0	151.1	142.6	216.6	850.0	297.1	311.0
December	100.0	180.4	182.1	235.7	725.1	284.7	250.9
Mean	217.7	218.2	222.2	171.0	964.8		
S.D	72.0	32.1	56.6	49.2	149.2		

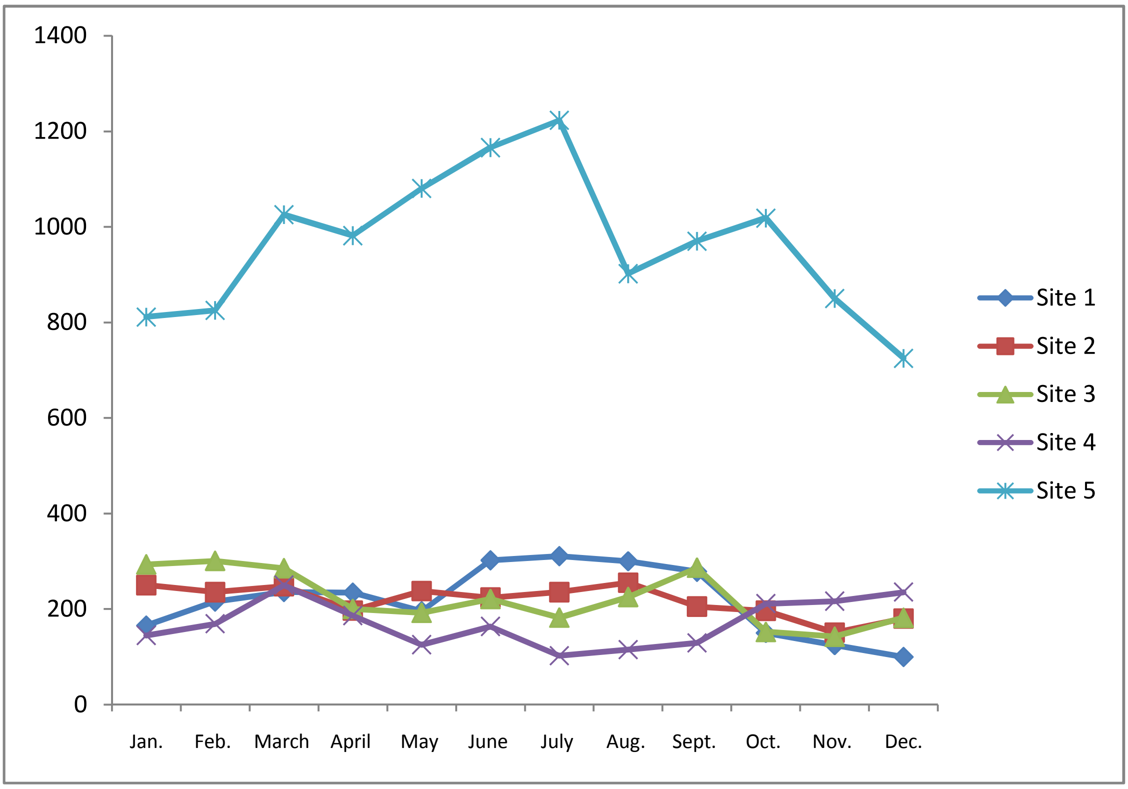


Fig. 12: Monthly fluctuation in Ammonical-Nitrogen (µg/l) at five sampling sites.

Table 13: Monthly fluctuation in nitrate-Nitrogen (µg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	432.8	573.1	445.3	450.3	140.6	408.4	160.1
Feb	389.7	605.6	615.4	465.2	210.5	457.3	167.7
March	392.8	436.5	515.6	590.3	245.6	436.2	130.6
April	316.9	513.4	493.7	502.2	119.3	389.1	171.2
May	385.6	423	315.2	523.1	178.8	365.1	128.4
June	413.2	550	528.1	560.2	240.1	458.3	135.4
July	554.6	603.6	625.6	340.2	72.1	439.2	234.3
August	598.8	715.2	750.5	380.9	84.2	505.9	276.5
September	767.6	850.8	925.2	420.5	72.1	607.2	356.2
October	635.5	758.2	648.7	622.6	148.1	562.6	237.9
November	440.6	600.3	695.4	624.4	168.4	505.8	210.4
December	425.8	565.1	593.6	540.3	139.7	452.9	186.3
Mean	479.5	599.6	596.0	501.7	151.6		
S.D	131.1	124.8	156.5	92.5	60.0		

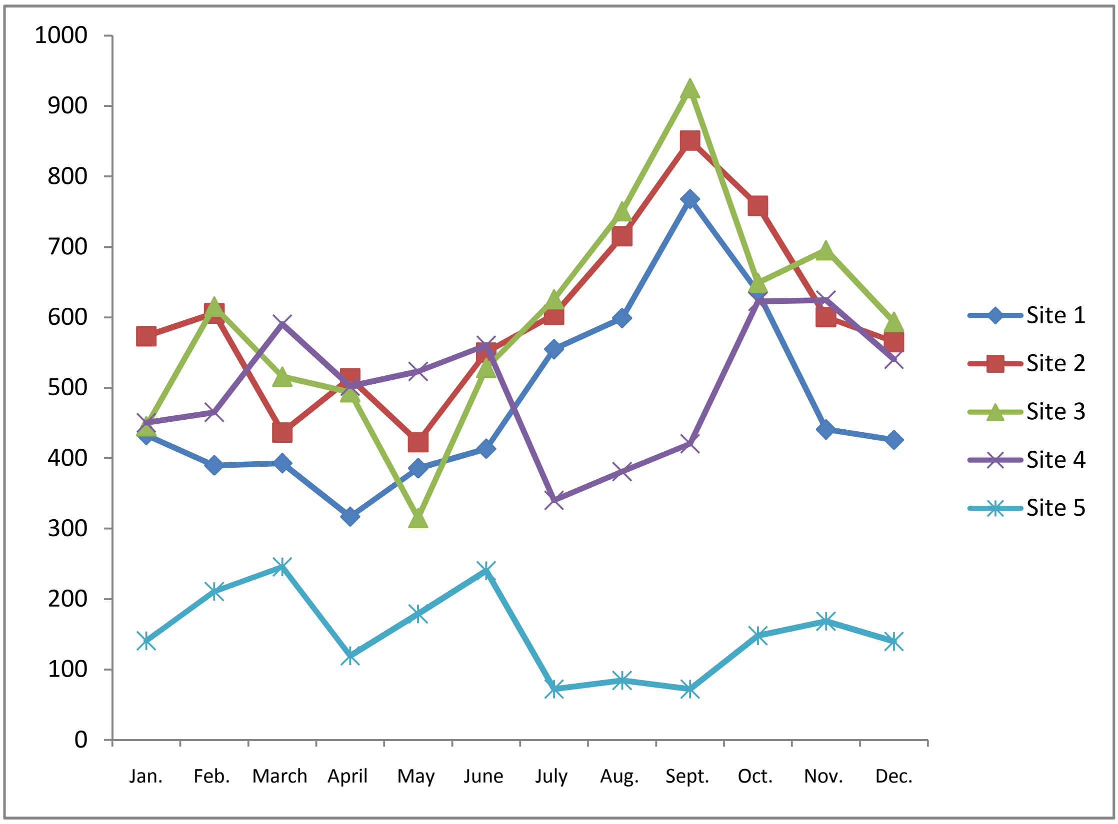


Fig.13: Monthly fluctuation in nitrate-Nitrogen (µg/l) at five sampling sites.

Table 14: Monthly fluctuation in nitrite-nitrogen (µg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	28	53	68	69	68	57.2	17.6
Feb	24	38	39	53	72	45.2	18.2
March	26	34	42	53	84	47.8	22.6
April	22	26	23	68	31	34.0	19.3
May	19	22	19	70	26	31.2	21.9
June	25	20	23	65	73	41.2	25.6
July	36	23	37	22	100	43.6	32.3
August	28	29	26	43	33	31.8	6.8
September	35	35	24	34	44	34.4	7.1
October	41	49	49	52	85	55.2	17.2
November	42	52	63	45	102	60.8	24.4
December	38	53	59	52	93	59.0	20.5
Mean	30.3	36.2	39.3	52.2	67.6		
S.D	7.7	12.7	17.1	14.8	27.5		

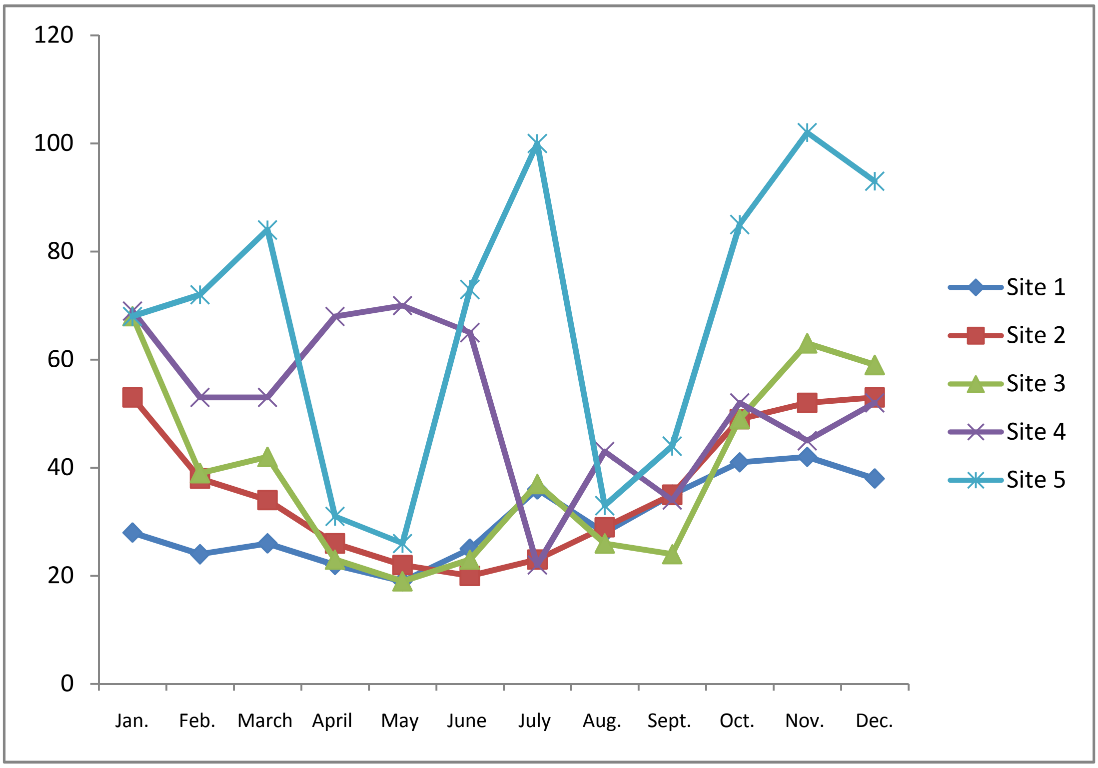


Fig. 14: Monthly fluctuation in nitrite-nitrogen (µg/l) at five sampling sites.

Table 15: Monthly Fluctuation in total phosphorous (µg/l) at five sampling sites.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Jan	434.6	432.6	602.8	640.0	910.0	604.0	195.6
Feb	536.7	560.7	723.8	538.0	1150.0	701.8	262.4
March	432.6	630.8	644.3	486.3	925.0	623.8	191.5
April	385.7	542.8	565.6	547.4	1212.0	650.7	322.0
May	401.1	530.2	591.7	528.1	1865.0	783.2	608.7
June	525.6	736.6	748.6	669.2	1501.0	836.2	382.1
July	536.6	528.4	802.6	770.4	1235.2	774.6	287.3
August	318.9	535.2	432.4	680.0	2130.0	819.3	744.7
September	475.2	755.2	585.6	580.0	2325.0	944.2	778.4
October	560.1	602.5	635.8	635.1	2050.0	896.7	645.5
November	312.6	541.4	591.7	725.2	1985.3	831.2	662.1
December	430.4	583.6	732.5	436.0	1895.7	815.6	616.4
Mean	445.8	581.7	638.1	603.0	1598.7		
S.D	83.6	90.7	100.7	100.3	499.3		

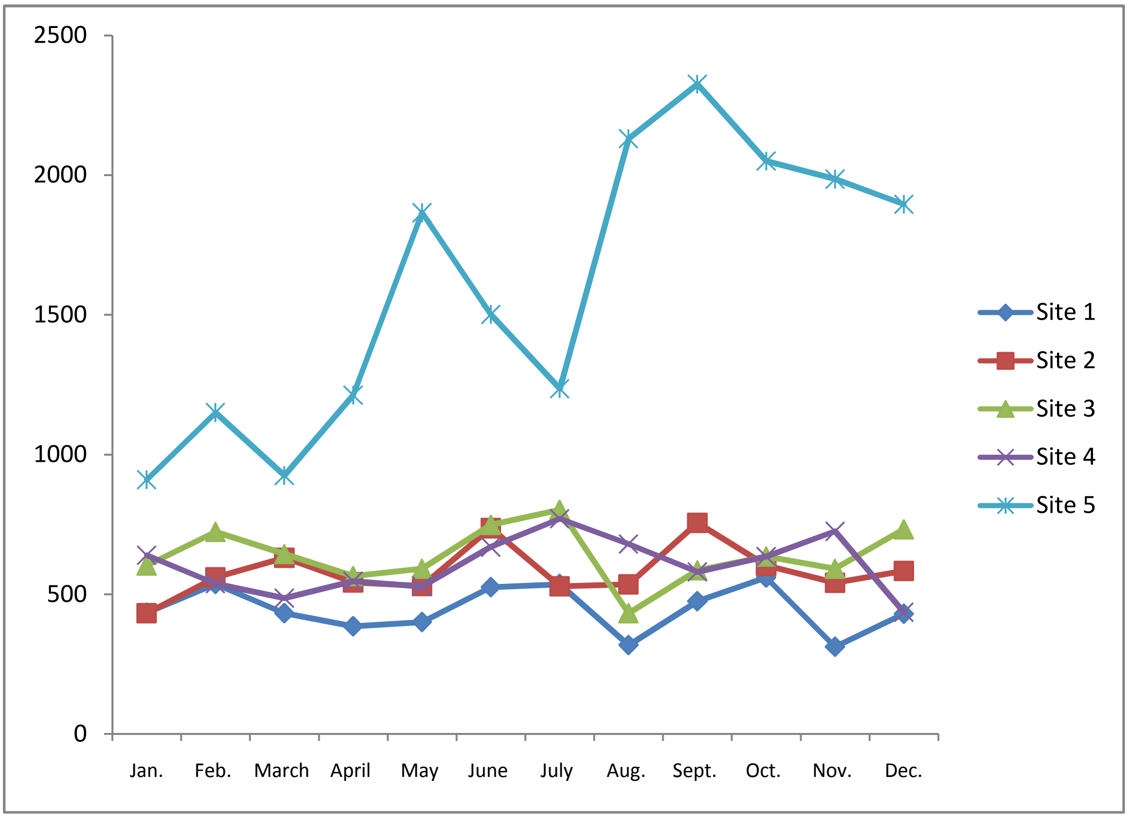


Fig. 15: Monthly Fluctuation in total phosphorous (µg/l) at five sampling sites.

II. Bio-ecology

a) Rotifera

(i) Species composition

The rotifera was represented by 20 species of which 16 belonged to order ploima, 2 to Flosculariaceae and 2 to order Bdelloida.

Phylum : Rotifera

Class : Monogononta

Order : Ploima

Family : Brachionidae

1. *Brachionus angularis*
2. *Brachionus calyciflorus*
3. *Brachionus plicatilis*
4. *Brachionus quadridentata*
5. *Platyias quadricornis*

Family : Synchaetidae

6. *Synchaeta sp.*
7. *Polyarthra vulgaris*

Family : Lecanidae

8. *Lecane sp.*
9. *Monostyla bulla*

Family : Trichocercidae

10. *Trichocerca sp.*
11. *Trichocerca longiseta*

Family : Gastropidae

12. *Ascomorpha sp.*
13. *Gastropus sp.*

Family : Asplanchnidae

14. *Asplanchna priodonta*

Family : Colurellidae

15. *Lepadella ovalis*

Family : Proalidae

16. *Proales*

Order : Floscularíaceae

Family : Filinidae

17. *Filinia longiseta*
18. *Filinia terminalis*

Class : Bdelloidae

Order : Bdelloida

Family : Philodinidae

19. *Bdelloid sp.*

20. *Philodina sp.*

ii) Population Dynamics of Rotifera

Brachionus angularis

This species was recorded at all sites. At site I, this species was seen only in March (380 Ind./m^3). At site II, it appeared from April to June, then in September and October recording its Peak in the month of May (2000 ind./m^3). At site III, it was recorded continuously from February to April and then after remaining absent upto June it showed its appearance from July to September and then remained absent again. The peak population was recorded in April (1450 ind./m^3). At site IV, it remained absent upto May and then made its appearance in June and in September. The peak population was recorded in September (1000 ind./m^3). At site V, it was first recorded from May to July and then in October with peak population of 2500 ind./m^3 in the month of July.

Brachionus calyciflorus

This species was recorded at all sites. At site I, it was recorded continuosly from April to September with peak population of 2120 ind./m^3 in the month of August. At site II, it was first observed in May and then after remaining absent from June to August, it again reappeared in September and October. Its peak population was recorded in May (1800 ind./m^3). At site III, it first remained absent from January to April and then it was continuously recorded from May to September with highest population density in July (2800 ind./m^3). At site IV, it was recorded from June to September with peak population of 3050 ind./m^3 in September. At site V, it was continuously recorded from March to September with peak population of 4000 ind./m^3 in the month of May.

Table 16:*Brachionus angularis*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1			380									
Site 2				1364	2000	1064			1800	598		
Site 3		180	828	1450			500	1220	1310			
Site 4						890			1000			
Site 5					1000	2220	2500			500		

Table 17:*Brachionus calyciflorus*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1				1364	1856	1000	975	2120	800			
Site 2					1800				1682	320		
Site 3					1050	1730	2800	1660	2150			
Site 4						1800	2800	2420	3050			
Site 5			1000	3580	4000	3980	880	3990	120			

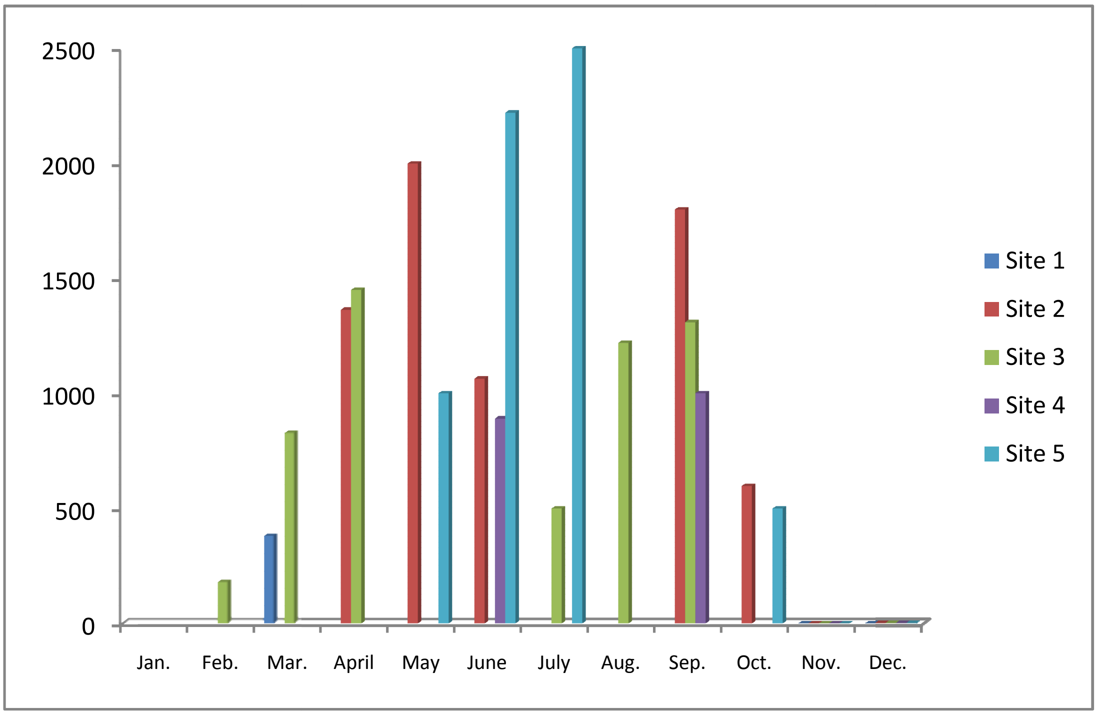
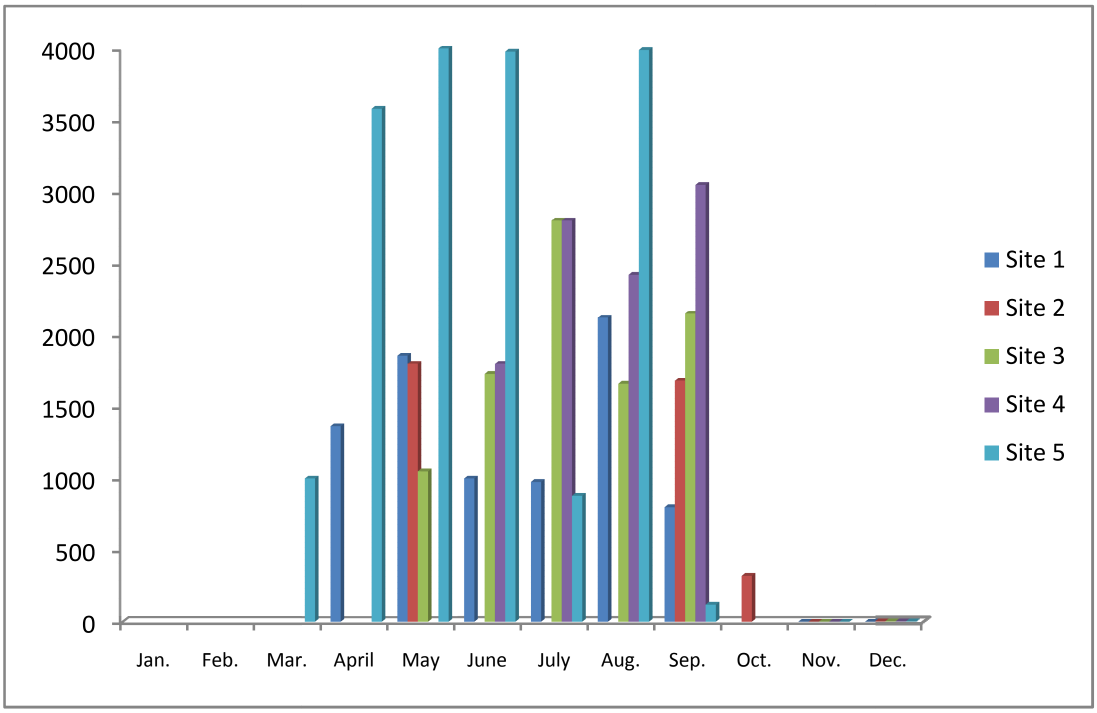


Fig. 17:*Brachionus angularis*



17:*Brachionus calyciflorus*

Brachionus plicatilis

This species was absent throughout the year at site I and site III. At site II, it remained absent from January to September and then it was seen in October and November. The highest population density was recorded in November (880 ind./m^3). At site IV, it was recorded continuously from May to July and then again showed its presence in the months of September and November with peak population of 1760 ind./m^3 in June. At site V, it was recorded continuously from January to May and then after remaining absent from June to November it again appeared in December. The peak population was recorded in May (2808 ind./m^3).

Brachionus quadridentata

This species was absent at sites I and II. At site III, it was recorded only once during the month of October (1200 ind./m^3). At site IV, it was recorded from July to October with peak population recorded in october (2300 ind./m^3). At site V, it was first recorded continuously from February to July and then in November. The peak population was recorded in July (1280 ind/m^3)

Table: 18. *Brachionus plicatilis*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2										520	880	
Site 3												
Site 4					420	1760	1050		500		120	
Site 5	2000	2150	900	2000	2808							1210

Table 19*: Brachionus quadridentata*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2												
Site 3										1200		
Site 4							1665	1430	1000	2300		
Site 5		800	920	1000	790	1000	1280				1128	

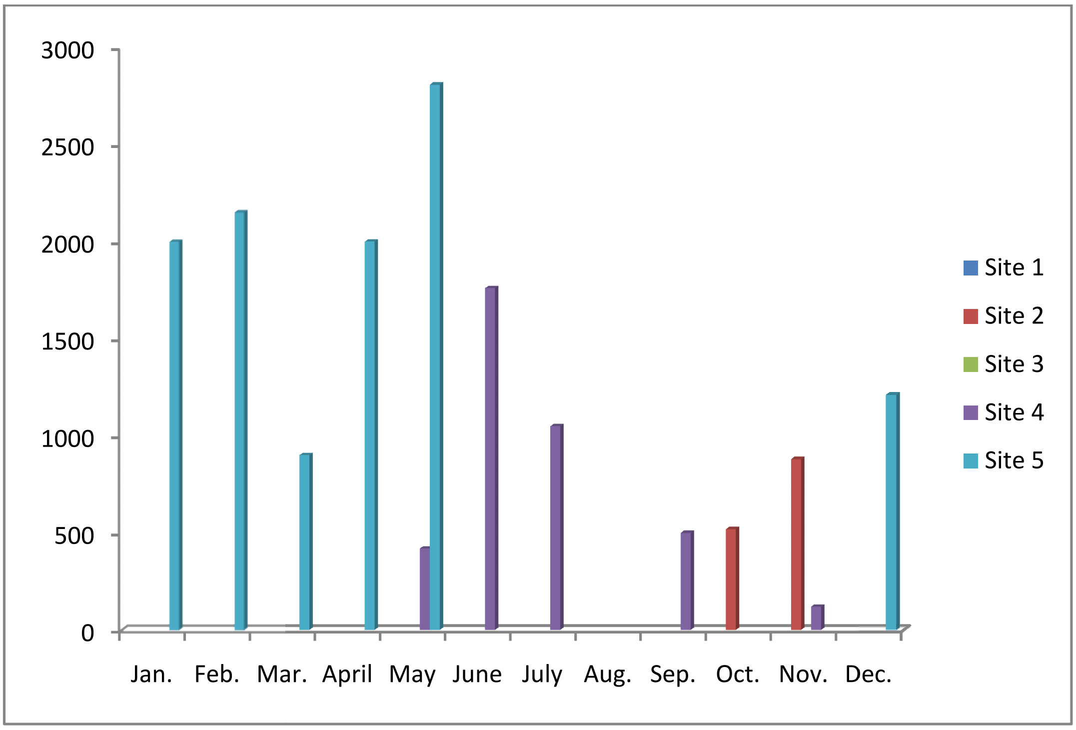


Table 18*: Brachionus plicatilis*

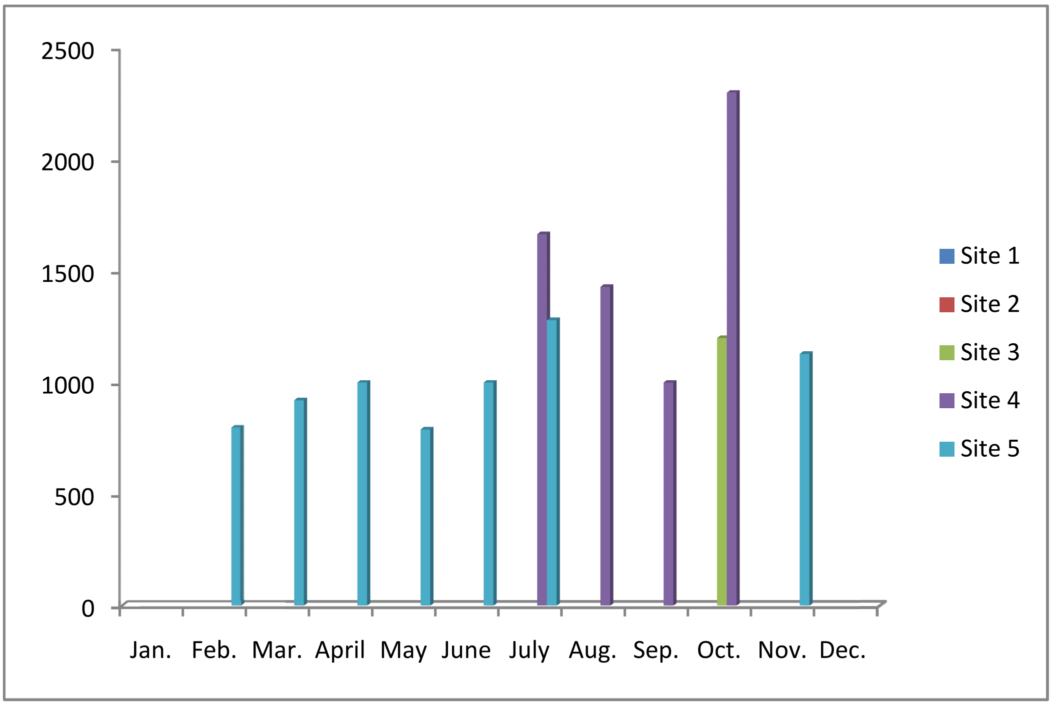


Fig. 19*: Brachionus quadridentata*

Platiyas quadricornis

This species was recorded from all the sites. At site I, it was recorded from the month of June to September with peak population in August (1268 ind./m^3). At site II, it was recorded first from April to July and then in September. The peak population was recorded in May (2020 ind./m^3). At site III, it was recorded from March to July with peak population of 2200 ind./m^3 in July. At site IV, it was first recorded from April to June and then in August and September with peak population in September (4200 ind./m^3). At site V, it was recorded thrice i.e. June, July and October. The peak population was recorded in October (1238 ind./m^3).

Family : Synchaetidae

Synchaeta sp.

This species was absent at site IV and site V. At site I, it appeared from January to Apil and remained absent after that recording its peak in February (1320 ind./m^3). At site II, this species was first recorded in January, then March. It again reappeared in November and December. Its peak population was recorded in March (1228 ind./m^3). At site III, it was recorded from January to April and then from October to December with peak population of 2160 ind./m^3 in January.

Table 20:*Platiyas quadricornis*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1						880	1268	1580	524			
Site 2				510	2020	1185	600		250			
Site 3			420	1828	1000	460	2200					
Site 4				1650	3000	3650		1650	4200			
Site 5						880	1000			1238		

Table 21: *Synchaeta sp.*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	1000	1320	900	980								
Site 2	1000		1228								1000	864
Site 3	2160	1600	1728	630						828	1800	1760
Site 4												
Site 5												

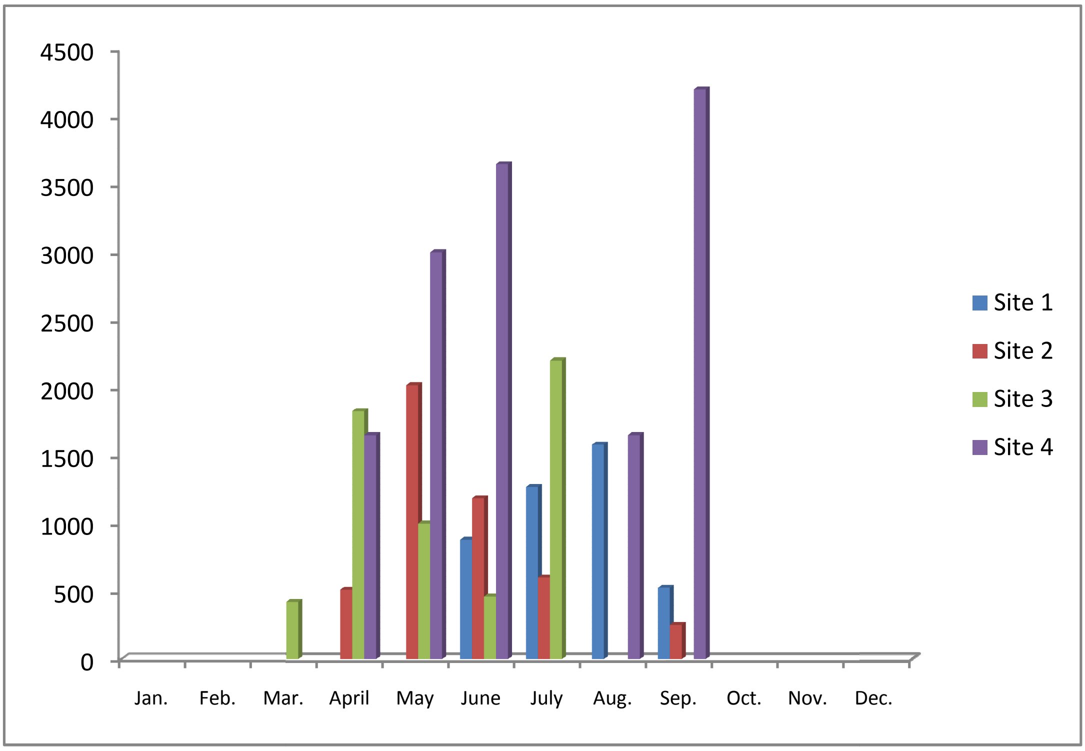


Fig. 20:*Platiyas quadricornis*

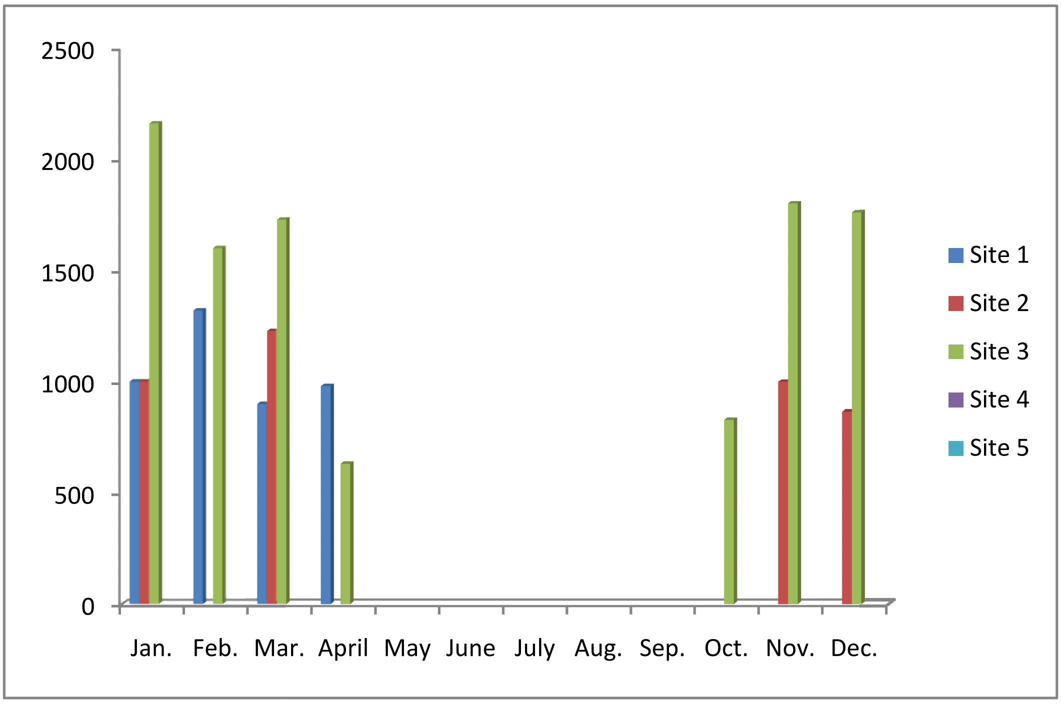


Fig. 21: *Synchaeta sp.*

Polyarthra vulgaris

This species remained absent at site V throughout the study period. At site I, it was first recorded continuously from January to May and then from August to November recording peak population of 2280 ind./m^3 in September . At site II, it was present throughout the study period except the months of January, March and November. The peak population was observed in September (2011 ind./m^3). At site III, it first made its appearance in March and remained continuously present upto June. After remaining absent in July it again showed its presence in August. The highest population density was recorded in March (2100 ind./m^3). At site IV, this species was recorded from May to July and then in November recording its highest population density of 2865 ind./m^3 in May.

Family : Lecanidae

Lecane Sp.

This species was completely absent at site I and Site V throughout the study period. At site II, it was recorded from March to August continuously with peak population in June (2530 ind./m^3). At site III, it was recorded from March to July. The highest population density was attained in April (1350 ind./m^3). At site IV, it was recorded twice i,e. June (720 ind./m^3) and July (1000 ind./m^3).

Table 22:*Polyarthra vulgaris*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	160	250	400	1000	1800			1500	2280	1200	800	
Site 2		380		1528	1400	600	220	930	2100	955		250
Site 3			2100	1264	1008	400		1800				
Site 4						1690	820				2528	
Site 5												

Table 23*: Lecane sp.*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2			1900	1500	1560	2530	1400	2000				
Site 3			1000	1350	1300	908	480					
Site 4						720	1000					
Site 5												

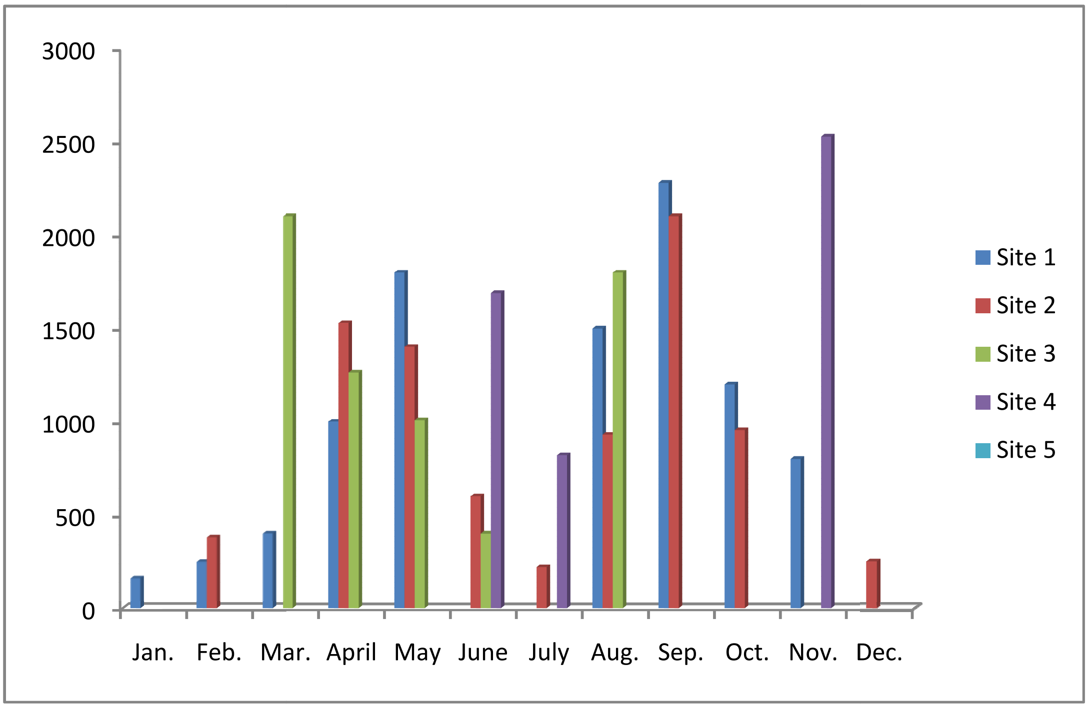


Fig. 22:*Polyarthra vulgaris*

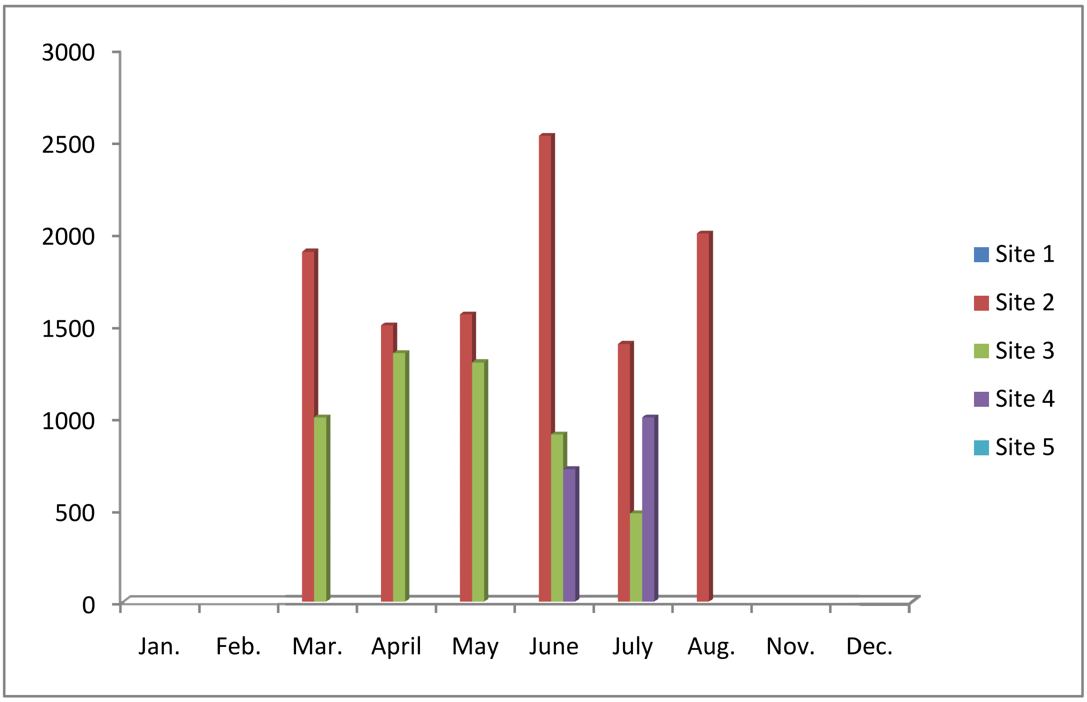


Fig. 23: *Lecane sp.*

Monostyla bulla

At site I, it was recorded from April to June after which it remained absent throughout the remaining period. The peak population was recorded in May (2010 ind./m^3) . At site II, it was first recorded from May to August and then again in October with a peak population of 2100 ind./m^3 in August. At site III, it was continuously present from April to September with peak population in May (3030 ind./m^3) . At site IV, it first made its appearance in March and then from May to August, and October. The highest population density was recorded in August (3400 ind./m^3) . At site V, it was recorded in March, May and June with highest population density of 2100 ind./m^3 in May.

Family : Trichocercidae

***Trichocerca* sp.**

This species remained absent at site I and Site V throughout the study period. At site II, it was first recorded in April and then after remaining absent in May and June, it again reappeared in July and continued to be present upto September. The peak population was recorded in August (1960 ind./m^3). At site III, it first appeared from April to June and then in August, November and December with a peak population of 3050 ind./m^3 in November. At site IV it was recorded from June to September recording its highest population density 1650 ind./m^3 in July.

Table 24: *Monostyla bulla*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1				620	2010	1300						
Site 2					964	1400	1860	2100		380		
Site 3				2150	3030	870	2150	2800	1000			
Site 4			1000		2150	2650	1880	3400		3268		
Site 5			1000		2100	390						

Table 25: *Trichocerca* sp.

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2				1860			828	1960	1364			
Site 3				2510	1350	1000		500			3050	1000
Site 4						1000	1650	1000	312			
Site 5												

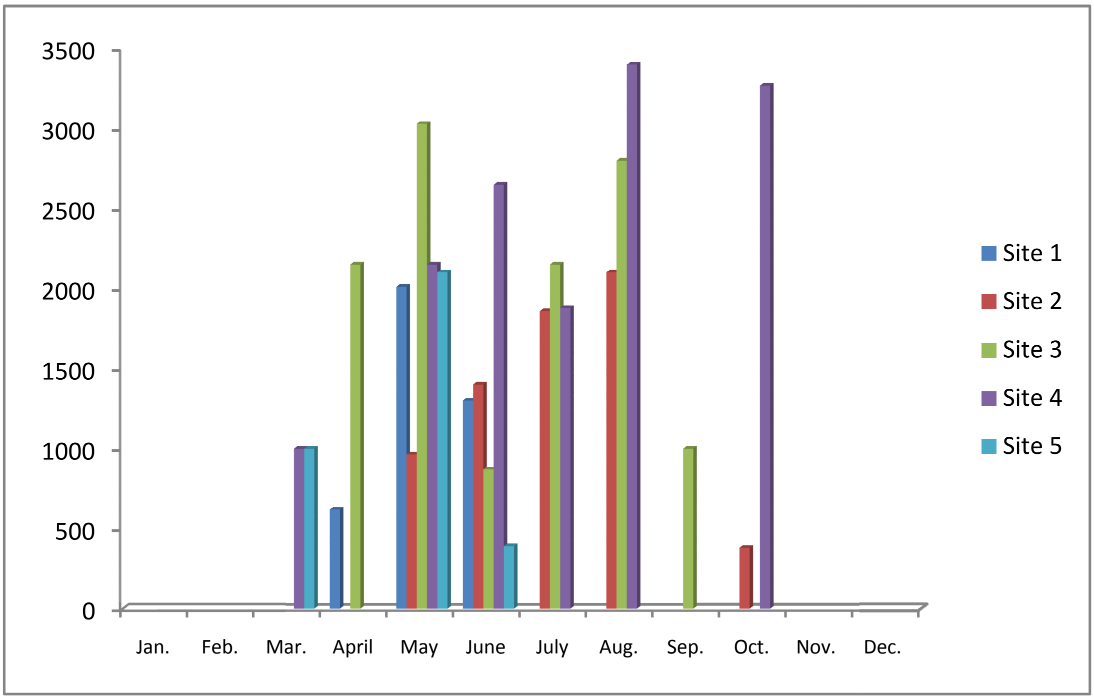


Fig. 24: *Monostyla bulla*

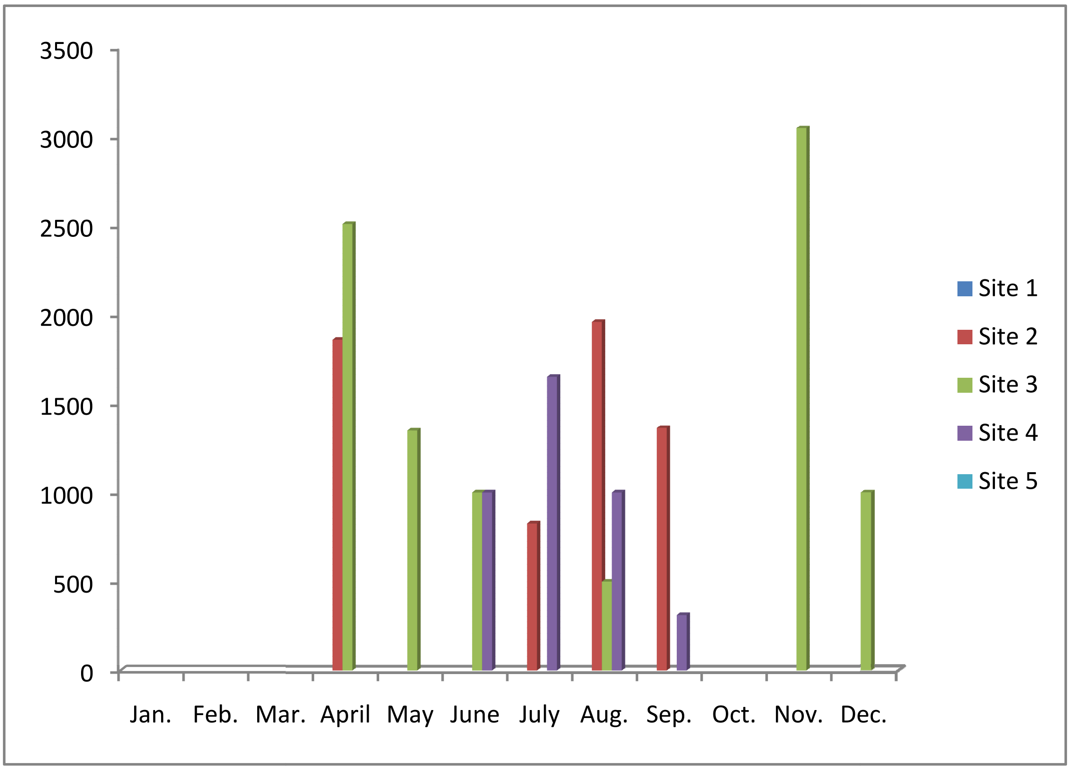


Fig. 25: *Trichocerca* sp.

Trichocerca longiseta

This species was absent at sites II, III and IV. At site I, it was recorded only once i.e. May (300 ind./m^3). At site V, it was again recorded only once i.e. August, (1050 ind./m^3).

Family : Gastropidae

***Ascomorpha* sp.**

At site I, this species was first recorded in February, then March and then again from May to June with peak population in June (780 ind./m^3). At site II, it was recorded in April, May, June and October. The peak population was observed in June (900 ind./m^3). At site III, it was present continuously from February to June and then in August. The peak population was recorded in August (1100 ind./m3). At site IV it was recorded in the months of April and September with highest population in September (1180 ind./m3). At site V, it was recorded only twice i.e. May and June with highest population density in June (1028 ind/m^3).

Table 26:*Trichocerca longiseta*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1					300							
Site 2												
Site 3												
Site 4												
Site 5								1050				

Table 27:*Ascomorpha* sp.

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1		98	350		120	780						
Site 2				380	600	900				656		
Site 3		700	700	380	850	520		1100				
Site 4				1150					1180			
Site 5					1000	1028						

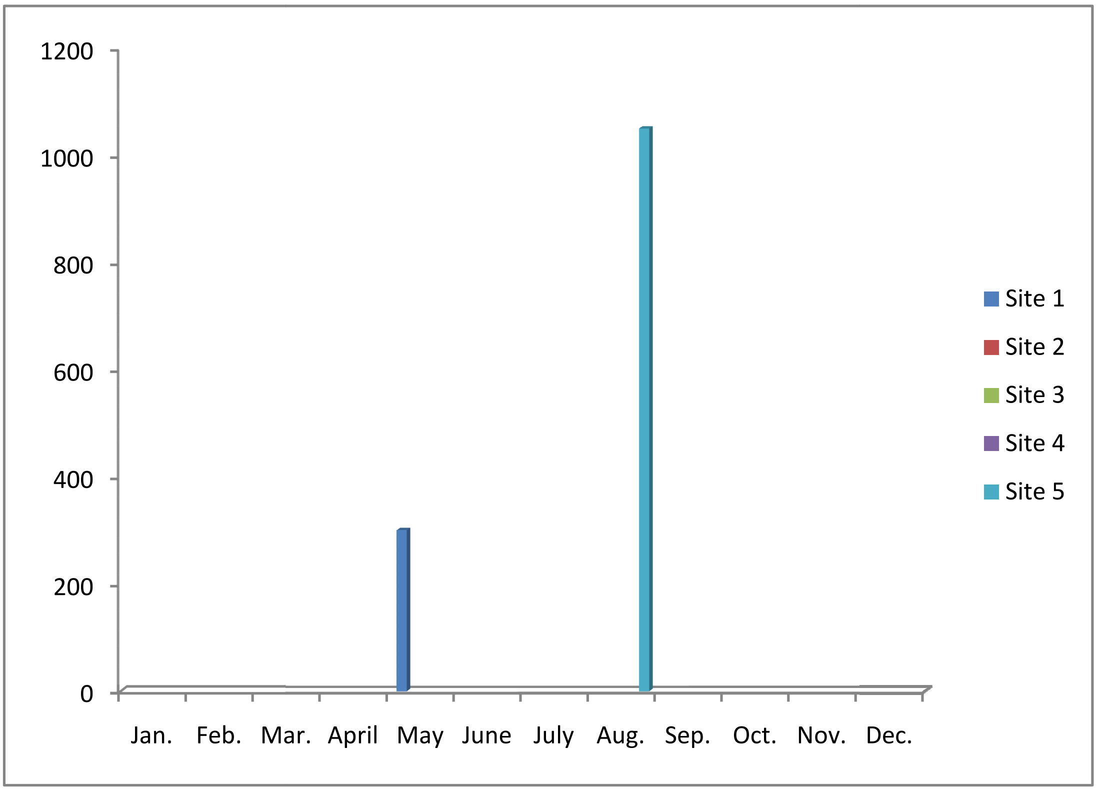


Fig.26:*Trichocerca longiseta*

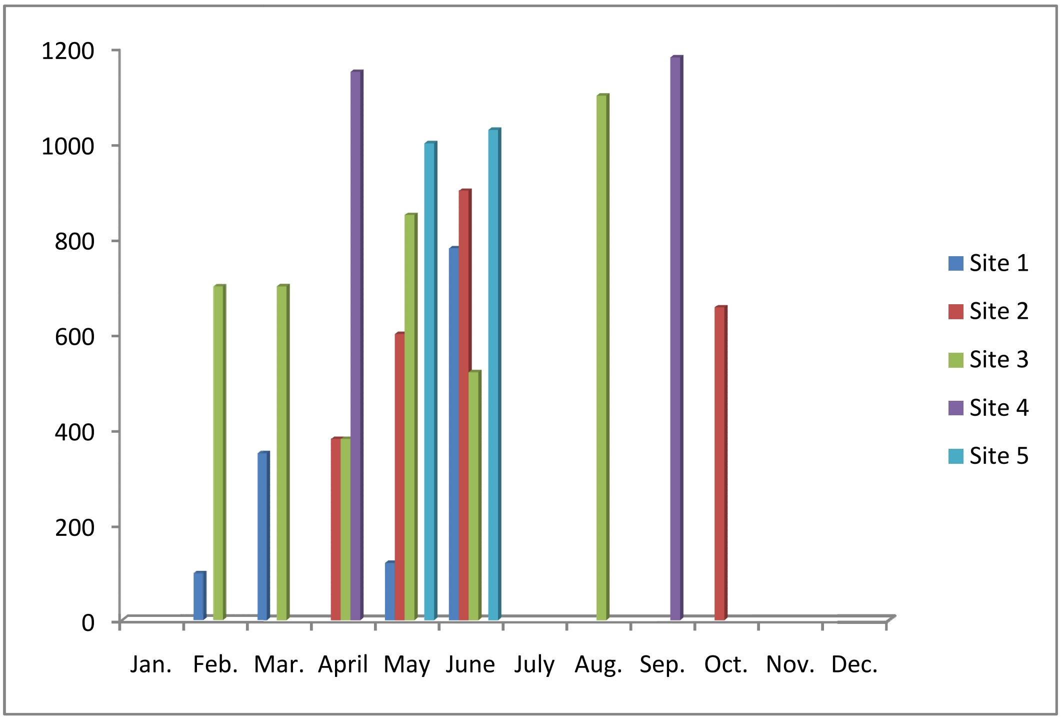


Fig. 27:*Ascomorpha sp.*

Gastropus sp.

At site II and IV, this species remained completely absent throughout the study period. At site I, it was recorded only from April to June. Its peak population was recorded in April (1000 ind./m3). At site III, it was recorded from march to June and then in August with peak population of 1578 ind./m^3. At site IV, it was recorded in same months as at site III with peak population of 3230 ind./m^3 in May.

Family : Asplanchnidae

Asplanchna priodonta

At site I, this species was first recorded in March and then remained absent till July. It reappeared in August and September recording its highest population density in March (1360 ind./m^3). At site II, it was seen in March, April and October with peak population in March (1600 ind./m^3) .Atsite III, it first appeared in January and then continuously from April to August and then December. The highest population density was observed in May (1750 ind./m^3). At site IV, it was present in all the months except February, April, September and November with peak population of 2418 ind./m^3 in June. At site V, it was recorded only once in June (1000 ind./m^3).

Table*28:* *Gastropus sp.*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1				1000	880	800						
Site 2												
Site 3			728	1220	1138	1000		1578				
Site 4			1000	1000	3230			2850				
Site 5												

Table 29:*Asplanchna priodonta*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1			1360					1810	1200			
Site 2			1600	1600						1464		
Site 3	998			1000	1750	1080	1000	1500				350
Site 4	460		460		1000	2418	890	200		200		200
Site 5						1000						

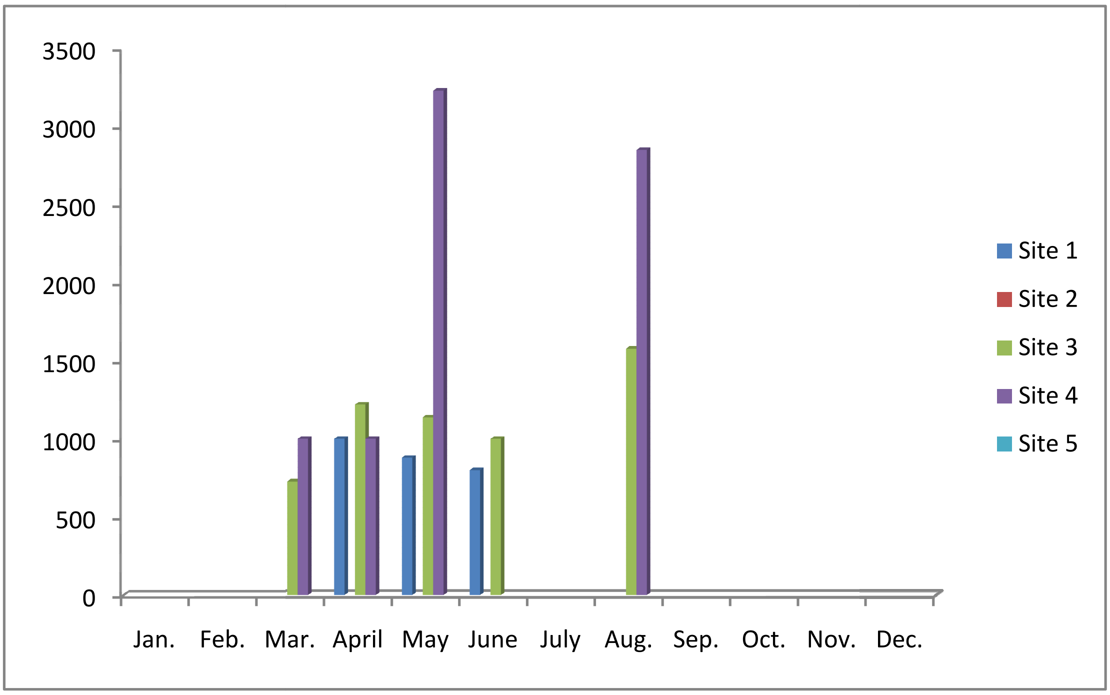


Fig. *28: Gastropus sp.*

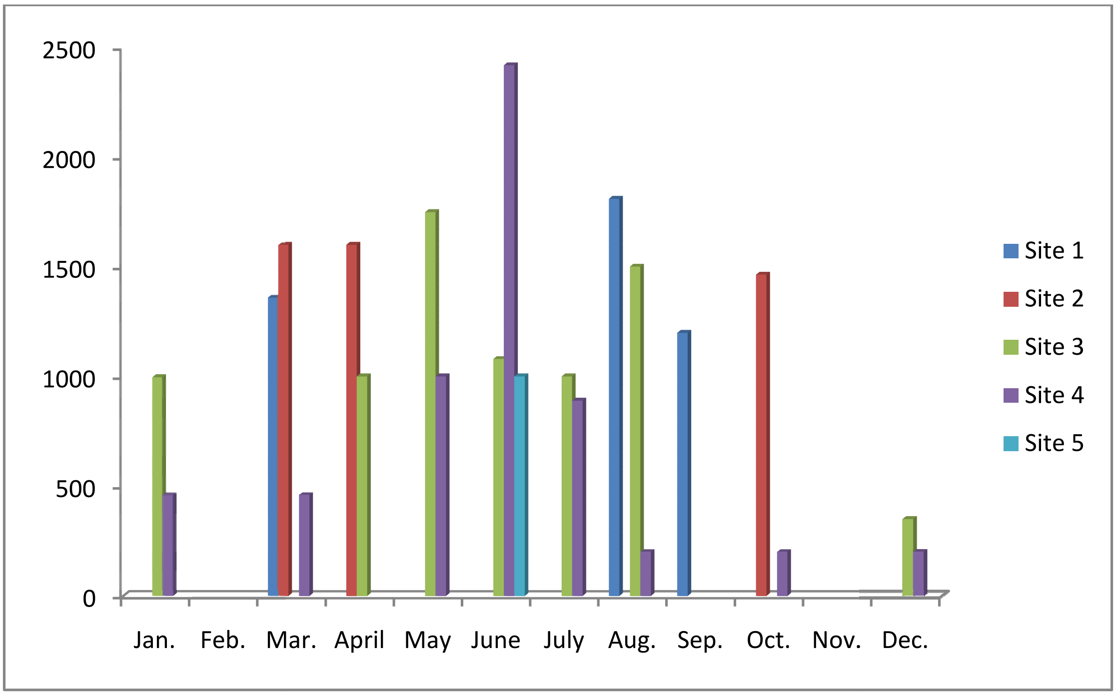


Fig. 29:*Asplanchna priodonta*

Family : Colurellidae

Lepadella ovalis

This species was absent at site I and site III. At site II, it was first recorded continuously from march to June and then remaining absent upto November it again reappeared in December.Its peak population was recorded in June (2530 ind./m^3). At site IV, it first showed its appearance in January and February and then in July and August with peak population of 2470 ind./m^3 in August.

Family : Proalidae

Proales

At site I and Site III, this species was completely absent. At site II, it was recorded in warmer months i.e. June to September with peak population 780 ind./m^3 in August. At site IV, it was observed from May to July and then in September. The highest population density was recorded in May (1000 ind./m^3). At site V, it was recorded only twice i.e. June and July with peak population of 3200 ind./m^3 June.

Table 30: *Lepadella ovalis*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2			900	500	560	2530						
Site 3												
Site 4	166	1000					2364	2470				
Site 5				806			500	1850				

Table 31: *Proales*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2						520	480	780	310			
Site 3												
Site 4					1000	866	428		778			
Site 5						3200	2260					

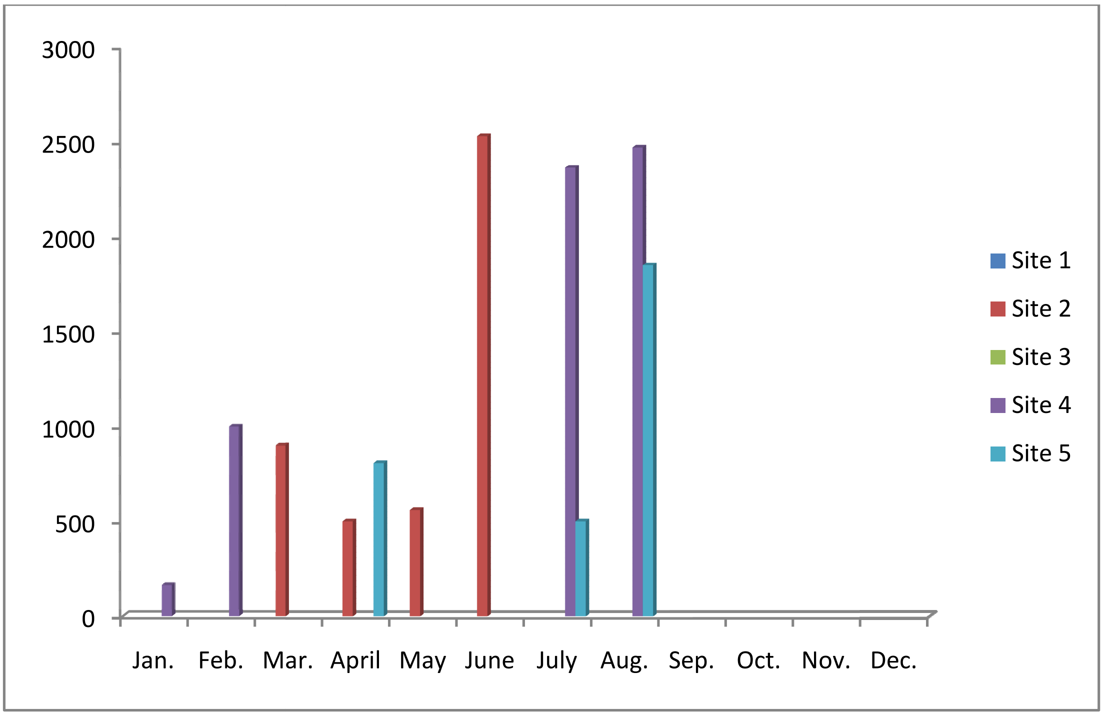


Fig. 30: *Lepadella ovalis*

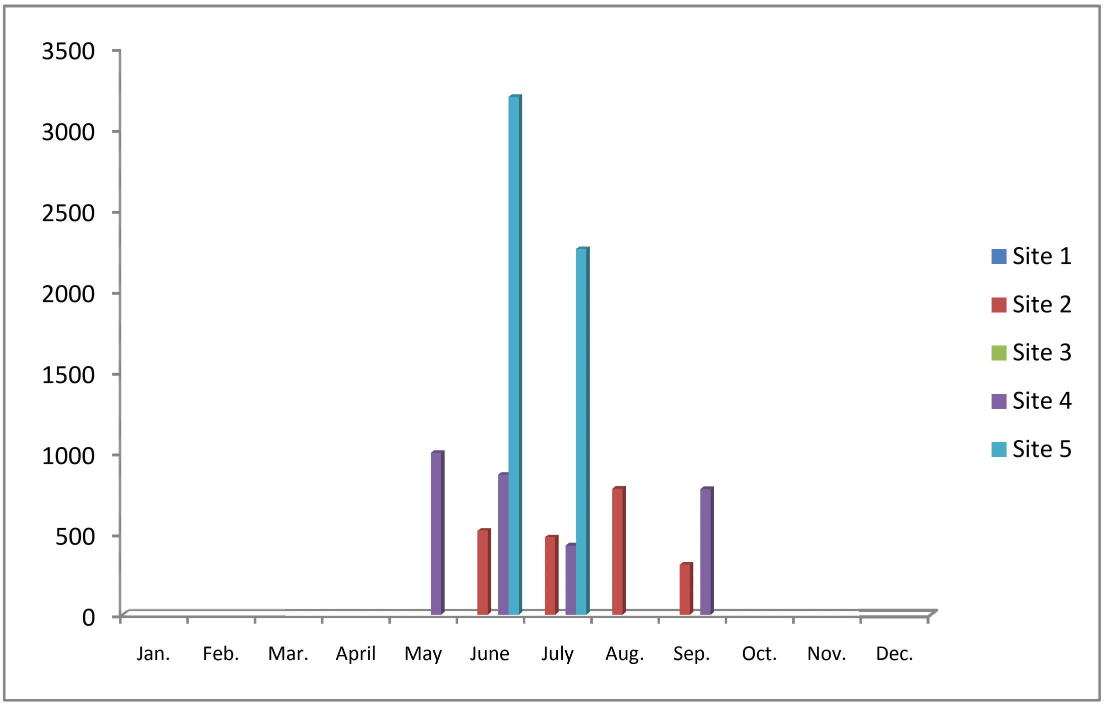


Fig. 31: *Proales*

Order : Floscularíaceae

Family : Filinidae

Filinia longiseta

This species was recorded at all sites. At site I, it was recorded only once in March (400 ind./m^3). At site II, it showed it presence first in March, then April and then remained absent upto August, It reappeared in September and continued its appearance upto November with peak population of 1828 ind./m^3 in April. At site II, it was recorded during the months of April, June, July, September and October with highest population density in October (3050 ind./m^3). At site IV, this species was continuously recorded from March to September with peak population of3440 ind./m^3 in May. At site V, it was recorded continuously from March to September and then December. Its peak population was observed in June (2430 ind./m^3).

Filinia terminalis

This species was recorded only at site I and site III, It remained absent at the other sites. At site II, this species was recorded first in April, then May and after remaining absent upto July it again reappeared in August and September. The peak population was observed in August (1230 ind./m^3).At site III, this species was recorded continuously from May to October with highest population density of 1000 ind./m^3 in May.

Table 32*: Filinia longiseta*

Sites	**Jan.**	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Site 1			400									
Site 2			990	1828					628	1564	252	
Site 3				500		1500	2850		1890	3050		
Site 4			750	2100	3440	2000	998	2460	2514			
Site 5			1470	920	2000	2430	1728	2108	2000			490

Table 33:*Filinia terminalis*

Sites	**Jan.**	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Site 1												
Site 2				328	930			1230	818			
Site 3					1000	628	798	220	850	850		
Site 4												
Site 5												

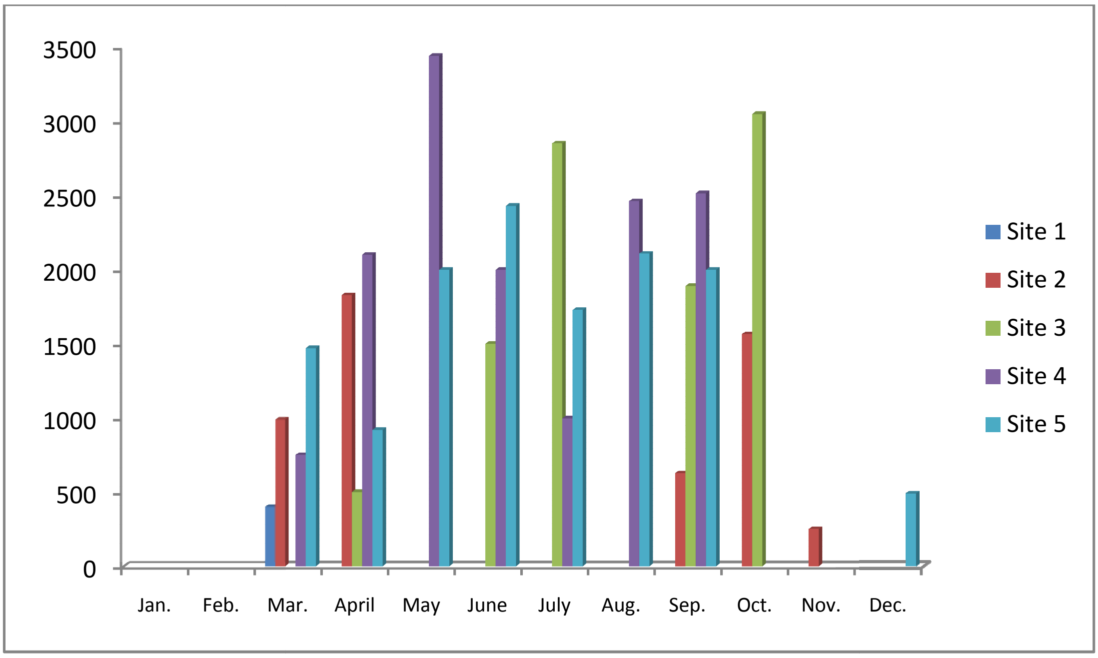


Fig. 32: ***Filinia longiseta***

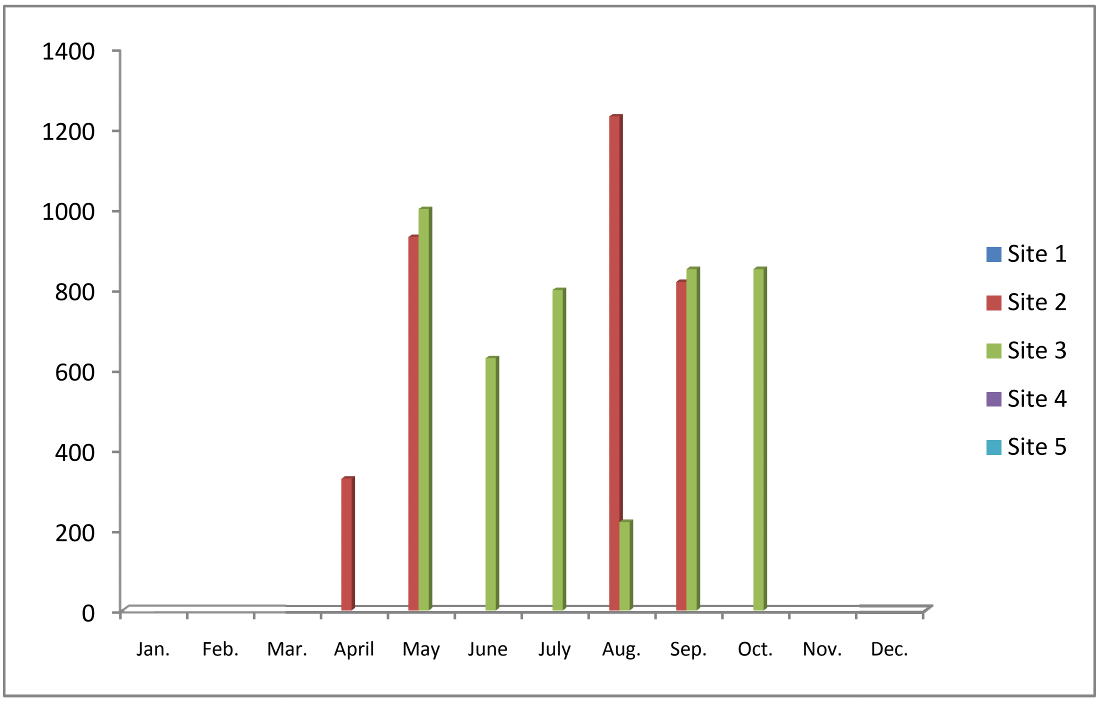


Fig. 33:***Filinia terminalis***

Class : Bdelliodae

Order : Bdelloida

Family : Philodinae

Bdelloids

This species was completely absent at sites I, II and III. At site IV, this species first appeared in February. After remaining absent in March and April it again reappeared from May to October. The peak population was recorded in October (3000 ind./m^3). At site V, this species remained absent during most of the study period and was recorded only during the months of March, April and July with peak population of 2900 ind./m^3 in July.

***Philodina* sp.**

This species was observed at all sites. At site I, it was recorded in June and July with peak population of 650 ind./m^3 in July. At site II, this species was seen during the months of May and June with peak population in May (1800 ind./m^3). At site III, this species was observed continuously from March to September and then in November with peak population 1574 ind./m^3 in August. At site IV, this species was recorded continuously from February to July with peak population of 3240 ind./m^3 in June. At site V, this species was seen in the months of May, June and October. The peak population was recorded in October (2124 ind./m^3).

Table 34:*Bdelloids*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2												
Site 3												
Site 4		166			1000	830	2270	1100	2498	3000		
Site 5			2000	2350			2900					

Table 35:*Philodina sp.*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1						200	650					
Site 2					1800	350						
Site 3			800	1000	1200	980	800	1574	600		600	
Site 4		500	1000	2850	3000	3240	700					
Site 5					2000	1240				2124		

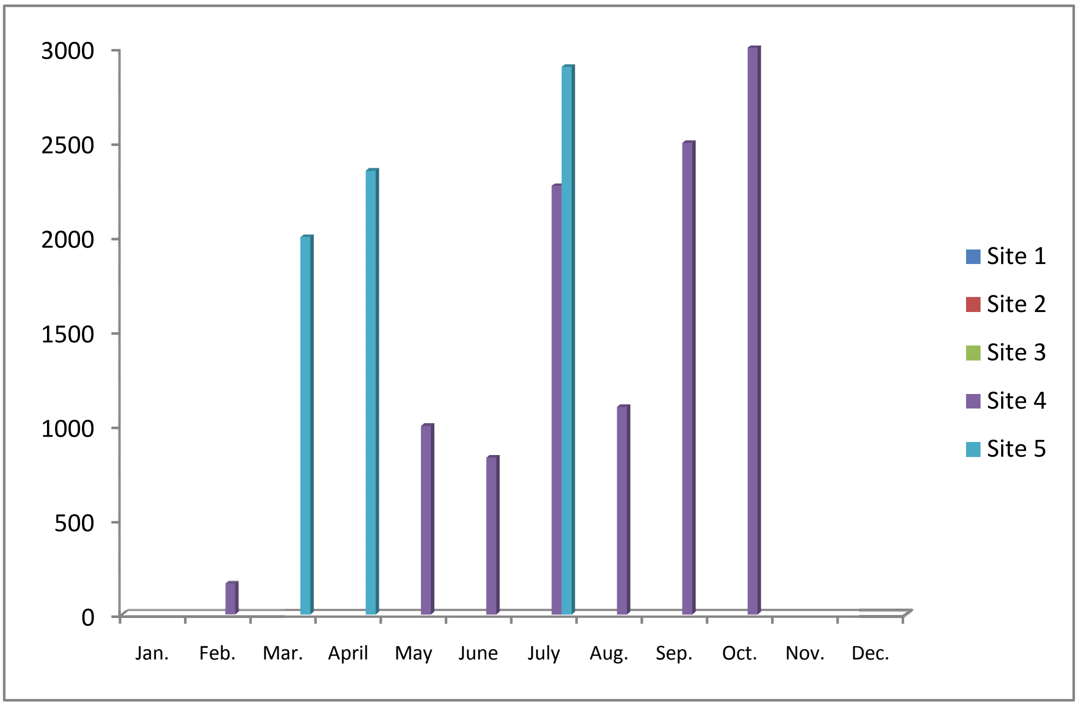


Fig. 34:*Bdelloids*

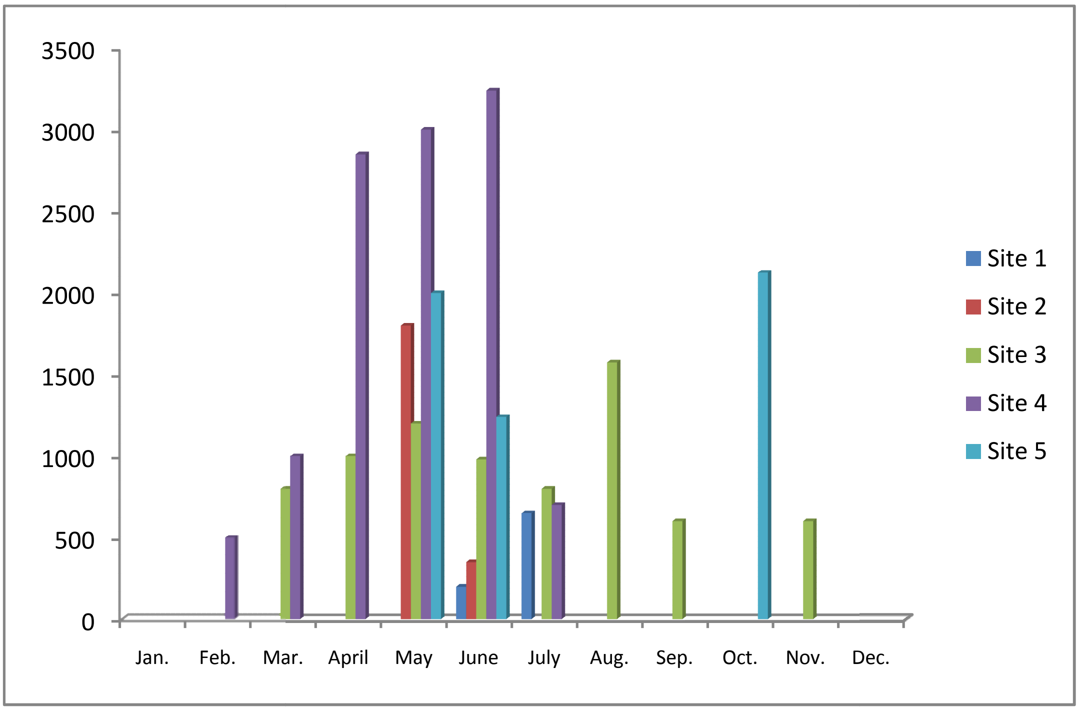


Fig. 35:*Philodina* sp.

b. Cladocera

i. Species composition

The cladocera was represented by 18 species belonging to 6 families.

Class : Phyllopoda

Order : Cladocera

Family : Daphnidae

1. *Daphnia pulex*
2. *Daphnia longispina*
3. *Daphnia similis*
4. *Ceriodaphnia reticulata*
5. *Simocephalus sp.*
6. *Moinadaphnia*

Family : Bosminidae

7. *Bosmina longirostris*
8. *Bosmina coregoni*

Family : Sididae

9. *Sida crystallina*
10. *Diaphanosoma brachyurum*

Family : Moinidae

11. *Moina sp.*

Family : Macrothricidae

12. *Macrothrix rosea*
13. *Chydorus sphaericus*
14. *Graptolebris testudinaria*
15. *Pleuroxus sp.*
16. *Alona affinis*
17. *Alona guttata*
18. *Alonella sp.*

ii. Population dynamics

Family : Daphnidae

Daphnia pulex

This species was recorded at all study sites. At site I, itwas first recorded from March to June, then after remaining absent in July and August, it again reappeared from September to December. The peak population was recorded during October (4568 ind./m^3). At site II, it was recorded from May to July and then in November with peak population of 1000 ind./m^3in July. At site III, this species was first recorded from February to May. After remaining absent during June, July and August, it again reappeared in September and remained present upto December. The peak population was observed in May (3000 ind./m^3). At site IV, it was recorded continuously from February to June and then in November with peak population of 3250 ind./m^3April. At site V, it was recorded only thrice i.e. March, April and May with highest population in April (3220 ind./m^3).

Daphnia longispina

This species was completely absent at site I, II and IV. At site III, it appeared only twicei.e. July and November with peak population of 1800 ind./m^3 in the month of July. At site V, it was continuously present from February to May and then in October. Its peak population was observed in March (4000 ind./m^3).

Table 36*: Daphnia pulex*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1			1000	760	1128	1000			1000	4568	1000	
Site 2					280	400	1000				420	
Site 3		1000	1828	2534	3000				400	108	920	560
Site 4		1000	2000	3250	2850	1420					680	
Site 5			2150	3220	800							

Table 37:*Daphnia longispina*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2												
Site 3							1800				500	
Site 4												
Site 5		2000	4000	1828	2440					230		

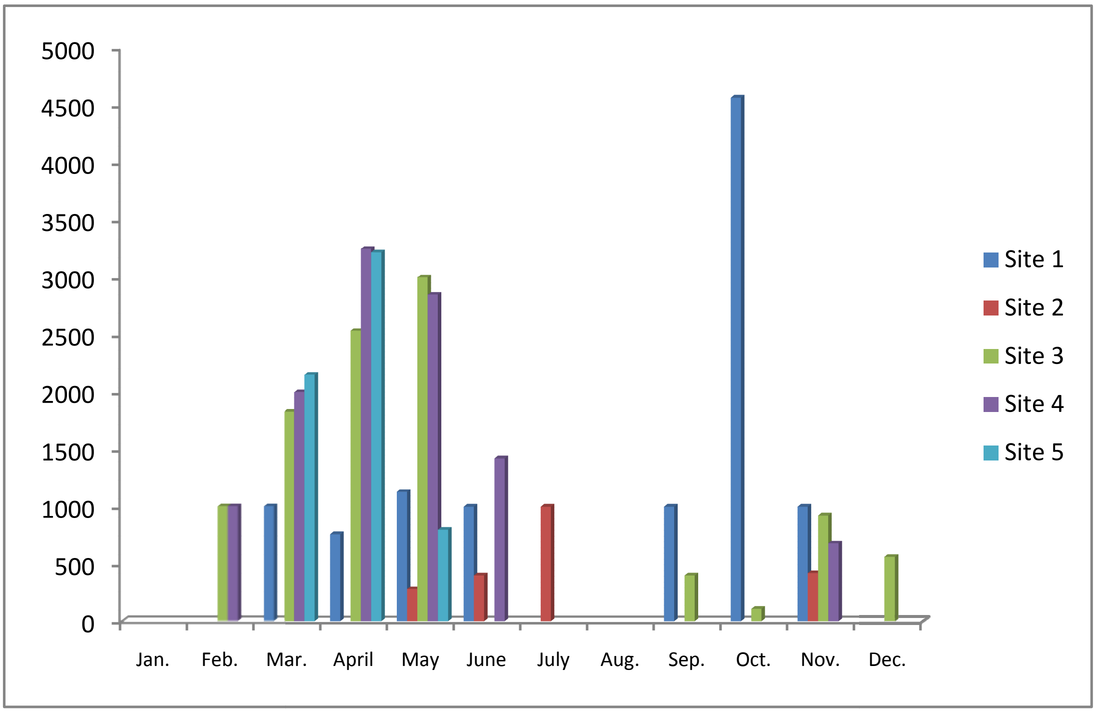


Fig. 36*: Daphnia pulex*

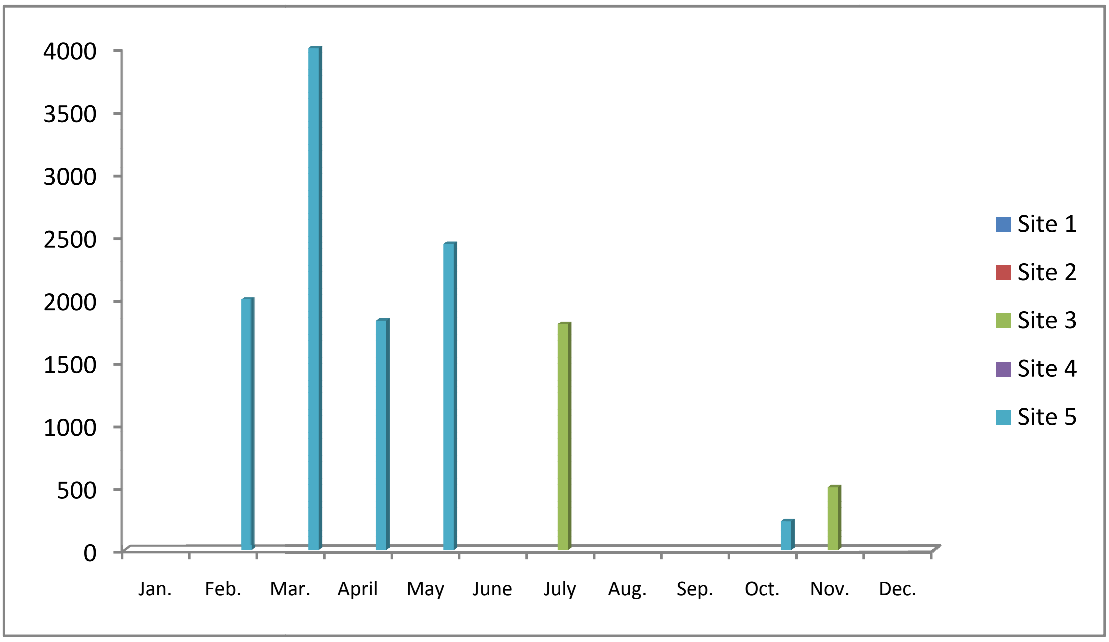


Fig. 37:*Daphnia longispina*

Daphnia similis

This species was recorded at all sites. At site I, it was first recorded continuously from February to May and then September. The peak population was observed in April (1838 ind./m^3). At site II, it was again recorded from February to April after which it remained absent upto October. It again reappeared in November and December. The highest population density was recorded in April (1422 ind./m^3). At site III, it was recorded almost throughout the year except January, February, July and August with peak population observed in March (2500 ind./m^3). At site IV, it was recorded from January to April.Itthen remained absent continuously till November and again reappeared in December. The peak population was observed in the month of February (2500 ind./m^3). At site V, it was recorded only during March and April with peak population recorded in April (4260 ind./m^3).

Ceriodaphnia reticulata

At site I, it was first recorded in February and then from April to June. It again reappeared in October recording its peak population in February (2500 ind./m^3). At site II, it was first recorded from February to April and then in August and September. Itshighest population density of 1200 ind./m^3 was recorded in March. At site III, this species was present almost throughout the year except January and February. Peak population was recorded in June (2120 ind./m^3). At site IV, it was recorded only in August (2000 ind./m^3). At site V, it was again recorded only once during the month of April (1288 ind./m^3).

Table 38:*Daphnia smilis*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1		300	1300	1838	1428				420			
Site 2		900	1028	1422							388	210
Site 3			2500	1000	1894	132			1820	192	500	500
Site 4	1428	2500	1650	1570								2210
Site 5			3250	4260								

Table 39: *Ceriodaphnia reticulata*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1		2500		1520	222	1000				200		
Site 2		306	1200	732				1000	920			
Site 3			700	520	230	2120	1228	1600	**500**	132	508	780
Site 4								2000				
Site 5				1288								

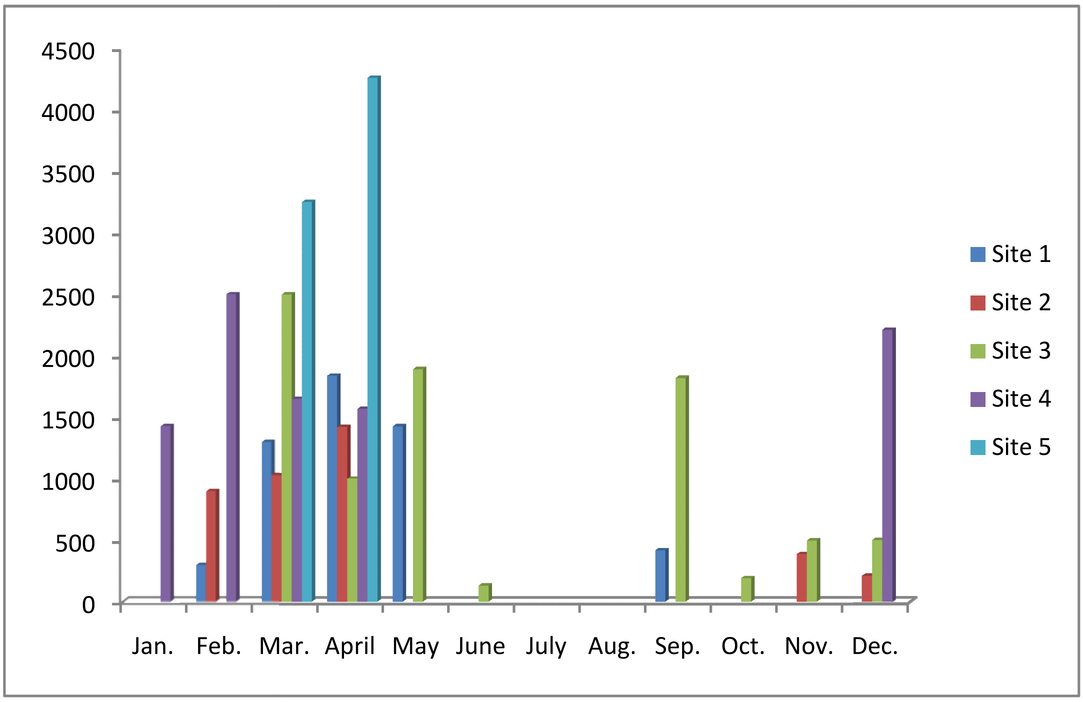


Fig. 38:*Daphnia smilis*

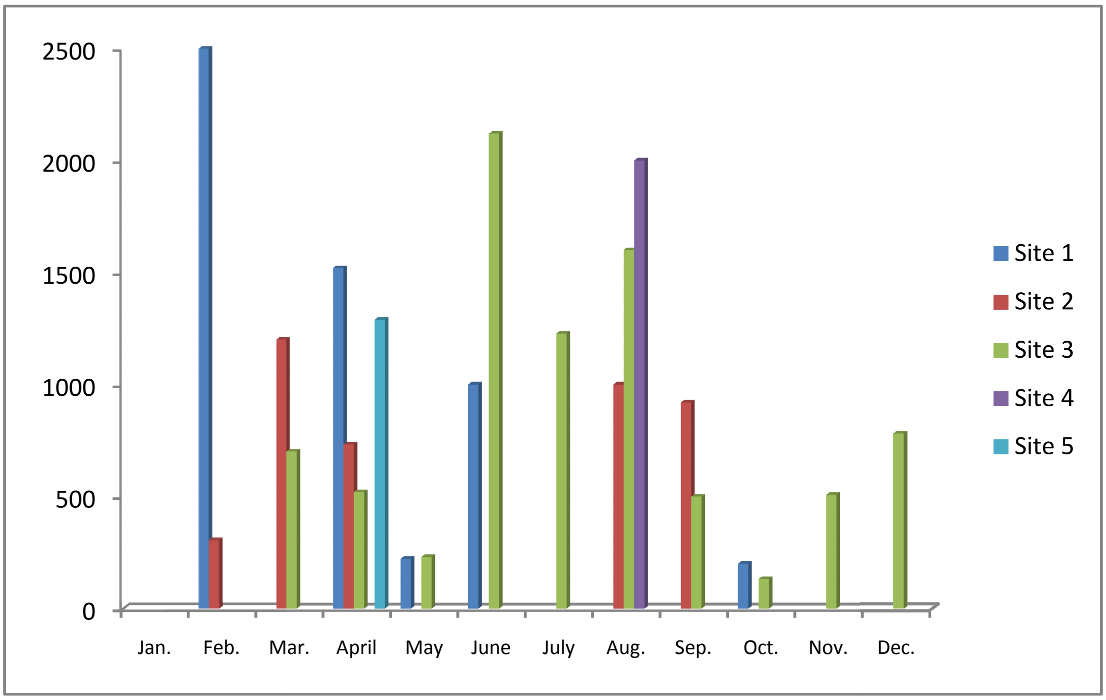


Fig. 39: *Ceriodaphnia reticulata*

***Simocephalus* sp.**

This species was recorded only at site I and site III.At site I, it was recorded only during the month of September (780 ind./m^3). At site III, it was recorded from August to October only. The highest population density was recorded in September and October (2000 ind./m^3).

Moinadaphnia

It was recorded at all sites. At site I, it was recorded from January to April and then in August. Its peak population was observed in April (1228 ind./m^3). At site II, it was recorded continuously from March to May and then in September with peak population of 2528 ind./m^3in April. At site III, it was present from April to July and then it was seen September and October with peak population in June(2400 ind./m^3).At site IV, it was recorded only twicei,e. July and August with peak population in July (1800 ind./m^3).At site V, it first appeared in February and then continuously from June to September recording its highest population density in August (3268 ind./m^3).

Table 40: *Simocephalus* sp.

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1									780			
Site 2												
Site 3								1850	2000	2000		
Site 4												
Site 5												

Table 41:*Moinadaphnia* sp.

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	1000	320	1000	1228				196				
Site 2			2000	2528	1400				2164			
Site 3				2030	2000	2400	1000		2000	1528		
Site 4							1800	1260				
Site 5		2188				500	2460	3268	1000			

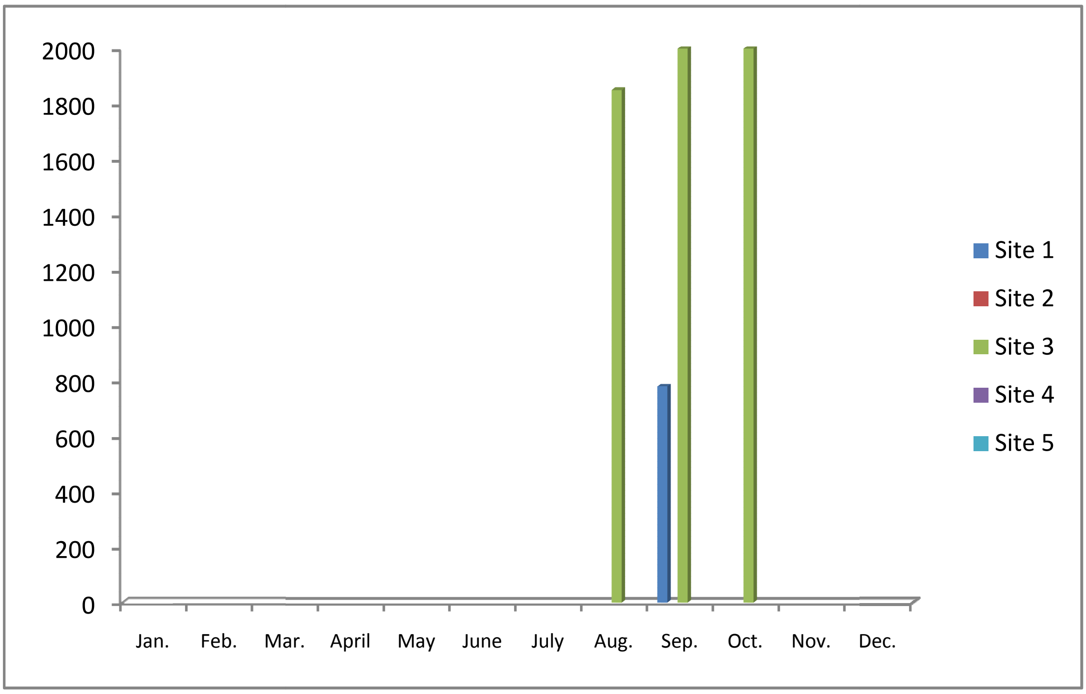


Fig. 40: *Simocephalus* sp.

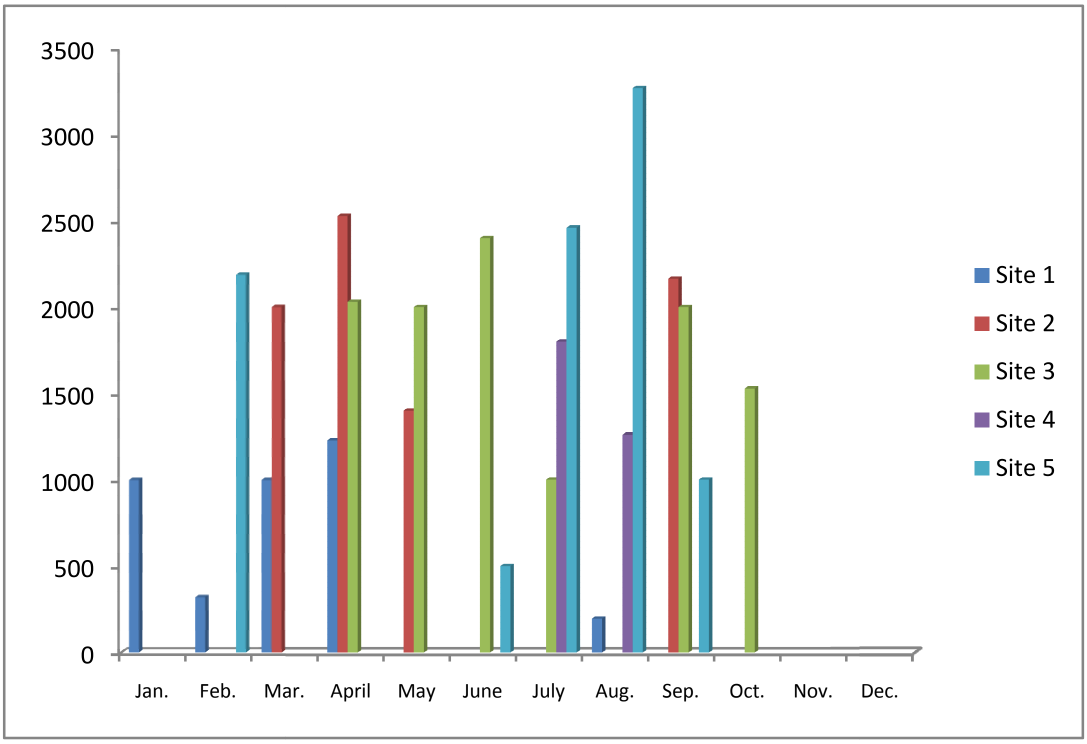


Fig. 41:*Moinadaphnia* sp.

Family : Bosminidae

Bosmina longirostris

This species was seen at all sites. At site I, it was recorded from April to June and then again from September to November. Peak population being recorded in June (3270 ind./m^3). At site II, it was first recorded in January and then in March and April. It again showed its presence in September and remained continuously present upto December. Its peak population was observed in March (2410 ind./m^3). At site III, it was continuously seen throughout the year with peak population of 3280 ind./m^3in September. At site IV, it was again recorded throughout the study period with peak population in April (2820 ind./m^3). At site V, it was first observed in January after which it remained absent upto May .It again showed its presence in June and remained present upto September and was again seen in December with peak population of 1480ind.//m^3 recorded in August.

Bosmina corregoni

It wasrecorded at site IV only where it first appeared continuously from March to May and then in September. Peak population was recorded in April (1550 ind./m^3).

Table 42:*Bosmina longirostris*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1				2100	1430	3270			400	1200	120	
Site 2	180		2410	1200					600	400	650	79
Site 3	1000	2000	2850	850	850	1180	1520	500	3280	3050	2000	1100
Site 4	500	176	998	2820	170	1710	490	322	1500	2000	1628	1456
Site 5	880					800	1000	1480	908			1000

Table 43:*Bosmina coregoni*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2												
Site 3												
Site 4			260	1550	1000				500			
Site 5												

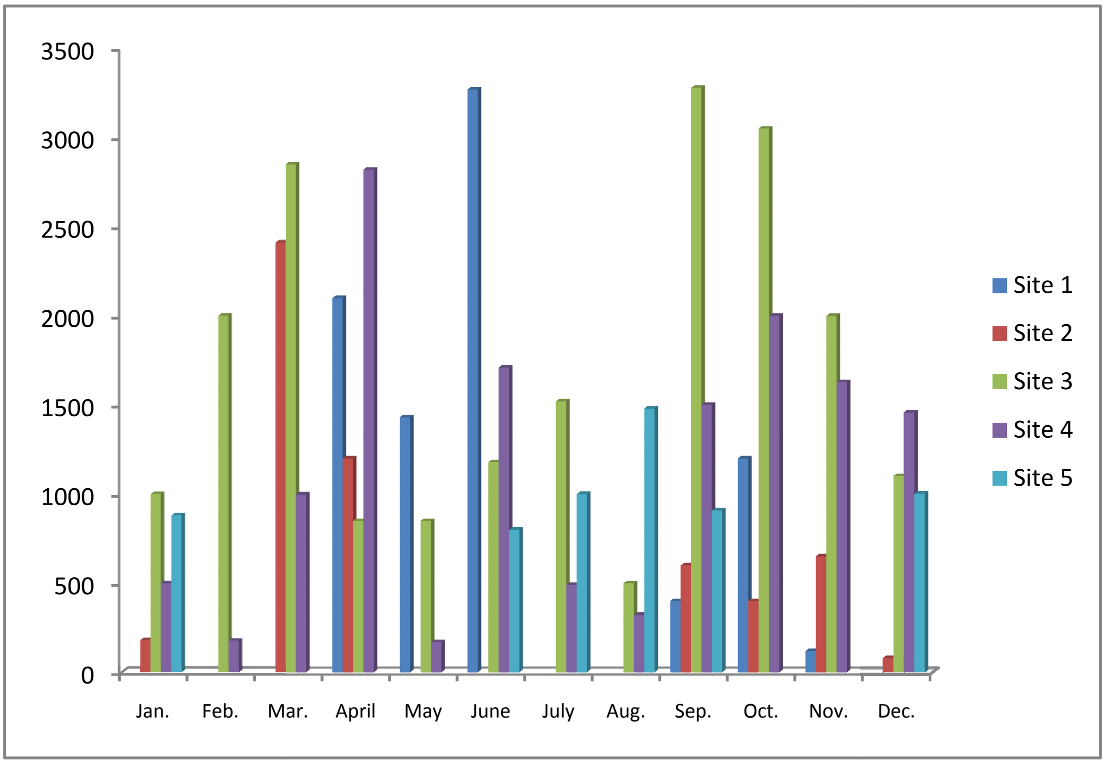


Fig. 42:*Bosmina longirostris*

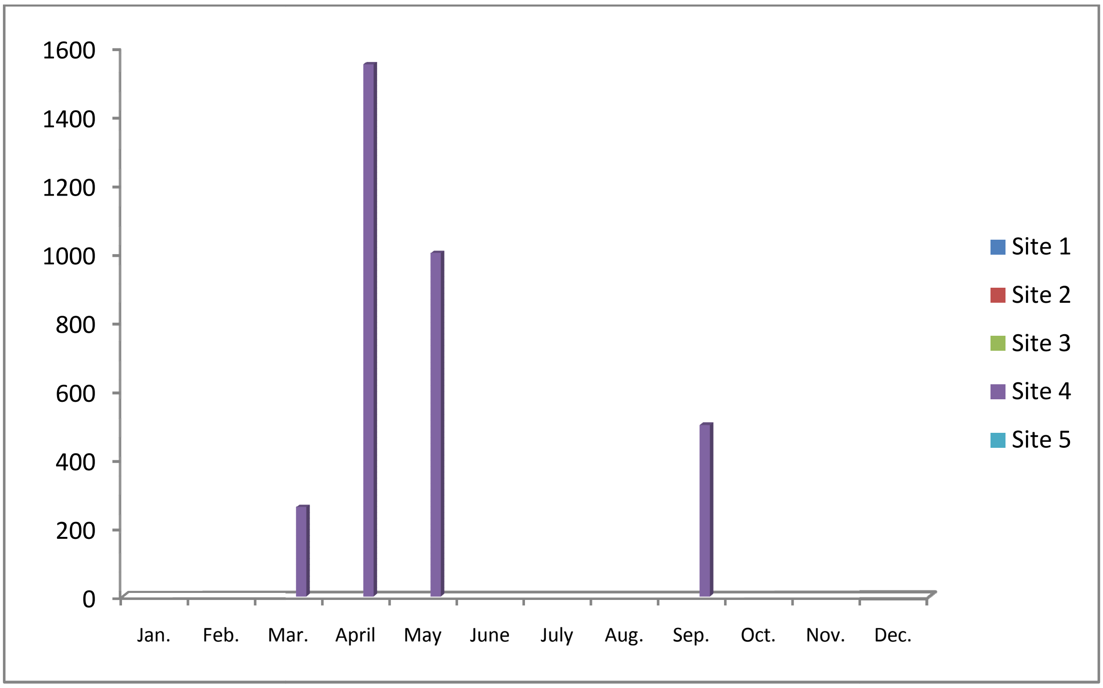


Fig. 43:*Bosmina coregoni*

Family : Sididae

Sida crystallina

This species was recorded at all sites except site V. At site I, it was recorded only during May, June and September with peak population in September (1250 ind./m^3). At site II, it was recorded during the months of March, April, June and September with peak population of 2218 ind./m^3 in September. At site III, it remained absent during winter months and was then recorded continuously from March to October with peak population of 3254 ind./m^3 in September. At site IV, it was recorded only in summer from June to August with peak population in August (1524 ind./m^3).

Diaphanosoma brachyurum

This species was completely absent at site V. At site I, it was recorded only twice i.e. June and July with highest population density in July (1228 ind./m^3). At site II, it was recorded in February and March and again in September with peak population in September (1778 ind./m^3). At site III, it was first recorded from March to May and then again in September with peak population in May (2118 ind./m^3). At site IV, it was observed only in April, May and November. The highest population density was recorded in April (2800 ind./m^3).

Table 44:*Sida crystallina*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1					500	1100			1250			
Site 2			328	1650		1432			2218			
Site 3			1000	1220	1000	1680	928	900	3254	3200		
Site 4						1050	400	1524				
Site 5												

Table 45:*Diaphanosoma brachyurum*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1						620	1228					
Site 2		828	1600						1778			
Site 3			1500	930	2118				1690			
Site 4				2800	2430						250	
Site 5												

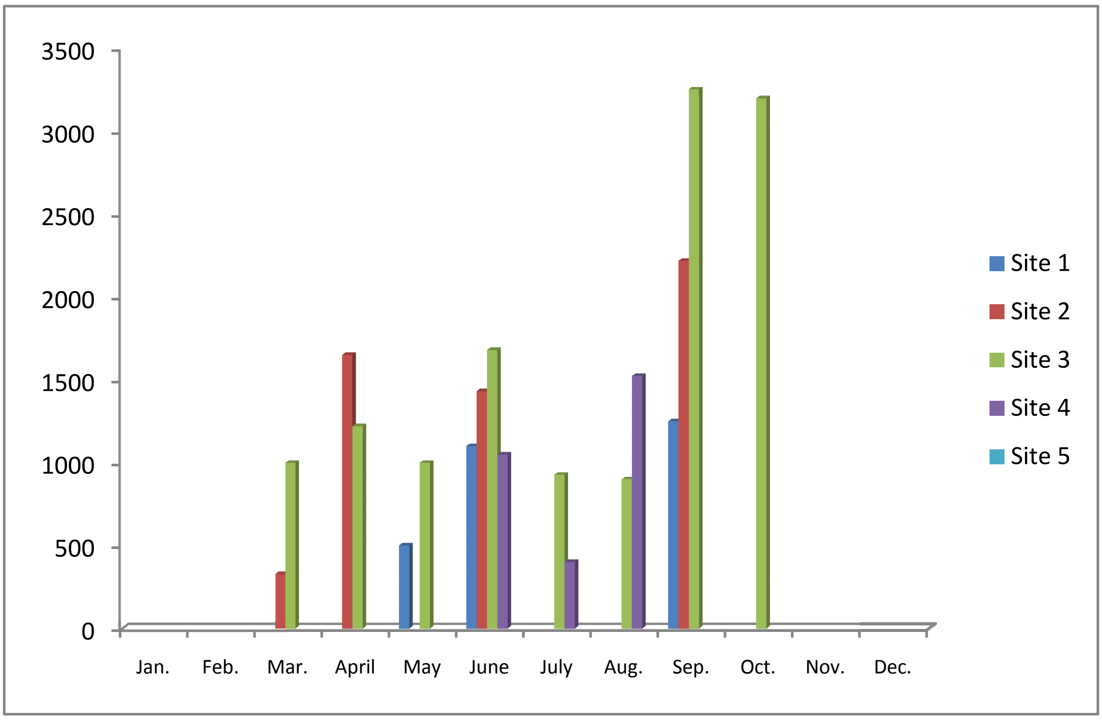


Fig. 44:*Sida crystallina*

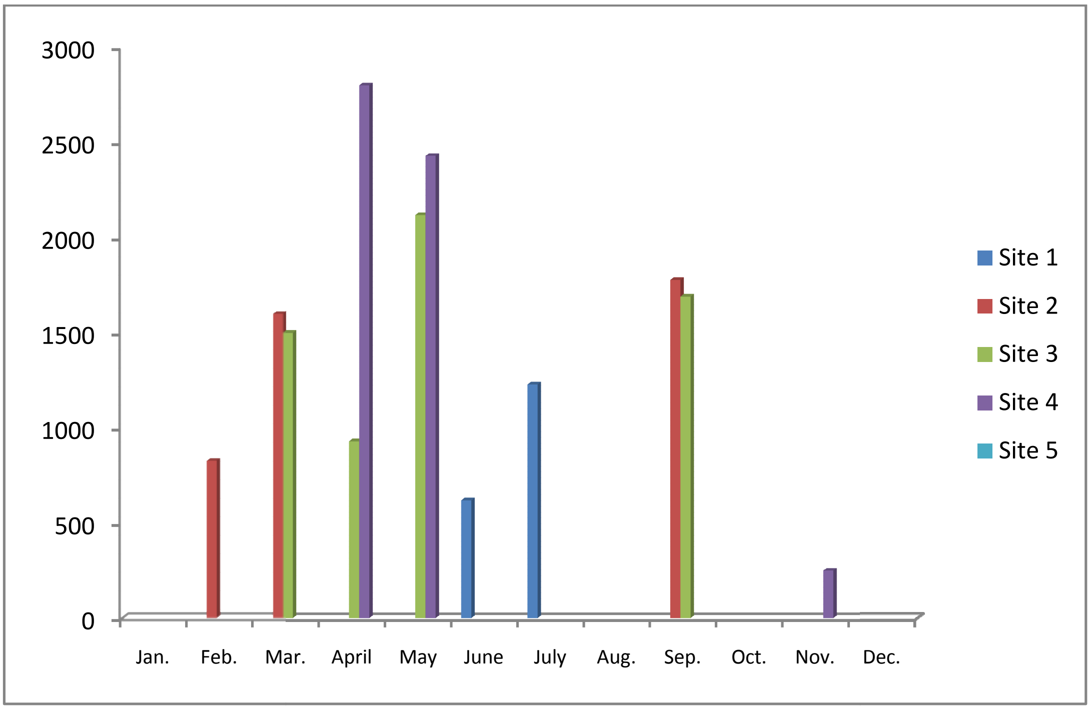


Fig. 45:*Diaphanosoma brachyurum*

Family : Moinidae

***Moina* sp.**

This species remained absent at site IV and site V. At site I, it was recorded only from June to August and then remained absent during the rest of the study period recording a peak population of 1050 ind./m^3 in August. At site II, this species was recorded from March to May and July with peak population observed in May (1666 ind./m^3). At site III, it was recorded only during the months of May and June with peak population of 1018 ind./m^3 in June.

Family : Macrothricidae

Macrothrix rosea

This species was recorded at all sites. At site I, it was first recorded in May and June and then in November and December with peak population of 1230 ind./m^3 recorded in June. At site II it was absent upto July and made its appearance from August to July with peak population in October (1450ind./m^3). At site III, it first appeared from February to May and then from September to November. The highest population density was recorded in May (2418 ind./m^3). At site IV, it was recorded only twice in February and June with population density of 350 ind./m^3 and 1200 ind./m^3 respectively. At site V, this species made its appearance only inJune and July with peak population in July (1650 ind./m^3).

Table 46:*Moina sp.*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1						212	860	1050				
Site 2			1464	1000	1666		1200					
Site 3					784	1018						
Site 4												
Site 5												

Table 47:*Macrothrix rosea*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1					880	1230					428	690
Site 2								600	400	650	790	
Site 3		1000	120	1406	2418				2000	1300	1420	
Site 4		350				1200						
Site 5						1200	1650					

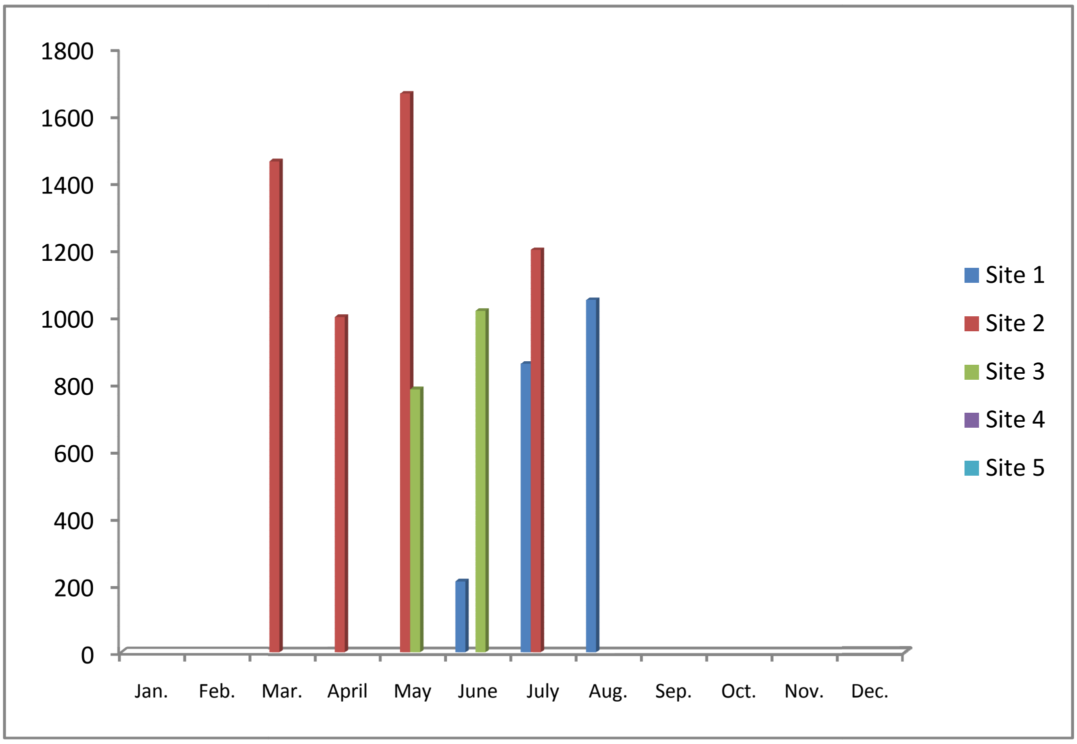


Fig. 46:*Moina sp.*

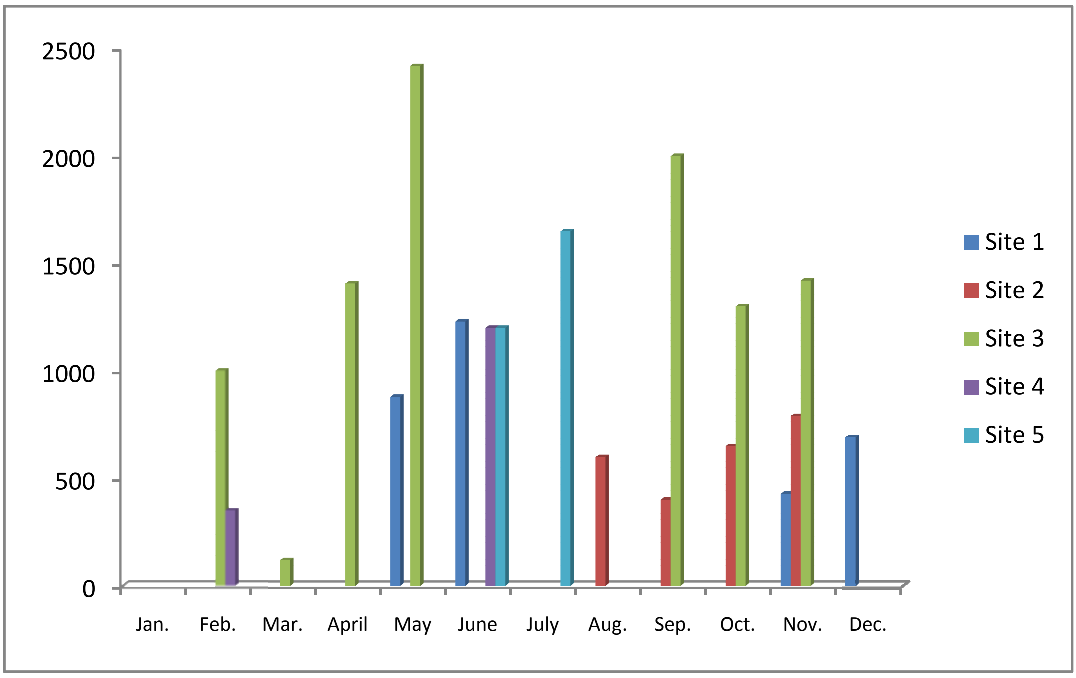


Fig. 47:*Macrothrix rosea*

Family : Chydoridae

Chydorus sphaericus

This species was recorded at all sites. At site I, it was recorded throughout the study period except July with peak population in October (2848 ind./m^3).At site II, this species made its appearance continuously from January to July and then appeared in October. Its highest population density was observed in June (2816 ind./m^3). At site III, it was recorded throughout the year with peak population of 3000 ind./m^3in May. At site IV, it was first observed in January and February and then in May. It remained absent upto October and again appeared in November. The peak population was recorded in November (2260 ind./m^3). At site V, it was recorded during the months of February, March, July and December with highest population density in March (1550ind./m^3).

Graptolebris testudinaria

At site I, this species was recorded throughout the study period except February with peak population of 1582 ind./m^3in September. At site II, it was first observed in February and then from April to June. It again appeared in October and November. The highest population density was recorded in October (1198 ind./m^3). At site III, it first appeared from April to June and then again showed its presence continuously from August to November with peak population of 3500 ind./m^3 in August. At site IV, this species was recorded only during the months of August, September and October with peak population in September (3300 ind./m^3). At site V, it was recorded only twice i.e. April and May with peak population of 1650 ind./m^3 in May.

Table 48:*Chydorus sphaericus*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	1332	2150	800	480	620	1528		830	1800	2848	2000	2128
Site 2	700	700	728	2000	1000	2816	600			2000		
Site 3	164	380	2810	1426	3000	608	348	688	1600	700	108	500
Site 4	1650	800			990						2260	
Site 5		690	1550				1000					1000

Table 49: *Graptolebris testudinaria*

Sites	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	230		230	750	1400	864	454	200	1582	1120	98	630
Site 2		218		1000	706	628				1198	800	
Site 3				1150	1000	1220		3500	2000	2108	2100	
Site 4								3208	3300	2000		
Site 5				1000	1650							

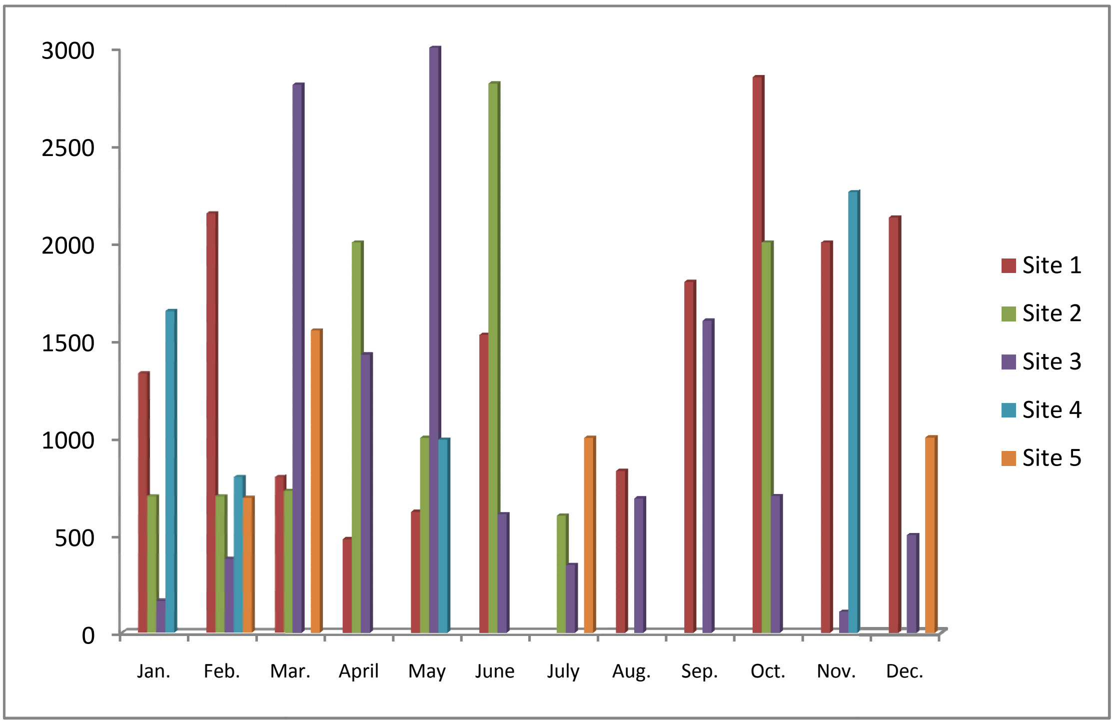


Fig. 48:*Chydorus sphaericus*

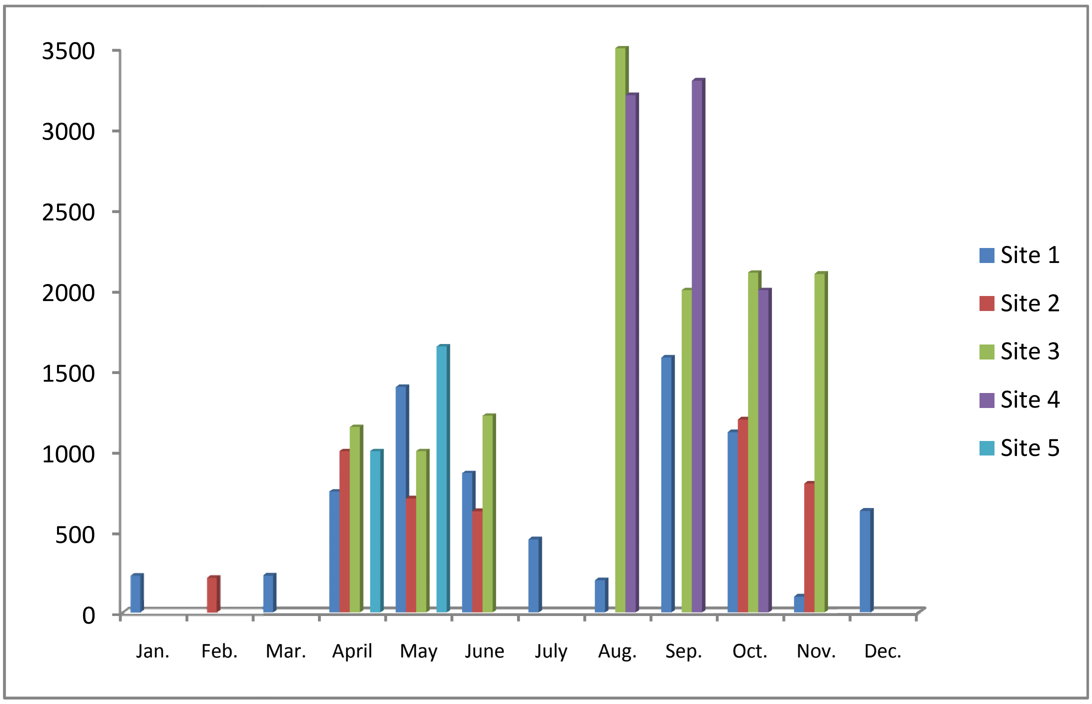


Fig. 49: *Graptolebris testudinaria*

***Pleuroxus* sp.**

This species was completely absent at site I, II and III. At site IV, this was recorded only twice during the month of March and April. The peak population of 2000 ind./m^3 was recorded in April. At site V, it was recorded only in July and October with population density of 1200 ind./m^3.

Alona affinis

This species was recorded at all sites except site V. At site I, it was first observed in April after which it remained absent till October and then reappeared in November and December. The peak population was recorded in April (2462 ind./m^3). At site II, it remained almost absent throughout the year except September (400 ind./m^3). At site III, it was recorded only in May (1150 ind./m^3) and June (928 ind./m^3). At site IV, it was again recorded only twice i.e. September and October with peak population in September (1278 ind./m^3).

Table 50:*Pleuroxus* sp.

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2												
Site 3												
Site 4			660	2000								
Site 5							1200			1200		

Table 51:*Alona affinis*

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1				2462							1534	648
Site 2									400			
Site 3					1150	928						
Site 4									1278	910		
Site 5												

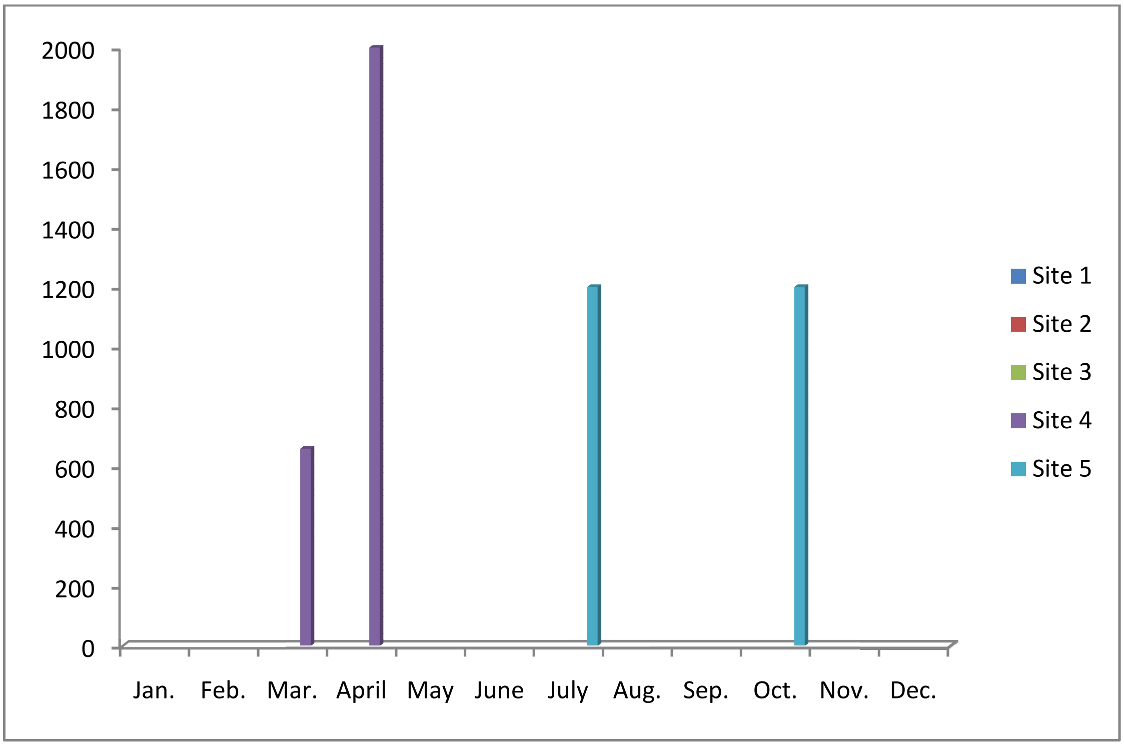


Fig. 50:*Pleuroxus* sp.

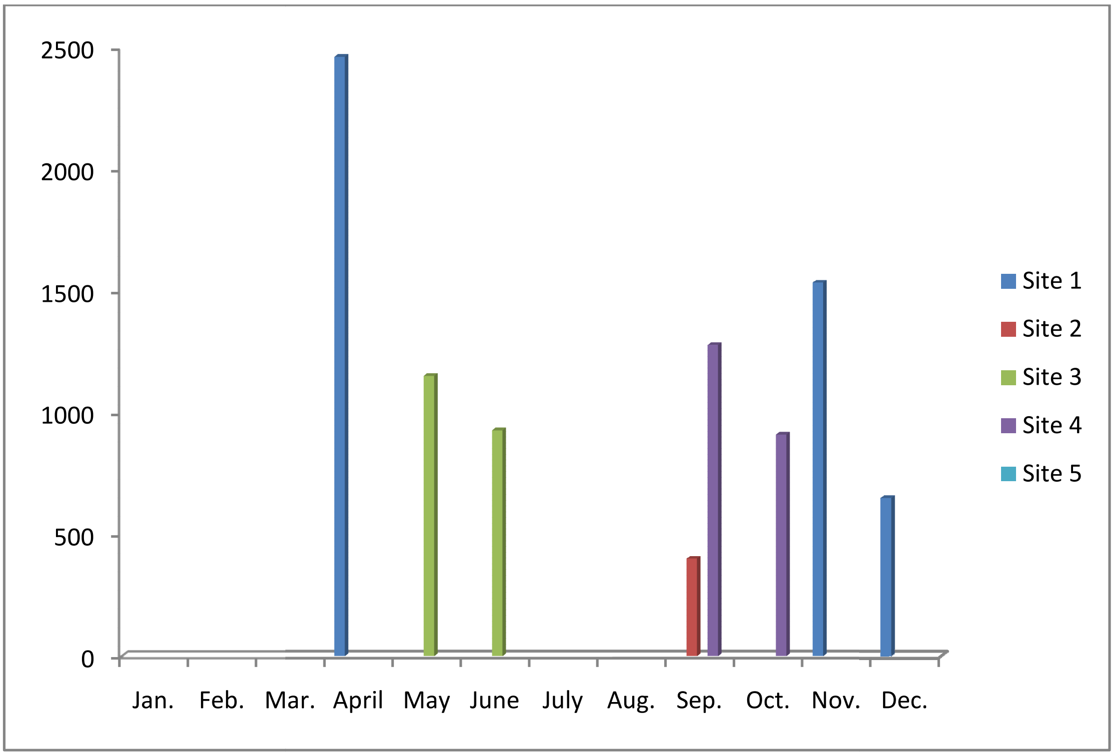


Fig. 51:*Alona affinis*

Alona guttata

This species was recorded only at sites I and III. At site I, it was recorded once in February (408ind./m^3). At site III, it was observed only twice i.e. May and June with peak population of 1480ind./m^3 in June.

***Allona* sp.**

This species remained absent at all sites except site IV. At site IV, it was present only once during the month of October (2100 ind./m^3).

Table 52:*Alona guttata*

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1		408										
Site 2												
Site 3					1200	1480						
Site 4												
Site 5												

Table 53:*Allonela* sp.

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1												
Site 2												
Site 3												
Site 4										2100		
Site 5												

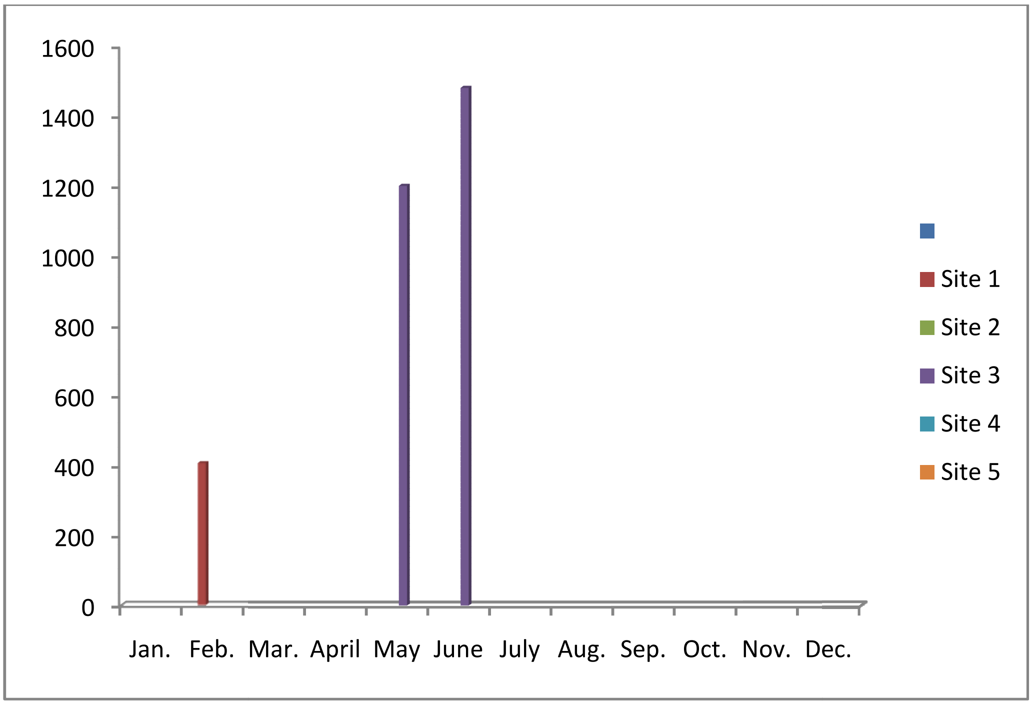


Fig. 52:*Alona guttata*

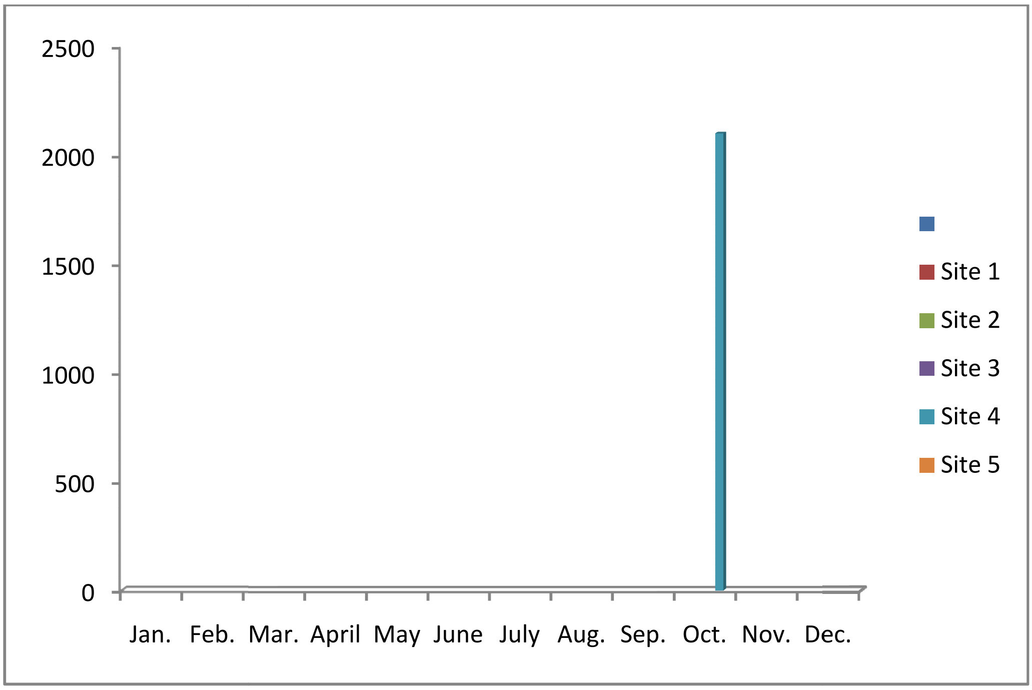


Fig. 53:*Allonela* sp.

c. Copepoda

i. Species Composition

The copepoda was represented by 4 species belonging to 2 sub orders.

Suborder : Cyclopoida

Family : Cyclopoidae

1. *Cyclops* sp.
2. *Eucyclops speratus*
3. *Macrocyclops albidus.*

Sub order : Herpacticoida

Family : Canthocamptidae

4. *Canthocamptus* sp.

ii. Population dynamics

Family : Cyclopoidae

***Cyclops* sp.**

This species was recorded at all sites. At site I, it showed scattered presence. It first appeared in January and remained absent upto May. It reappeared in June, July and then in November and December. The highest population density was observed in June (650 ind./m^3). At site II, it was first observed from February to April and then again in October and November with peak population of 1028 ind./m^3 in November. At site III, it was recorded almost throughout the year except April and November. The highest population density was recorded in October (1400 ind./m^3). At site IV, it was observed throughout the study period except March and April with peak population of 1500 ind./m^3 observed in October. At site V, it was recorded throughout the study period. The highest population density was recorded in August (1428 ind./m^3).

Eucyclops speratus

This species was completely absent at site V. At site I, it first appeared in February and then in May and June. It remained absent from July to September and then reappeared in October and November. The peak population was recorded in February (1000 ind./m^3). At site II, it was first recorded from February to April and then in November and December with peak population of 678 ind./m^3 in March. At site III, it was recorded only during the months of January, February and October .The peak population was observed in February (660 ind./m^3). At site IV, it was almost absent except in April (100 ind./m^3) and August (500 ind./m^3).

Population dynamics of various species of Copepoda

Table 54:*Cyclops* sp.

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	300					650	510				480	490
Site 2		800	400	450						750	1028	
Site 3	690	800	800		1000	800	800	1120	1228	1400		300
Site 4	900	450			450	1250	1300	1428	1298	1500	500	168
Site 5	800	880	218	250	800	1120	800	1428	1410	600	820	800

Table 55:*Eucyclops speratus*

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1		1000			420	888				96	900	
Site 2		360	678	500							628	128
Site 3	450	660								660		
Site 4				1000				500				
Site 5												

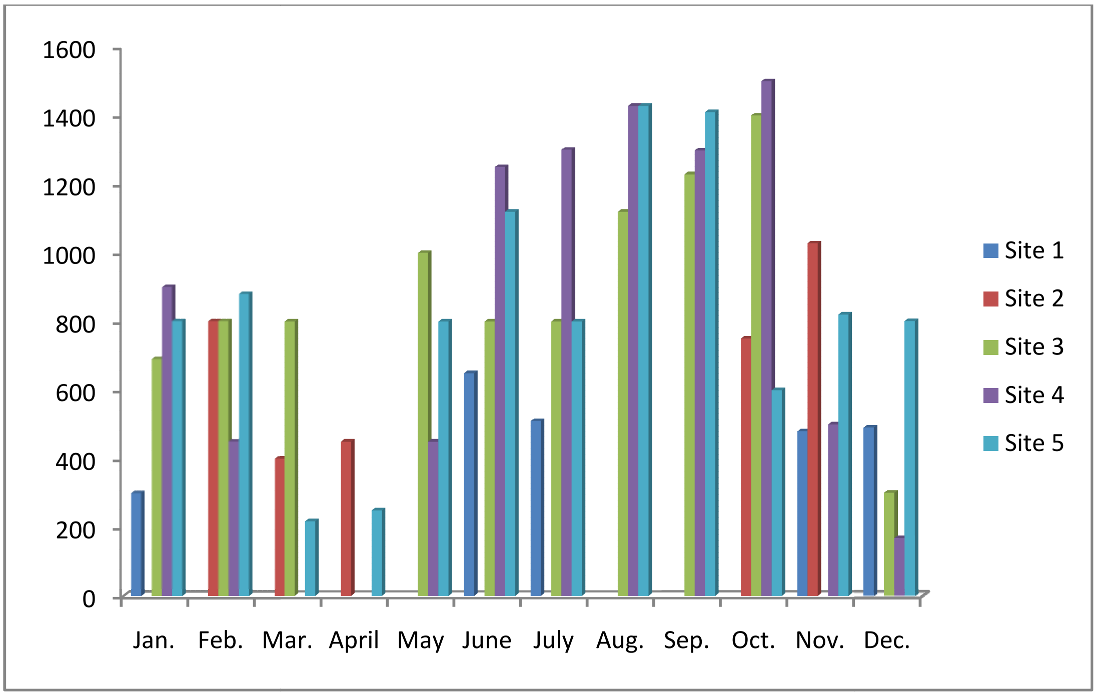


Fig. 54:*Cyclops* sp.

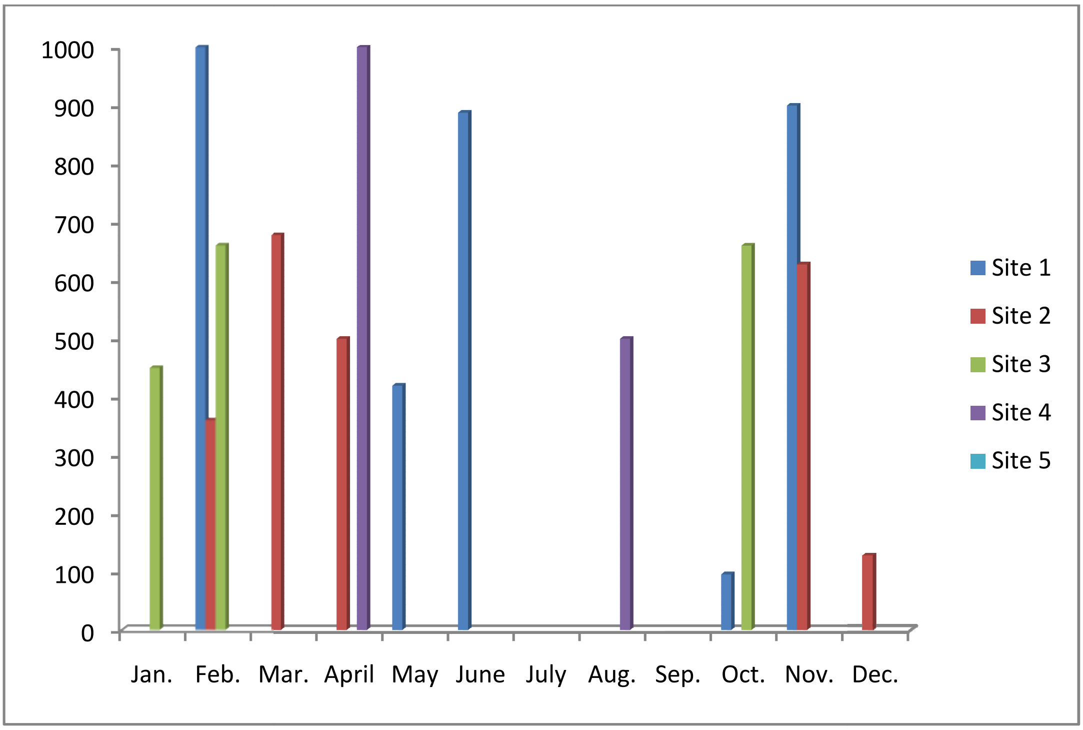


Fig. 55:*Eucyclops speratus*

Macrocyclops albidus

This species remained completely absent at site II and site V. At site I, it was present during the most part of the study period except during the months of April, August and December. The highest population density was recorded in February (2150ind./m^3). At site III, this species was recorded in the months of January, June, July, November and December with peak population of 1650 ind./m^3 in November. At site IV, it first made its appearance in July and then in September and continued its presence till December with peak population of 1380ind./m^3 in November.

***Canthocamptus* sp.**

This species was completely absent at site IV and site V. At site I, it was first recorded in April and continued its presence upto June. It reappeared in November with peak population of 800 ind./m^3 in April. At site II, it first showed its presence continuously from January to March and remained absent upto October. It again reappeared in November. Its peak population was recorded in March (628ind./m^3). At site II, it was recorded only in the months of May, June and December with peak population in June (978 ind/m^3).

Table 56:*Macrocyclops albidus*

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1	890	2150	92		1000	1280	400			1200	1808	
Site 2												
Site 3	100					1000	1000				1650	800
Site 4							850		128	1200	1380	400
Site 5												

Table 57:*Canthocamptus* sp.

Sites	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Site 1				800	690	728					700	
Site 2	220	418	628								220	
Site 3					428	978						300
Site 4												
Site 5												

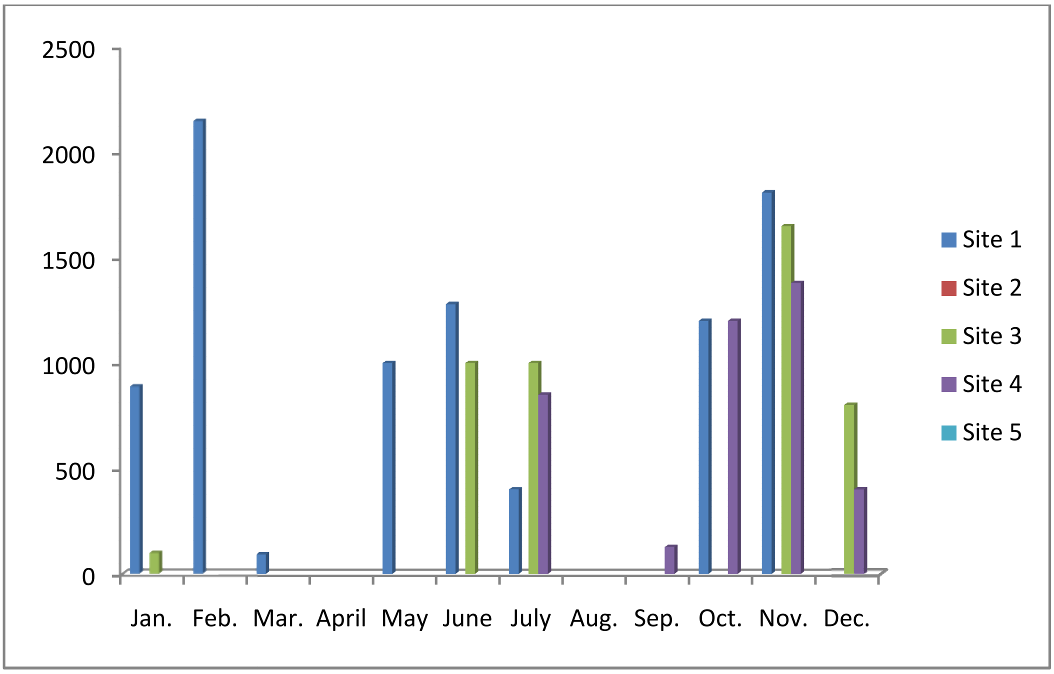


Fig. 56:*Macrocyclops albidus*

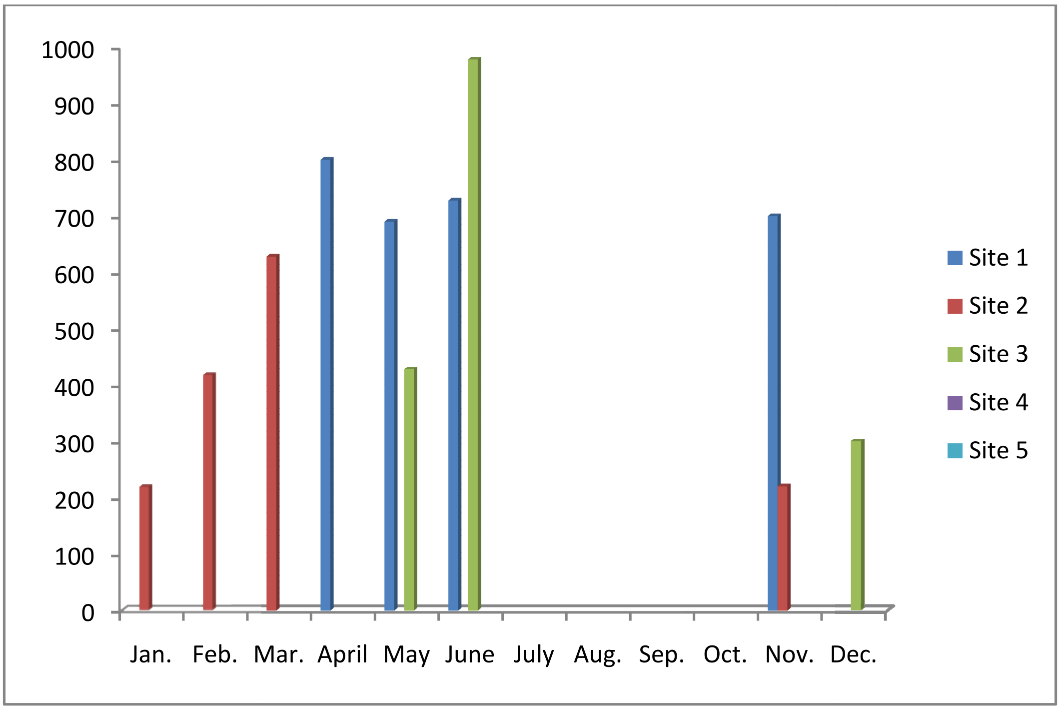


Fig. 57:*Canthocamptus* sp.

CHAPTER - 5

DISCUSSION

The basic aim of the present investigation was to study the population dynamics of different rotifer species with special reference to genus *Keratella*, other zooplankton associations and physico-chemical environment in different areas of Dal lake.

The species composition of the zooplankton results from the influence of physical, chemical, biological and geographical factors among lakes (Hutchinson, 1969). Environmental stress can operate with these factors to alter species composition (Odum 1985, Margalef 1975). In lake ecosystem zooplankton form an important group in the food chain as invertebrates, fish and sometimes birds often use zooplankton as food (Altindag 1999).

The main group of zooplankton consist of Rotifera, cladocera and copepoda. Studies on rotifer show that certain species act as indicators of water quality, pollution and eutrophication (Altindag, 1999). Rotifera present a high diversity in freshwater ecosystems (Serafen *et al.,* 2003). They constitute an important link in the food chain of most fishes and there is enough evidence to show that tolerance for and the optimal values of various ecological factors for influencing population dynamics of a rotifer species vary considerably with its geographical distribution (Jyoti and Sehgal 1979). In the present lake the order of dominance of zooplankton groups was rotifera>cladocera>copepoda. This clearly indicates that the peaks of population are not governed by a single factor.

Extensive environmental variation is one of the most basic facts of life for any organism living in temperate lakes. Among the most notable contribution to this environmental variation is the temperature and chemistry of water and the qualitative and quantitative composition of phytoplankton and zooplankton.

Water temperature is one of the most important limnological parameters that plays a prominent role in regulating nearly all physico-chemical characteristics of water as well as biological productivity (Wetzel, 1983) & also in controlling the nutrient input and turnover. A close relationship was recorded between water temperature and air temperature which is in line with the findings of Qadri and Yousuf (1987), Chowdhary and Mazumdar (1981). Both atmospheric and water temperature peaks were recorded in summer and the minima in winter with the water temperature generally lower than air temperature. The water at site 1 was generally cooler than other sites which can be attributed to the melted glacial` water that enters to the lake through Telbal Nallah from upper reaches.

The Secchi disc transparency in fresh water shows spatial as well as seasonal fluctuation. Transparency represents the optical characteristics of water and plays an important role in aquatic ecosystem and productivity is directly dependent on it. The higher the secchi disc transparency deeper the penetration of light and higher the rate of photosynthesis. Balkhi *et al.* (1981) have found transparency to be higher in winter than summer. A similar trend was observed during the present study. This has been attributed to different factors, viz, plankton population (Zutshi and Vass, 1970), setting of materials in calm weather (Spur, 1975), suspension of phytoplankton in water (Zutshi *et al.*, 1980), glacial silt (Zutshi & Khan, 1978).

The present study reveals that site 2 and site 3 has relatively higher transparency values than other sites. On the whole low transparency was observed throughout the lake which may be due to increased suspended matter, silt load and humus brought in from catchment area as well as due to rich macrovegetation.

pH is known to have a close relationship with several physical, chemical and biological features in the water body and acts as an index of overall environmental conditions prevailing in an aquatic ecosystem. Mean pH value in the present lake fluctuated from 7.8 to 8.8. According to Whitemore (1989) alkaline pH greater than 7.5 is mainly exhibited by eutrophic and mesotrophic water bodies. In present study, pH above 9.0 was recorded at sites 2,3 and 4. pH values above 9.0 have been attributed to high photosynthetic activity (Hutchinson, 1967). Similar results were reported by Devi and Sharma (2004). In Brarinambal basin, the pH values were always less than 8.0 during the present study as large quantities of raw sewage are drained into the water from the adjoining areas which result in continuous decomposition throughout the year. As a result large amount of carbon dioxide is liberated into the water column and PH decreases greatly and remains very low.

Hannon & Broz (1976) have also related decrease in pH to decomposition of organic matter. Similar results have been reported by Zutshi and Khan (1988). Lower pH values were recorded in cold season. As from the available data, it is concluded that fluctuations in the pH seem to be influenced by changes in the rate of photosynthesis & decomposition, so it may be that during cold season macrophytes either die or remain dormant & thus reduce pH, bringing it very close to neutrality.

The conductivity value is an index of the total nutrient level of a water body. Trisal (1987) reported conductivity in the range of 95µs to 490µs in different basins of Dal lake, while during the present study a higher range 163µs to 810µs was recorded, which is clearly related with ever increasing pollution level in the lake. Shashtree *et al.* (1991) also reported that high level of conductivity reflects pollution status as well as trophic level of the lake. During spring relatively lower values of conductivity were recorded which can be related to locking up of nutrients in the macrophytes while in Autumn higher values were recorded which can be attributed to decomposition of organic matter (macrophytes and animals). The higher values of conductivity were recorded at site 5 (Barinambal) due to decomposition of domestic sewage dumped at this site.

Dissolved oxygen is one of the most reliable parameters in assessing the trophic status and the magnitude of eutrophication in an aquatic ecosystem. It is essential for aerobic organisms and the dynamics of its distribution in the lakes is basic to the understanding of distribution, behaviour and growth of aquatic organisms (Wetzel 1999). Temperature and several biological activities influence its concentration in eutrophic water as a result of which large variations are expected (Hutichinson, 1967). In the present study, the overall concentration of oxygen ranged from 0.8 mg/litre to 9.8mg/litre, showing maximum concentration in spring which can be attributed to vigorous photosynthetic activity of autotrophs (phytoplankton & submerged vegetation) (Kumar *et al.,* 2004). The lower value of dissolved oxygen in summer can be assigned to the higher rate of decomposition of organic matter which in turn is controlled by temperature (Singh *et al.,* 2002; Kumar *et al.,* 2004). In Brarinambal basin, the concentration of dissolved oxygen remained low throughout the study period (0.8-3.0mg/l) which can be attributed to the organic decomposition in the hypereutrophic water body. The foul smell emanating from the site also suggests its eutrophic nature. The addition of effluents in the form of faecal matter, bathing run off from the house boats and huge amounts of refusal is responsible for causing a decline in DOcontent (Jyoti *et al.,* 2003).

The CO_2 concentration during the present study, was maximum in winter which appears to be related to the low rate of photosynthesis. However at site 2, 3, 4, the carbon dioxide was absent from May to August (Site 2 and 3) and May to September (Site 4) because of pH being higher. At high pH values more carbon dioxide is present as bi-carbonate ion and at low pH value it is present in free condition (Kumar *et al.*, 2004).

Total alkalinity has been used a rough index of lake productivity (Moyle 1956). The total alkalinity value has been used to differentiate soft and hard water bodies. Moyle (1945) designated the lake water having alkalinity values upto 40 mg/l as soft, those with 40-90mg/l as medium hard and those with values above 90 mg/l as hard types. During the present study the water at all sites appears to be typical hard as alkalinity values are higher than 90 mg/l. Site 5 showed relatively higher values of alkalinity which can be attributed to high loading of detergents, chlorides and other pollutants (Singh *et al.*, 2002).

Chloride concentration in fresh water is generally due to salts of Na, K, Mg and Calcium. High chloride concentration in water body is related to organic pollution of animal origin (Thresh *et al.*, 1944). The chloride concentration in Dal Lake has been reported to be 6 Mg/l to 13 Mg/l by Zutshi and Vass (1978). The present investigation reveals the range to be between 11.9 mg/l to 71 mg/l which clearly indicates that there has been a progressive trophic evolution of this water body due to anthropogenic stress. In Brarinambal basin chloride concentration was highest as it receives large quantities of domestic sewage and municipal wastes (Parveen, 1988; Jamila 2003). High chloride values may be attributed to organic wastes of animal origin and domestic wastes (Ara *et al.*, 2004).

The concentration of NH_4-N is usually low in aerobic water because it is utilized by the plants. High concentration in the lake may be attributed to the entry of domestic sewage, use of nitrogenous fertilizers in the catchment area and within the lake. In Brarinambal basin, the concentration of NH_4-N was extremely high (mean=964.8±149.2µg/l) which reveals that this basin is hypereutrophic.

Nitrate is the common form of inorganic nitrogen entering fresh water from the draining basin, ground water and precipitation and mostly occurs in low concentration (Wetzel 1983). During the present study higher concentrations of nitrate were recorded. Lower concentration was recorded in summer which can be attributed to its locking up in luxuriant macrophytic population. Higher concentrations were recorded in autumn (Sondergard *et al.,* 1979).

Nitrite nitrogen generally occurs in very minute quantities in natural waters (Paul and Clarke, 1989). During the present study nitrite concentration was recorded in the range of 19 µg/l to 100 µg/l. Higher concentration of nitrite nitrogen were recorded in Brarinambal basin showing the mean concentration of 67.6 µg/l. No definite trend was recorded in nitrite nitrogen throughout the study period.

Phosphorous is regarded as the key element in the eutrophication process. Previous records show that total phosphorous concentration fluctuated in the range of 9 µg/l to 25 µg/l (Kaul, 1977), 7µg/l to 103µg/l (Parveen, 1988). During the present study concentration of total phosphorous ranged from 312.6 µg/l to 2325.0 µg/l. As per classification of Wetzel (1983), the lake belongs to eutrophic category and its Brarinambal basin to hypereutrophic category. Yousuf and Parveen (1992) also reported high concentration of total phosphorus in the Brarinambal area. Much of phosphorus supplied to the lakes is introduced through point source e.g. sewage, detergents and industrial wastes (Zutshi and Wanganeo, 1989).

From the present investigation on various physico-chemical parameters of the Dal lake it can be concluded that this water body is significantly advanced in its trophic status and at present its different areas are either showing eutrophic or hypereutrophic status.

The structure and functioning of zooplankton communities are reported to be altered by eutrophication with typically an increase in predominance of cyclopoids (Patalas 1975; Gannon, 1981; Chapman *et al*., 1985). In the mesotrophic water bodies cyclopoid copepods often dominated the zooplankton populations and in eutrophic and hypereutrophic water bodies rotifers and cladocerans were dominant forms. In the present study the order of dominance of different zooplankton in Dal lake was Rotifera>Cladocera>Copepoda. This clearly indicates that the present lake is at a higher trophic level.

In term of abundance copepods dominate the more oligotrophic lakes, but rotifers comprise the major proportion in the eutrophic system (Blancher, 1984). This is in agreement with the present findings as the population of zooplankton in Dal lake was dominated by rotifers. Similar results were reported by (Parveen, 1988) while working on zooplankton of Dal lake. Rotifers are among the major micro invertebrate groups in many freshwater communities and play a vital role in ecology of such systems. The ecology of rotifers has been extensively studied by Yousuf and Qadri, 1981; Egborge and Tawari, 1987. Rotifers are sensitive to changes in water quality through the eutrophication process (Gannon and Stemberger 1978; Pejler 1983).

In the present investigation 22 species of rotifera were recorded in the lake of which 18 belong to order ploima, 2 to order flosculariaceae and 2 to order Bdelloida. There was an increase in the abundance of Rotifers. The number of rotifer taxa increase as a rule from oligotrophic to hypereutrophic (Maemets, 1983).

During present study, genus *Keratella* was represented by two species, i.e. *Keratella cochhlearis* and *Keratella quadrata*. *Keratella cochlearis* and *K. quadrata* are probably the commonest planktonic rotifers in temperate regions

(Hutchinson, 1967, Ruttner- Kolisko, 1974; Zankai and Ponyi, 1970). Both species have been reported to be present throughout the year in lake Manasbal (Kashmir) with the former species being more dominant (Yousuf, 1979). The present investigation also revealed the dominance of *K. cochlearis* in the *Keratella* group, which was represented by two species in Dal lake i.e. *K. cochlearis* and *K. quadrata*. *Keratella cochlearis* formed a perennial plankter exhibiting peak density in summer. Similar results were reported by Parveen (1988). *Keratella cochlearis* shared dominance in summer (Gulati; 1990; Radwan, 1980; Elenbaas and Grindel, 1994). According to Mikschi (1989) *K.cochlearis* shows great tolerance in relation to temperature. *Keratella cochlearis* shows a significant preference for eutrophic environment (Parveen, 1988). The present study also confirms this view as it contributed a significant proportion of total rotifer plankton of the lake. According to Radwan and Popiolek (1989), *Keratella cochlearis* is an indicator of high trophic status. Lewkowicz (1984) has also found *K. cochlearis* to resist wide fluctuations in nitrogen and phosphorous content.

Keratella quadrata was present at all sites except site 1. *Keratella quadrata* formed a winter and early spring species in the lake. Parveen (1988) also reported *Keratella quadrata* to be present during the colder periods of the study. Similar results were reported by Mageed (2007) while working on lake Manzala, Egypt. *K. quadrata* showed relatively more abundance in Brarinambal basin than other sites which is in line with the findings of Tasaduq (2005). According to Maemets (1983) *Keratella quadrata* shows a significant preference for eutrophic environments.

Genus *Brachionus* was represented by four species namely *Brachionus angularis, Brachionus calyciflorus, Brachionus plicatilis* and *Brachionus quadridentata.* Most species of *Brachionus* are characteristic of eutrophic alkaline waters (Maemets, 1983; Jyoti and Sehgal, 1979; Sampath *et al*., 1979). *Brachionus angularis* was present at all sites but at site 1 it was reported only once. This may be because of the higher density of macrophytes at other sites. This species is found in shallow waters associated with macrophytes. Uku and Mavuti (1994) reported *B. angularis* to be dominant in sewage laden waters of Nairobi. *Brachionus calyciflorus* was present at all sites and was very much represented at site 5 (Brarinambal). Pandit and Yousuf (2002) reported this species in hypereutrophic water. Kumar and Tripathi (2004) reported *B. calyciflorus* to be indicator of eutrophic nature of water. *Brachionus plicatilis* was found at three sites except site 1 and 3. It recorded its highest abundance at site 5 followed by site 4 and rarely observed at site 2. *Brachionus quadridentata* was very well represented at Brarinambal basin and was absent at sites 1, 2 and 3. It is a good indicator of eutrophic conditions. (Koste and Shiel, 1987; Margalef *et al*., 1976). Its abundance at site 5 indicates that it prefers nutrient rich waters.

Platiyas quadricornis was present at all sites. It showed high population during spring and summer which is the growing season of macrophytes. Pejler (1977) reported it to be frequent among littoral macrophytes.

Synchaeta sp. was present during the colder months which is in line with the findings of Chengalath *et al.,* (1984) and Parveen (1988). *Polyarthra vulgaris* was found at all sites except site 5 with well marked peaks in spring and autumn. This is in line with the findings of Sebestyen, 1954; Hutchinson, 1967). Yousuf and Qadri (1986) have reported *Polyarthra vulgaris* to be influenced by abiotic as well as biotic factors. This species was completely absent at site 5 thereby indicating its negative correlation with organic population.

Lecane sp. was absent at site 1 and site 5, because of absence of macrophytes. It was recorded at site 2, 3 and 4 because they prefer littoral habitats with rich macrophytic growth (De Manuel, 2000). *Monostyla bulla* constituted a warm water species and remained absent in colder months. Similar results were reported by Parveen (1988).

Trichocerca sp. were absent at site 1 and site 5. These were mainly present in summer and autumn at other sites (Jyoti and Sehgal, 1979; Hutchinson, 1967). *Trichocerca longiseta* was very rare and was recorded only twice. *Ascomorpha* sp. was present in low numbers at all sites and did not show any regular trend in its occurrence (Parveen, 1988; Anderson *et al.*, 1977). *Gastropus* sp. was absent at site 2 and Site 5. At other sites it was recorded during warmer months only.

Qadri and Yousuf (1980) and Gophen (1972) reported the perennial behaviour of *Asplanchna priodonta*. The present data also confirms this view. It was distributed throughout lake. However at site 5 it was very rare which may be due to higher level of organic pollution. Hakkari (1977) reported negative correlation of this species with the concentration of waste waters of wood processing industry.

Lepadella ovalis was found at three sites except Telbal and Nigeen basin. Higher population was recorded during early summer (Parveen, 1988). Balkhi *et al*., (1984) found *Lepadella* in shallow eutrophic Anchar lake.

Proales showed abundance in Brarinambal basin and was present mainly during summer season. It was absent at Telbal and Nigeen basins.

Filinia longiseta is a typical eutrophic rotifer (Gulati 1983; Hakkari 1977). Hakkari (1977) has found a positive correlation between rate of pollution and abundance of *F. longiseta*. This is confirmed by the distributional pattern of *F. longiseta* in the present lake. It was recorded abundantly in Brarinambal basin. *Filinia terminalis* made a very low contribution to the total population density of rotifer. *Philodina* sp. appeared mainly during spring and summer. *Bdeloid* sp. were present only at site 4 and Brarinambal basin and were mainly present in spring and summer.

Cladocera formed the second largest group of zooplankton in present lake. It was represented by 18 species of which *Daphnia pulex, Bosmina longirostris, Chydorus sphaericus* were widely distributed and contributed a significant proportion of total cladocera in the lake. While comparing the various sites with each other it was observed that Brarinambal basin contained least population density as well as species diversity of cladocera possibly because of hypereutrophic condition of the basin. The group preferred the waters which were better oxygenated (Qadri and Yousuf, 1980; Yousuf and Qadri, 1983).

Family *Daphnidae* was represented by six species namely *Daphnia pulex, D. longispina, D. similis, Ceriodaphnia reticulata, Simocephalus* sp. and *Moinadaphnia*. *Daphnia pulex* and *Daphnia similis* were recorded at all sites thereby indicating that they can tolerate wide range of fluctuations of physico-chemical factors of water, whereas *D. longispina* was recorded from Nigeen and Brarinambal basin thus showing its preference to eutrophic condition. Tundisi (1984), Lair (1991), Jindal and Rumana (1999) have also reported *Daphnia* sp. to be indicators of pollution. *Ceriodaphnia reticulate* is a perennial plankter characteristic of mesotrophic (Yousuf and Qadri, 1983) and eutrophic waters (Conell, 1976). In present study it was most abundant at Nigeen basin as it has been found to be associated with macrophytes (Armengol, 1978; Alonso, 1996). *Simocephalus* sp. was rare in the lake. *Moinadaphnia* sp. was present at all sites and showed much abundance in macrophyte rich Nigeen basin.

Family *Bosminidae* was represented by *Bosmina longirostris* and *B. coregoni*. Among the two, significant contribution was made by *B. longirostris*. *B. longirostris* shows a significant preference for eutrophic environment

(Hakkari, 1977) and has been shown to replace *B. coregoni* during eutrophication process (Endmondson *et al*., 1956; Freyer, 1969). *B. longirostris* recorded its peak population in macrophyte rich sites thereby indicating its affinity with highly macrophyte infested polluted waters (Freyer and Forshaw, 1979; Parveen, 1988; Balkhi, 1988; Balkhi and Yousuf, 1996). *B. longirostris* has been found to be a perennial cladoceran (Berg and Nygaard, 1929). The present study also confirmed this view.

Freyer and Forshaw (1979) and Chengalath (1982) reported *Sida crystalline* generally remains among the vegetation of littoral zone. Similar results were obtained during present study as this species showed higher population density at macrophyte rich sites i.e. site 2 and 3. *Sida crystallina* was found to avoid low temperatures as it was found only during warmer period. This is in line with the findings of Parveen (1988) who confirmed it to be a warm stenothermal species. *Diaphanosoma brachyurum* was mostly recorded in spring and showed less distribution. It was absent in Brarinambal basin which seems to be related with hypereutrophic condition of the basin (Siraj, 2003). *Moina* sp. was absent at site 4 and 5. At other sites it made appearance only during spring and summer (Balkhi and Yousuf, 1996) which indicate its preference for warm waters. Family *Macrothricidae* was represented by *Macrothrix rosea*. It recorded its maximum density in macrophyte rich Nigeen basin. This is in line with the findings of Siraj (2003).

Family *Chydoridae* was represented by six species. *Chydorus sphaericus* and *Graptolebris testudinaria* made a significant contribution to total cladocera population at site 1, 2 and 3. *Chydorus sphaericus*, a cosmopolitan species, showed widest distribution in Dal lake. During present investigation, *Chydorus sphaericus* was recorded almost throughout study period and as such can be regarded as perennial taxa (Balkhi *et al,* 1987; Parveen, 1988; Yousuf and Parveen, 1992; Balkhi and Yousuf, 1992). Appearance of large number of *C. sphaericus* in plankton has been related to change in trophic level of the lake (Siegfried and Kopache, 1984). Gannon (1981) reported *Chydorus sphaericus* to be indicator of eutrophic condition. However presence of this species in small numbers at Brarinambal basin indicated that highly polluted waters are not favourable for it.

Graptoleberis testudinaria is a typical littoral cladoceran and has marked preference for vegetation over which it creeps (Freyer and Forshaw, 1979; Parveen, 1988; Yousuf and Qadri, 1981). Yousuf and Qadri (1981) have reported it to be a perennial form in Manasbal lake with higher population from May to September. In present study this species occurred almost throughout the year with higher density from April to November. In Brarinambal basin, it was present in less numbers, thereby showing its avoidance of hypereutrophic conditions (Siraj, 2003).

Alona affinis, Alona guttata, Alonella sp. and *Pleuroxus* sp. were rarely found in the lake.

Copepoda population in the present lake was very low and was represented by four species of which three belonged to family *Cyclopoidae* and one to *Canthocamptidae*. Among these *Cyclops* sp. contributed a major population of copepods. The present data indicates that Brarinambal basin was inhabited by a single copepod i.e. *Cyclops* sp. All other copepods were absent. It seems that copepod fauna of the lake has gradually decreased with an increase in trophic status. Akhtar (1972) and Parveen (1988) recorded 14 and 7 species respectively from the lake but only four species were recorded during present investigation.

It may be concluded that the ecological conditions prevailing in the different basins of the Dal lake are conducive for rotifer population and as a result the group is well represented qualitatively and quantitatively in the lake.

CHAPTER - 6

SUMMARY AND CONCLUSION

The aim of present work was to study the species composition and population dynamics of genus *Keratella*, other zooplankton associations and physicochemical environment in Dal lake. The lake was investigated from January 2011 to December 2011 for different limnological features. Five study sites were selected. Different standard methods were employed to determine various Physical, chemical and biological features of the lake.

Water temperature in the lake fluctuated from 3.5^{o}C to 26^{o}C and a close relationship was recorded between air temperature and water temperature. Peaks in both were obtained in summer.

Transparency fluctuated from site to site and least transparency was found in Brarinambal.

The lake was alkaline throughout the year and pH value ranged from 7.19 to 9.6.

Conductivity fluctuated from, 163µs/cm to 810 µs/cm.

Dissolved oxygen ranged from 0.8mg/l to 9.8mg/l. Lower values were recorded during summer and higher during winter.

Chloride concentration seems to have increased due to sewage contamination.

Total alkalinity ranged from 94.8mg/l to 360.9mg/l.

No definite trend was recorded in ammonical nitrogen concentration throughout study period.

The concentration of nitrate nitrogen ranged from 72.1µg/lto 925.2µg/l.

Nitrite nitrogen was recorded in very small quantities.

Total phosphorous concentration indicated that lake is eutrophic in nature and the Brarinambal basin is in advanced hypereutrophic stage.

During present study a total of 44 species of zooplankton were recorded of which 22 belonged to rotifera, 18 to cladocera and 4 to copepoda.

Genus *Keratella* was represented by two species i.e. *Keratella cochlearis* and *K. quadrata.*

Braninambal basin stands quite separate from other basins in most of its limnological characters.

For checking any advancement in the trophic level of the lake, some measures need to be taken up immediately.

- Diversion of effluents entering into the lake is the major prerequisite for improving water quality in the lake.
- Inflow of organic wastes from houseboats has to be checked.
- Deweeding programme has to be taken up on more scientific lines.
- There should be a complete ban as construction of fresh floating gardens in the lake.
- The use of synthetic fertilizers and pesticides may be completely banned.
- Planning and continuous monitoring of the lake environment is required.
- All sections of people particularly local inhabitants should be involved through mass awareness so as to check further deterioration of the lake.

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